1.0 INTRODUCTION

Lily Pond is a 51-acre Great Pond located in Norfolk County, in the town of Cohasset, Massachusetts (Figure 1). The natural watershed of Lily Pond (the “Pond”) lies within Cohasset and Hingham, MA, although the Pond receives seasonal inputs from the Aaron River Reservoir. Lily Pond has served as the major drinking water sources for the Town of Cohasset (“the Town”) since the 1880s. It is classified with the Commonwealth of Massachusetts as a Class A, Outstanding Resource Water. Class A waterbodies are generally of outstanding water quality and aesthetic value and function as a potable water source. The pond is currently also used for limited secondary contact recreation, and provide habitat for fish, waterfowl, and other wildlife.

Lily Pond has a long history of organic productivity and it is this productivity which currently is of concern due to its potential to impair the primary function of the Pond as a drinking water source. A study performed in by Camp, Dresser and McKee (CDM, 1986) concluded that Lily Pond was eutrophic or possibly borderline mesotrophic. The study identified urban development as the cause of increased nutrient loading. A recent comprehensive watershed investigation, the Surface Water Supply Protection Plan (SWSPP) (Norfolk Ram Group, 2002) also identified watershed sources as a major contribution to Lily Pond’s trophic state. The most important manifestation of the productivity is the dense and pervasive beds of rooted aquatic macrophytes, which are currently at nuisance levels in the Pond. Water withdrawal was limited in 1997 and 1998 due to excessive plant densities and blockage of the raw water intakes. Of additional concern is the potential infilling of the pond with reduced storage capacity. Both conditions potentially pose a risk to the long-term usefulness of the Pond as a water supply.

Concerned over this perceived decline in storage capacity and impairment to water withdrawal and treatment, the Town, acting through its Board of Water Commissioners (the “Board”), secured ENSR International (ENSR) to conduct a *Limnology and Water’s Edge Study for Lily Pond*. This study, sponsored by a grant from the Massachusetts Department of Environmental Protection (MA DEM) and matching funds from the Town of Cohasset, was designed to assess the current limnological conditions (physical, chemical, and biological) within Lily Pond and evaluate the influence of its watershed. The results of this investigation and an assessment of alternatives for restoring, preservation, and maintaining the Pond and its watershed are presented in this report. The report provides specific recommendations and feasibility for both in-lake and water quality management alternatives.

Figure 1. Site Locus

2.0 WATERSHED HISTORY AND USE

2.1 Description of Lily Pond Watershed

The natural watershed of Lily Pond (Figure 2) is approximately 1,603 acres (an approximately 31:1 watershed to lake area ratio) and is comprised mainly of forested area (SWSPP; Norfolk Ram Group, 2002). It is classified in the Massachusetts Department of Environmental Protection (MADEP) South Coastal watershed basin. The two major tributary streams draining into Lily Pond are Brass Kettle Brook and Peppermint Brook. Brass Kettle Brook has a watershed that is located to the northwest of the Pond and enters in the southwestern quadrant of the lake. Peppermint Brook, which has a watershed to the north and northeast of the Pond, enters at the top end of the waterbody. There are two small direct drainage areas to Lily Pond. Herring Brook, which normally serves as the pond's outlet, can serve as a tributary when water is impounded at the Bound Brook control structure (BBCS).

Lily Pond can also receive hydrologic inputs from seasonal releases from the Aaron River Reservoir, completed in 1978, which is located upstream of the Pond. Due to the control elevation at the BBCS, water released by the Aaron River Reservoir may be pooled in the wetlands located to the south of the Pond. During periods when the surface elevation of the Pond falls below the controlling elevation at the BBCS and/or when water is withdrawn from the Pond, there is a potential for water to be drawn into the Pond via Herring Brook. Further discussion of the hydrologic budget is given in Section 4.1.3. Further information on the land use in the watershed in given in Section 4.1.1.

2.2 History of Land and Pond Use

Cohasset was originally named Conohasset after the Indian tribe that occupied the area and was part of Hingham. The first separation of land from Hingham into the new town occurred in 1638 and by 1717 the separation was formalized with precinct status granted to allow the formation of a separate church and school. The Town was incorporated in 1770. In the last century, the Town was a varied mixture of rural agricultural lands, residential and commercial areas, and luxury vacation homes, even up to the 1950s and early 60s. More recently, the town has become much more residential in nature, with little active commercial agriculture.

Figure 2. Lily Pond Watershed

The exact origin of Lily Pond is not certain, although it can be assumed that it was a product of the glaciation during the Pleistocene. It has been reportedly used by the Town for a drinking water supply since the 1880s (Norfolk Ram Group, 2002). There was only one structure depicted along the Pond shoreline on a historic topographic map. This is consistent with the reported location of a pumphouse used to directly pump water into the water distribution system (Norfolk Ram Group, 2002).

Examination of the density of structures around the Pond in the 1935 map (Figure 3) indicate that there were no structures shown in the Brass Kettle Brook watershed within Whitney Woods. Comparison of the historic maps to the most recent map (Figure 1) indicates that development has taken place, primarily along King Street near the Pond, while the Peppermint Brook sub-watershed is heavily developed.

Comparison of the outline of the Pond from the 1935 map indicates little change in the Pond's general shape and dimensions over time. One noticeable change has been the straightening and enlargement of Herring Brook in the most recent map. This channelization was part of the 1977-78 Aaron River Reservoir Project.

The present Water Treatment Plant was built in 1978 with a design capacity of 3.0 million gallons per day (MGD). It has a reported current capacity of 2.5 MGD and services 90% (about 7,100) of the residents in the Town (Norfolk Ram Group, 2002). The Water Treatment Plant operations created settling residuals that are treated in two lagoons located to the south of the plant with supernatant water returned to the Pond as a permitted discharge.

The Pond has been used as a water supply of Cohasset since 1880. Historical uses include boating, fishing, swimming and ice harvesting. Ice harvesting was an important historic activity at Lily Pond. The Souther family operated an ice house located along King Street near the former location of the water treatment pump house (Pratt, 1956). There is evidence from Massachusetts Division of Fish and Wildlife that stocking of fish was conducted as late as 1921, suggesting recreational fishing was active during that period (see Section 4.3.6).

Present uses of the pond are strictly limited as part of the source water protection. These pond restrictions are well marked on a sign at the Water Treatment Plant. No swimming is allowed. There is a motorized boat restriction on Lily Pond; both gasoline and electric engines are prohibited. Non-motorized boats are allowed, but only rowboats are acceptable; canoes are prohibited. There is some degree of public boat access to the pond through the Cohasset Water Treatment Plant parcel. The Town Recreation Department uses the Pond for ice skating in the winter, when safe ice conditions permit (pers. Comm. John McNabb).

Figure 3. Lily Pond Historic (1935) Watershed

2.3 Previous Studies

A number of studies and investigations have been conducted on Lily Pond and/or relevant portions of its wetlands. These range from the 1980s until the current year. These are briefly identified and described below.

Camp Dresser & McKee 1984. *Hydrological and Water Quality Study of Watersheds Tributary to Lily Pond and Great Swamp in the Area of Scituate Hill.*

Camp Dresser & McKee was contracted by the Town of Cohasset Water Commissioners to perform a water quality investigation of Lily Pond and Great Swamp and their watersheds. Areas specifically linked to the Scituate Hill drainage were investigated. Two areas of potential contamination were identified: the Cohasset Heights Limited (CHL), Inc. landfill and the Webb/Norfolk Conveyor Corporation Plant. The report recommended the implementation of a watershed monitoring program and specific requests that the Town should make to CHL to better control and monitor landfill leachate. There were no nutrient data gathered during this investigation.

Camp Dresser & McKee 1986. *Town of Cohasset, Massachusetts Water Resources Management Plan.*

Camp Dresser & McKee was contracted by the Town of Cohasset Board of Water Commissioners to develop a water resources management plan that included:

- Watershed delineation
- Evaluation of impacts from future development
- Evaluation of current by-laws and their effectiveness of water quality protection
- Alternative management actions
- Recommendations for modification of by-laws and regulations

Nutrient levels were evaluated once in June 1985 as part of the management plan. Unfortunately the detection limit was too high to obtain an accurate assessment of surface water total phosphorus (TP) in Lily Pond (0.066 mg/L). The bottom sample and two tributary values (Peppermint Brook and Brass Kettle Brook), however, were higher than this detection limit (Table 1). It should be noted that the nitrate nitrogen levels in Peppermint Brook were significantly higher that elsewhere in the system. An approximate nutrient budget representing current conditions for Lily Pond was estimated using land use and literature derived export coefficients for nitrogen and phosphorus. Nutrient budgets were also estimated under two additional scenarios: 1) fully developed (i.e., a build-out analysis) watershed with existing sewer system, and 2) fully developed watershed with an expanded town sewage system (Table 2).

Table 1. Lily Pond and Tributary Water Quality June 1985.
(Selected data from Table 4. CDM, 1986).

Sample Location	pH (SU)	Color (units)	Alkalinity (mg/L)	Chloride (mg/L)	Total Phos. (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)
Lily Pond Surface	7.2	45	8.9	32.5	<0.066	0.5	<0.01
Lily Pond Bottom	7.0	60	22.2	18.0	0.33	2.0	0.05
Brass Kettle Brook	5.4	150	0	31.7	0.073	1.0	0.02
Peppermint Brook	7.1	105	26.7	79.4	0.19	0.5	0.53

Table 2. Lily Pond Nutrient Budget. (Selected data from Table 8. CDM, 1986).

Condition	Total Phosphorus (lbs/yr)	Total Nitrogen (lbs/yr)
Existing (1985)		
▪ Runoff	398	4056
▪ Sewage	72	4363
▪ Landfills	15	1543
Total	485	9962
Fully Developed – current sewage system		
▪ Runoff	444	4693
▪ Sewage	74	8962
▪ Landfills[1]	0	0
Total	518	13658
Fully Developed – expanded sewage system		
▪ Runoff	444	4693
▪ Sewage	74	6986
▪ Landfills[1]	0	0
Total	518	11679

[1]Landfill assumed to be closed

Norfolk Environmental 1998. *Report on Potential Contaminant Migration from Cohasset Heights Landfill to Lily Pond.*

This report summarized historic data relating to the Cohasset Heights Landfill operation and supplemental data from surface water discharging to Brass Kettle Brook. The report concluded that elevated levels of chloride, chemical oxygen demand (COD), lead, and toluene were attributable to the landfill or other upgradient industries. Generally concentrations decreased downgradient of the landfill.

United States Army Corps of Engineers 1999. *Cohasset Water Quality Study.*

A limited watershed investigation was performed to determine the impact from the former Hingham Annex waste site, Cohasset Heights Landfill, and residential areas proximal to Peppermint Brook. Similar to the Norfolk 1998 investigation, elevated levels of lead were reported in Brass Kettle Brook with concentrations decreasing downgradient of the landfill. Elevated levels of fecal coliform were reported in Peppermint Brook.

Quarterly Testing of Cohasset Landfill (state required landfill monitoring)

As required by the Commonwealth of Massachusetts, quarterly monitoring of the Cohasset Heights Landfill and downgradient areas is ongoing. Levels of sodium and chloride are consistently elevated in surface waters downgradient of the landfill.

Norfolk Ram Group 2002. *Surface Water Supply Protection Plan for Lily Pond and Aaron River Reservoir.*

The Norfolk Ram Group was contracted by the MA DEP Bureau of Resource Protection and the United States Environmental Protection Agency (USEPA) to prepare a water supply protection plan for Lily pond and Aaron River Reservoir. This plan states that non-point pollution is the most immediate threat to Lily Pond and Aaron River Reservoir water quality. The report classifies Lily Pond as eutrophic to hyper-eutrophic based on limited water quality information. A variety of recommendations were made and prioritized based on relative importance to watershed protection. These recommendations included:

- Watershed monitoring and assessment,
- Stormwater and non-point source pollution controls,
- Septic system and other point source controls,
- Land use bylaws modification,
- Management and enforcement funding,
- Open space acquisition and conservation restrictions, and
- Watershed management

Results of semi-annual sampling by Tutela Engineering Associates (1998-2000) and quarterly sampling by Norfolk Ram Group (2001-2002) were summarized. Select data from the Norfolk Ram Group 2002 report are provided in Table 3.

Table 3. Average Surface Water Sampling Results 1999-2002. (Selected data from Table 4-2a. Norfolk Ram Group, 2002).

Sample Location	pH (SU)	Conductivity (ms/cm)	Turbidity (NTU)	Alkalinity (mg/L)	Chloride (mg/L)	Fecal Coliform (#/100 ml)	Total Phos. (mg/L)	Nitrate Nitrogen (mg/L)	Total Nitrogen (mg/L)
Lily Pond Surface	6.5	129.8	15.2	5.9	34.7	NT	0.09	0.18	0.26
Lily Pond Bottom	7.1	128.5	18.1	5.5	34.0	13	0.29	0.22	NT
Lily Pond Outlet (Herring Brook)	6.8	129.4	20.5	3.6	39.7	10	0.04	0.08	1.55
Brass Kettle Brook	6.0	103.1	20.3	6.9	22.3	NT	0.42	NT	NT
Peppermint Brook	6.4	186.9	13.3	11.6	58.7	20	0.23	0.57	NT

* Values less than detection limit were reported as ½ the detection limit to calculate averages

2.4 Summary

Data regarding potential critical contaminants to Lily Pond from the watershed has been previously collected and assessed. Key watershed areas of concern include the landfill and non-point source runoff, specifically from Peppermint Brook. There is little data, however, to conclusively assess the in-lake status of Lily Pond. Phosphorus detection limits were too high during many of the sampling events. There is limited information regarding the hydrology of Lily Pond other than estimates based on runoff coefficients that do not take into consideration back flow from Herring Brook, water withdrawals, and the morphometric characteristics of the pond itself. There is also little or no previous information regarding the bathymetric contours of the Pond or the nature of the aquatic communities in the pond (e.g., rooted plants, algae, zooplankton, fish, etc.). Thus, the ENSR *Lily Pond Limnology and Water's Edge Study* was designed to fill in these data gaps and integrate the previous information into a more comprehensive evaluation of the current state of Lily Pond.

3.0 STUDY APPROACH AND METHODS

The study approach and investigation/survey methods used in the Study are detailed below. These are divided between tasks use to determine the physical (Section 3.1), chemical (Section 3.2), and biological characteristics (Section 3.3) of the Pond.

3.1 Physical Characteristics

3.1.1 Watershed Features

Field investigations, United States Geological Survey (USGS) 7.5 minute topographic maps, and information from previous reports were used to delineate the watershed draining to Lily Pond (CDM, 1986). Drainage patterns were used to further divide the watershed into sub-basins. Soil types were obtained from the Soil Conservation Service Soil Survey of Norfolk and Suffolk Counties, Massachusetts (1989). Major land use categories in the watershed were obtained from the Massachusetts Geographic Information System (MASSGIS), the Norfolk Ram Group Report (2002), characterization of soils, and fieldwork. A field reconnaissance was conducted by a qualified wetland scientist to describe habitat characteristics within 300 feet of the shoreline of Lily Pond.

3.1.2 Lake Features

Water and sediment depths of Lily Pond were mapped during the field investigation. A graduated metal rod was used to measure water depth and soft sediment depth at 131 survey points along 19 transects (Figure 4). The resulting bathymetric map was used to calculate pond surface area, average water depth, maximum water depth, and total pond volume. Benthic substrate composition and depth were evaluated by probing the pond bottom with the metal rod. The water depths were confirmed by a hand-held depth finder in areas of hard substrate where the absence of plants allowed a true reading. Sediment depth was measured in areas where the total depth (water plus sediment) was less than 10 feet. Select areas (e.g., chemical sampling stations) were probed to a total depth of 20 feet in an attempt to obtain a more accurate assessment of sediment depth and quantity. The sediment map was used to calculate sediment volumes for various proposed dredging options.

Tributary locations were identified from field investigations and review of USGS 7.5 minute topographic maps. Hydrologic loading was determined using literature derived runoff coefficients based on watershed land use and additional hydrologic estimates (Tutela Engineering, undated). Average annual precipitation was estimated from the nearby Hingham weather station, which has a long-term data set. Direct precipitation was estimated by multiplying average annual precipitation by the total Pond area. An evaporation rate of 26”/yr

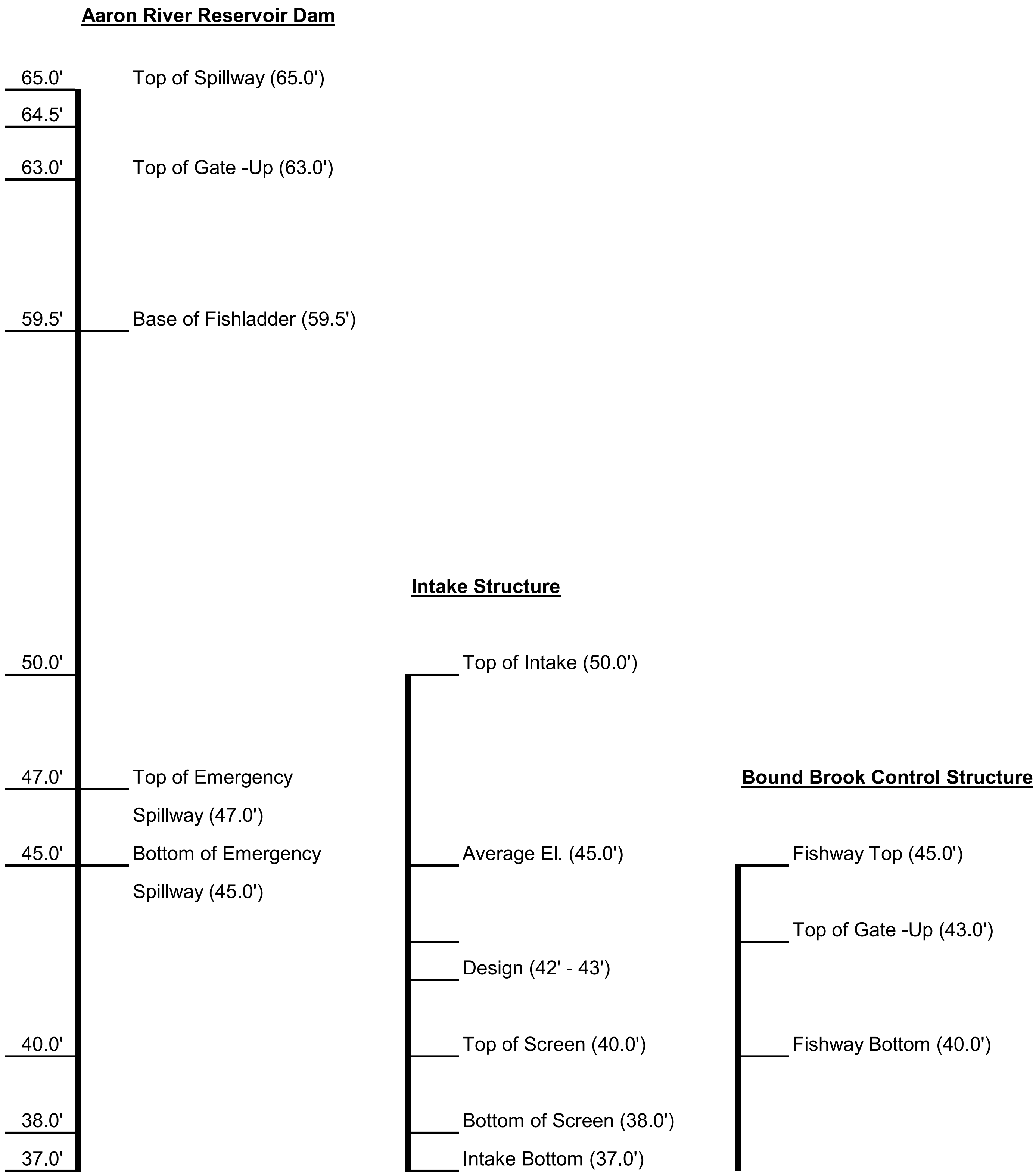
Figure 4. Lily Pond Vegetation Survey Transects and Points

was used, which is typical of southeastern Massachusetts (Water Atlas of the United States, 1973). Surface water flow was estimated for each sub-basin by multiplying average annual precipitation by selected runoff and base-flow coefficients relating to land use and adjusted with data provided in previous investigations. Total inflow and morphometric features of the pond were used to estimate flushing rate and detention time.

Water level values provided by the water treatment plant from a staff gauge located at the intake were used to estimate water volume and hydrologic loading when Lily Pond is at full capacity. The calculated volume at the time of the 2002 survey was adjusted based on the elevation of the intake structure and BBCS (Figure 5). Flushing rate and hydrologic residence time were estimated based on full capacity and at the time of the survey. Although these values have limited use in terms of water supply yield, these values are appropriate for the estimation of nutrient loading expression (i.e., chlorophyll concentrations and water clarity). A complete hydrological investigation is necessary to determine full storage capacity of the Lily Pond basin and associated wetlands.

A rough estimate of the annual hydrologic budget was prepared based on input calculations provided above. A water withdrawal rate was provided from the water treatment plant and represents a portion of the hydrologic output. The sum of the exports (evapotranspiration and water withdrawal) was set equal to the sum of all calculable inputs. Ecosystem loss, an arbitrarily determined value, was used to balance the budget and represents water loss over the BBCS, loss from Brass Kettle Brook draining to the south of Lily Pond into the large wetland system instead of the main basin, and evapotranspiration of that wetland system. The contribution of Aaron River Reservoir was not determined. Although Aaron River Reservoir contributes to Lily Pond on a seasonal basis, it is difficult to quantify this contribution on an annual basis. It may not provide significant inflow on an annual basis, only seasonally. A detailed study evaluating hydrologic imports and exports throughout the year would be necessary for this analysis.

Figure 5. Structure Elevations in Lily Pond and Aaron River Reservoir.



3.2 Chemical Characteristics

3.2.1 Surface Water

Surface water sampling was conducted on three occasions during the field work: July 31st, August 29th, October 2nd, 2002, and a supplemental sampling on December 30, 2002. Sampling was conducted at three in-lake stations (LP-1, LP-2, and LP-4), two tributaries (Brass Kettle Brook: BK-1a and BK-1b, and Peppermint Brook: PB-1), and the lake outlet (Herring Brook: LP-3). The supplemental sampling was conducted at two shoreline segments (LP-SS1 and LP-SS2) and at the two tributaries (BK-1b and PB-1). A description of sampling locations is provided in Table 4 and approximate locations are provided on Figure 6. In-situ measurements included temperature, dissolved oxygen (DO), specific conductivity, and Secchi disk transparency (SDT). Grab samples were collected and sent to a State Certified Laboratory (Berkshire Enviro-Labs, Lee, MA) and analyzed for a variety of water quality variables. Total organic carbon was the only parameter analyzed during the supplemental sampling. A State Certified Laboratory (Thorstensen Laboratory) analyzed these samples. The complete list of variables analyzed, the sample date and location are provided in Table 5.

Sampling results were compared to both the Massachusetts State Surface Water Quality Standards for Class A Inland Waters and Massachusetts Drinking Water Maximum Contaminant Level (MCL). If standards do not exist for a water quality variable analyzed, sample results were compared to thresholds from literature values and background levels for this area of Massachusetts.

Table 4. Description of ENSR 2002 Sampling Locations

Sample Identifier	Description
LP-1S	In-lake station, surface grab sample, southeast of water supply intake
LP-1B	In-lake station, grab sample at sediment/water interface, southeast of water supply intake
LP-2S	In-lake station, surface grab sample, eastern portion of the pond
LP-2B	In-lake station, grab sample at sediment/water interface, eastern portion of the pond
LP-3S	Outlet – Herring Brook, surface grab sample, approximately 400 feet south of pond
LP-3B	Outlet – Herring Brook, grab sample at sediment/water interface, approximately 400 feet south of pond
LP-4S	In-lake station, surface grab sample, deepest portion of pond approximately 300 feet southeast of bedrock outcrop
LP-4B	In-lake station, grab sample at sediment/water interface, deepest portion of pond approximately 300 feet southeast of bedrock outcrop
PB-1	Peppermint Brook, approximately 15 feet upstream of King Street
BK-1a	In-lake station, surface grab sample, where Brass Kettle Brook discharges to Lily Pond - July only.
BK-1b	Brass Kettle Brook, approximately 1.2 miles upstream of Lily Pond end of Howes Lane
LP-SS1	In-lake station, surface grab sample, shoreline near treatment intake
LP-SS2	In-lake station, surface grab sample, shoreline southeast portion of Lily Pond

Figure 6. Lily Pond Sampling Stations

Table 5. Water Quality Variables Sampled in 2002.

Water Quality Variable	July 31, 2002	August 29, 2002	October 10, 2002
Field Parameters			
temperature, pH, specific cond.	All Stations	All Stations except BK-1b[1]	All Stations
dissolved oxygen,	All Stations	All Stations except BK-1b[1]	Not Sampled
Secchi disk transparency	In-lake Stations	In-lake Stations	In-lake Stations
Conventional Water Quality[3]			
alkalinity, chloride	All Stations	All Stations except BK-1b[1]	All Stations
hardness	LP-3S,LP-4S,PB-1,BK-1a	LP-3S,LP-4S,PB-1	LP-3S,LP-4S,PB-1,BK-1b
biological oxygen demand	All Stations	LP-3S&B,LP-4S&B,PB-1	LP-3S&B,LP-4S&B,PB-1,BK-1b
Nutrients			
ammonium-N, nitrite-N, nitrate-N, total Kjeldahl nitrogen, dissolved phosphorus, and total phosphorus	All Stations	All Stations except BK-1b[1]	All Stations
RCRA 8 Metals			
arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver	All Stations	LP-3S&B,LP-4S&B,PB-1	LP-3S&B,LP-4S&B,PB-1,BK-1b
Iron	All Stations	All Stations except BK-1b[1]	All Stations
Biological			
fecal coliform	All Stations except BK-1a[2]	All Stations except BK-1b[1]	All Stations except LP-1S & LP-2S
chlorophyll a	LP-1 & LP-4	LP-3 & LP-4	LP-3 & LP-4

1 Tributary was dry on sampling date and no sample was taken.

2 Glass sample bottle broke during shipping and no analysis made.

3 Total organic carbon sampling occurred on December 30, 2002 at LP-SS1, LP-SS2, BK-1b, and PB-1

3.2.2 Benthic Sediments

Four benthic sediment samples were collected in Lily Pond on August 29th, 2002 and shipped to a State Certified Laboratory (SciLab, Weymouth, MA). Sampling locations were the same as in-lake water quality stations (i.e., LP-1 through LP-4; see Figure 6). The samples were collected with the aid of an Eijelkamp core sampler, and were composited within the area of the sample location and over a maximum sediment depth of approximately seven feet. Parameters evaluated in all sediment samples included particle size distribution, pH, total organic carbon, total nitrogen, total phosphorus, solids content, and RCRA 8 metals (Ag, As, Ba, Cd, Cr, Hg, Pb, Se). Two of the four sediment samples (LP-1 and LP-4) were also analyzed for additional parameters - total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs).

Sample results were compared to two State thresholds: the Massachusetts Contingency Plan (MCP) Soil 1 Reportable Concentration (RCS-1) and the Massachusetts consensus-based threshold effect concentrations (TECs). In the event of dredging, once removed from Lily Pond, soft sediment would be considered soil by regulators and therefore the "soil" quality would determine disposal location. The MCP RCS1 standard is the strictest state standard. Soil meeting these criteria would be considered clean and greatly increase disposal options, and decrease disposal costs. The second threshold, consensus-based threshold effect concentrations (TECs) for the 28 chemicals listed in MacDonald et al. (2000), is used for screening freshwater sediment for risk to benthic organisms. Although not very useful in regards to dredging and disposal options, TECs are intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms are not expected.

3.2.3 Nutrient Loading

Two separate approaches were used to estimate nitrogen and phosphorus loading to Lily Pond: an empirical model approach and a land use export coefficient model approach. The first approach estimated nutrient loading with empirical models. These models use hydrologic lake features and known in-lake concentrations to back-calculate the load which would yield the observed concentrations. A variety of such models are available; we have chosen a single three-part nitrogen model (Bachman 1980) and several phosphorus models that tend to represent the range of possible conditions (Kirchner and Dillon 1975, Vollenweider 1975, Reckhow 1977, Larsen and Mercier 1976, Jones and Bachman 1976).

The second approach employed nutrient export coefficients for land use types, tempered by known attenuation mechanisms, specific watershed features, and existing data. This second approach also results in a model that can be used to predict the impact of various management actions on in-lake water quality. This model was developed by ENSR personnel as a spreadsheet that can be adapted to various uses, and incorporates the predictive capability of the empirical models and the "reality checks" afforded by actual data for the target system.

A third approach not utilized in this investigation, uses actual flow measurements and nutrient concentrations. Due to the restricted seasonal sampling, both tributaries had either no flow or extremely low flow during the time of sampling. Therefore there are no flow data to correspond with nutrient concentration data.

3.2.4 Quality Control/Quality Assurance

All sampling was carried out in order to assure sample precision, accuracy, completeness, and representativeness. Precision is a measure of the degree to which two or more measurements are in agreement, and was assessed through the determination of duplicate samples, collected or measured randomly, representing about 12% of the actual number of samples. Precision was measured as the relative percent difference (*RPD*) between sets of values:

$$RPD = \frac{(Amount\ in\ Sample\,1 - Amount\ in\ Sample\,2)}{0.5\,(Amount\ in\ Sample\,1 + Amount\ in\ Sample\,2)}\,x\,100$$

A total of three duplicate samples were taken during the sampling period: one duplicate sample for tributaries, and two for in-lake stations. RPD values for water quality ranged from 0% to 67%, depending on the parameter, with RPD values higher than about 25% resulting from small differences in results near the detection limit for several parameters (e.g., ammonium-N, BOD-5) (Table 6). High RPD values for TKN and total phosphorus are likely due to differences in amount of particulate material in the sample. Values for the dissolved fraction of these nutrients were low.

Accuracy is the degree of agreement between the observed value (i.e., measured, estimated, or calculated) and an accepted reference or true value (i.e., the real value). Accuracy was achieved through the adherence to all sample collection, handling, preservation, and holding time requirements, but was not tested with blanks or spikes in this study. The laboratories employed to analyze the samples perform such tests on a regular basis, and it is assumed that their certification by the Commonwealth signifies an acceptable degree of accuracy.

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions (defined as the conditions expected if the sampling plan was implemented as planned). Completeness is calculated as

$$Completeness = \frac{(number\ of\ valid\ measurements)}{(number\ of\ measurements\ planned)}\,x\,100$$

and was 100% for most samples. Values for dissolved oxygen were not obtained for all stations on October 10, 2002 due to malfunctioning equipment. Fecal coliform was not assessed at BK-1 because the glass sample bottle broke during shipment on July 31, 2002. Brass Kettle Brook was dry during the August sampling. In total, completeness was 95% for this investigation.

Table 6. Quality Assurance/Quality Control (QA/QC) on Lily Pond Water Quality Data for Tributaries and In-lake samples Combined.
QA/QC is expressed as RPD (relative percent difference), a measure of precision. Std. dev.: standard deviation from average range of values; not calculable (nc) for n=1.

			Range of Values					Std. Dev.
Water Quality Variable	Unit	n	Min	Max	Min %RPD	Avg %RPD	Max %RPD	of Differences
Alkalinity	mg/L	3	10	56	0.00	6.06	18.18	1.15
Ammonia (as N)	mg/L	3	0.02	0.09	0.00	9.52	28.57	0.01
Nitrite (as N)	mg/L	3	0.005	0.005	0.00	0.00	0.00	0.00
Nitrate (as N)	mg/L	3	0.005	0.47	0.00	0.72	2.15	0.01
TKN (as N)	mg/L	3	0.4	0.8	0.00	28.28	66.67	0.21
Dissolved-Phosphorus	mg/L	3	0.01	0.04	0.00	0.00	0.00	0.00
Total Phosphorus	mg/L	3	0.02	0.05	0.00	35.56	66.67	0.01
BOD5	mg/L	3	0.5	1	0.00	22.22	66.67	0.29
Total Fe	mg/L	3	0.87	1.8	1.14	4.95	8.00	0.05
Chloride	mg/L	3	28	177	0.34	0.42	0.57	0.52
Hardness	mg/L	3	20	96	0.00	9.98	18.18	2.31
Conductance	umhos/cm	1	114	117	2.60	2.60	2.60	nc
Arsenic	mg/L	3	0.0025	0.01	0.00	0.00	0.00	0.00
Barium	mg/L	3	0.0046	0.0235	3.02	6.77	14.14	0.00
Cadmium	mg/L	3	0.0001	0.0005	0.00	0.00	0.00	0.00
Chromium	mg/L	3	0.001	0.0035	0.00	0.00	0.00	0.00
Lead	mg/L	3	0.0005	0.005	0.00	0.00	0.00	0.00
Mercury	mg/L	3	0.00002	0.00002	0.00	0.00	0.00	0.00
Selenium	mg/L	3	0.0005	0.01	0.00	0.00	0.00	0.00
Silver	mg/L	3	0.001	0.005	0.00	0.00	0.00	0.00

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a parameter, process, population, or environmental condition within a defined spatial and/or temporal boundary. Representativeness of the data collected was maximized by following the study design and applying the proper sampling techniques and analytical testing. Where choices of stations to be sampled were made, effort was expended to ensure that those sites sampled were most representative of the conditions the study intended to assess.

3.3 Biological Characteristics

Water samples for biological characterization of planktonic (open-water) biological communities were collected at LP-1 and LP-4 on July 31, 2002 (Figure 6). Planktonic communities include photosynthetic organisms (algae, or phytoplankton) and the invertebrates that feed directly on them (collectively called zooplankton). Both types of organisms influence and reflect other in-lake characteristics such as water quality and fish community features.

Phytoplankton samples were collected with a ¾ inch diameter plastic tube with lake water. The tube is immersed vertically, with a terminal weight maintaining the tube vertical position throughout the water column. When the tube is full, the top end is sealed, the bottom end is retrieved and the content is emptied in a container. The water sample collected this way is a composite sample of the water column from the surface to the Secchi disk transparency (SDT) depth (2 - 3.5 feet in this case). Because most of the phytoplankton community lives in the upper water layers of a lake, samples collected this way were representative of the open-water algal community. The collected planktonic algae were preserved by addition of gluteraldehyde.

Taxonomic identification and algal counts (density and biomass) were performed by an ENSR taxonomist, and served as the basis for an expanded ecological discussion of phytoplankton (including community structure, relative abundances, species richness, diversity, and evenness) as related to water quality and other biological components of Lily Pond. Samples were concentrated and the concentrate was viewed in a counting chamber under phase contrast optics at 400X power. Algae were identified, sized and enumerated, and a computer program converted the raw data to density, either as cells/ml or biomass (µg/L).

Water samples were collected using the same method for phytoplankton, described above, and analyzed for chlorophyll *a*. Chlorophyll samples were filtered through a 0.45 µm glass fiber filter within 12 hours from collection and frozen until spectrophotometric determination of chlorophyll *a* content.

Zooplankton were collected by means of a 53-µm mesh, funnel-shaped plankton net towed just below the water surface; tow length was recorded. The collected zooplankton were preserved by addition of glutaraldehyde.

Taxonomic identification and organism counts (density and biomass) were performed by an ENSR taxonomist, and served as the basis for an expanded ecological discussion of zooplankton (including community structure, relative abundance, size distribution, species richness, diversity, and evenness) as related to water quality and other biological components of

Lily Pond. Samples were concentrated and the concentrate was viewed in a counting chamber under brightfield optics at 100X power. Zooplankton were identified, sized and enumerated, and a computer program converted the raw data to density, either as individuals/L or biomass (µg/L).

The community of aquatic plants or macrophytes (including angiosperms, macroalgae, and benthic mats of filamentous algae) was mapped along the same transects used for water depth and sediment thickness observations (Figure 4), on July 31, 2002 with an underwater videocamera. Use of an underwater camera allowed visual inspection at depths much greater than those reached with a more traditional unaided observation from the boat, rendering the underwater camera method comparable to direct examination by divers. Shoreline (emergent or amphibious) vegetation was mapped by visual inspection.

Plants were identified to the lowest possible taxonomic level by ENSR personnel. When identification *in situ* was not possible, samples were collected and identified in the laboratory with the help of a binocular microscope and several keys (Fassett 1957; Hellquist & Crow 1980, 1982; Crow & Hellquist 1981, 1982, 1983, 1985). Plant data were used to construct vegetation maps illustrating qualitative and quantitative species distribution. Quantitative analysis was based on *in situ* analysis of taxa relative abundances (expressed as percent of biovolume occupied by a single taxon with respect to total plant biovolume), total macrophyte percent cover (defined as the portion of the bottom sediments of the examined area covered with plants), and total macrophyte percent biovolume (defined as the portion of the water column of the same area filled with plant material). Macrophyte cover and biovolume were expressed using a 0 to 4 semi-quantitative scale ranging from absence of plants (zero) to maximum possible biomass or cover (four) (Table 7). Vegetation maps were used to extract pond-wide semi-quantitative measures of plant species richness and diversity, and to relate the macrophyte community to water quality and other biological components of Lily Pond.

No fish sampling was conducted as part of this study. The fish community of Lily Pond was analyzed by reviewing the existing information available through the Massachusetts Division of Fisheries and Wildlife, which is neither recent nor complete. This information was used to relate the fish community to water quality and other biological components of Lily Pond.

Table 7. Classification Scales used for the *In Situ* Macrophyte Percent Cover and Percent Biomass Evaluation.

Percent Macrophyte Coverage	
Scale	**Description**
0	plants absent (all visible sediment area is devoid of plants)
1	1-25% cover (1 to 25% of the visible sediment area is covered with living plant material)
2	26-50% cover (26 to 50% of the visible sediment area is covered with living plant material)
3	51-75% cover (51 to 75% of the visible sediment area is covered with living plant material)
4	76-100% cover (76 to 100% of the visible sediment area is covered with living plant material)
Percent Macrophyte Biomass	
Scale	**Description**
0	plants absent (the whole water column as delimitated by the viewing area is devoid of plants)
1	1-25% of the water column filled with living plants (plants growing only as a low layer on the bottom sediments)
2	26-50% of the water column filled with living plants (plants protruding into the water column, but rarely reaching the surface, and not at nuisance densities)
3	51-75% of the water column filled with living plants (plants filling more than half the water column and often reaching the surface; nuisance conditions and/or habitat impairment perceived)
4	76-100% of the water column filled with living plants (water column filled and/or surface completely covered, nuisance conditions and/or habitat impairment severe)

4.0 STUDY RESULTS

The results of the Pond and watershed investigations and surveys are detailed below. These are divided between results from investigations of the physical (Section 4.1), chemical (Section 4.2), and biological characteristics (Section 4.3) of the Pond.

4.1 Physical Characteristics

4.1.1 Watershed Features

4.1.1.1 Land Use

The watershed draining to Lily Pond is approximately 1,603 acres in size, not including Lily Pond surface area (Figure 2). Three sub-basins were delineated within the watershed: Brass Kettle Brook draining approximately 1,216 acres (Basin 1), Peppermint Brook draining approximately 260 acres (Basin 2) and two direct drainage areas draining approximately 127 acres directly into Lily Pond. The Lily Pond watershed is relatively undeveloped (approximately 64% forested; Table 8), with the residential development concentrated to the north and east (Figure 7). Land use data was taken directly from MassGIS and is based interpretation of aerial photography. Wetland areas are often underreported using this technique since forested wetlands are combined with forested uplands. An analysis of the MassGIS soils and the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) data layers, also obtained through MassGIS, were used to supplement the MassGIS land use data layer to better represent forested uplands. According to the Cohasset soil data, the Lily Pond watershed contains 17.3% hydric soils (Hingham soils were unavailable). The NWI data layer lists 17.0% of the Lily Pond watershed as non-tidal scrub-shrub or forested wetland cover. Other estimates of forest and wetland land use include 67% and 20%, respectively within the watershed (Tom Keefe, Tutela Engineering, comments on draft report). For the purposes of this report, a range of 17-20% wetland coverage is representative; a value of 16.4% was assumed (Table 8).

Much of the current forested/forested wetland area is zoned residential, however, and could be considered as potential development, with the exception of wetland areas. Luckily, much of these lands are protected as open space by inclusion in the Wompatuck State Park, the Whitney and Thayers Woods Reservation, and other protected open space or are considered wetland areas and not developable without replication. Industrial facilities, such as the Cohasset Heights Landfill and former Hingham Annex waste site are potential concerns for water quality as demonstrated in previous investigations. However, the SWSPP (Norfolk Ram Group, 2002) suggested that non-point source pollution entering Peppermint Brook from the north is the largest immediate threat to Lily Pond’s water quality.

Table 8. Land Use Type by Sub-Watershed (in Acres) for the Lily Pond Watershed.

Land Use	Brass Kettle Brook Basin 1	% of Total Basin	Peppermint Brook Basin 2	% of Total Basin	Direct Drainage to Pond	% of Total Basin	Total Area	Percent of Total Watershed
Cropland	6.8	0.6					6.8	0.4
Forest	870.2	71.5	88.4	34.0	60.9	47.9	1019.5	63.6
Forested Wetland	240.4	19.8	15.5	6.0	7.0	5.5	262.9	16.4
Wetland	6.9	0.6			4.1	3.2	11.0	0.7
Open Land	19.0	1.6	1.8	0.7	1.0	0.8	21.8	1.4
Participation Recreation			2.9	1.1			2.9	0.2
Residential Multi-family			1.2	0.5			1.2	0.1
Residential 1/4 - 1/2 acre lots			44.5	17.1	0.4	0.3	44.9	2.8
Residential Larger than 1/2 acre lots	6.6	0.5	84.5	32.6	44.6	35.1	135.8	8.5
Commercial			16.6	6.4	4.2	3.3	20.8	1.3
Industrial	17.1	1.4					17.1	1.1
Water	0.3	<0.1					0.3	<0.1
Waste Disposal					1.9	1.5	1.9	0.1
Powerlines	12.1	1.0			3.0	2.4	15.1	0.9
Urban public	36.6	3.0	4.1	1.6			40.7	2.5
TOTAL	**1216.0**	**100.0**	**259.5**	**100.0**	**127.1**	**100.0**	**1602.6**	**100**

Land use coverage is taken directly from MassGIS. The land use data layer is derived by interpreting aerial photography and can underestimate wetland land cover. An analysis of hydric soils from MassGIS and National Wetland Inventory data layers were used to supplement the land use data to better represent forested wetlands.

Figure 7. Lily Pond Land Use

4.1.1.2 Geology and Soils

According to the Soil Survey of Norfolk and Suffolk Counties, Massachusetts (1989) there are six different soil types / complexes mapped within 300 feet of Lily pond's ordinary high water line (Figure 8). Soil types were verified in the field through observations of topography, landscape position, and other surficial features (i.e., stone walls, boulders and bedrock outcrops). None of the soil units mapped adjacent to Lily Pond pose a risk to water quality in their currently stable, vegetated condition. The predominant upland soils adjacent to Lily pond are the Hollis, Charlton, and Rock outcrop complexes, comprising approximately 80% of the land area (34.8 acres) within 300 feet of Lily pond's ordinary high water line. These three soils occur closely together on varying slopes throughout this region and are lumped together because the Natural Resources Conservation Service (NRCS) does not map soils on a fine enough spatial scale to separate them.

The four main complexes mapped adjacent to Lily Pond include Rock outcrop-Hollis complex (RoD) on 3-25% slopes, Hollis-Rock outcrop-Charlton complex (HrC) on 3-15% slopes, Hollis-Rock outcrop-Charlton complex (HrD) on 15-35% slopes, and Charlton-Hollis-Rock outcrop complex (ChB) found on 8-15% slopes. The Charlton soil in typically in low pockets, is very deep and well drained, and formed in friable glacial till. The shallow and excessively drained Hollis soils are on the tops of hills and ridges or near outcrops, and formed in a thin mantle of glacial till over hard bedrock. Both soil types exhibit a slight to moderate erosion hazard if unvegetated. The Charlton soil is well suited to use as sites for dwellings with basements and for septic tank absorption. Conversely, the Hollis soil is poorly suited for these applications because it is typically less than 20 inches deep to bedrock.

Other upland soils adjacent to Lily Pond include the extremely stony Canton Fine Sandy Loam (CbB) occurring on 3-8% slopes and the Newport silt loam (NpD) on 15-25% slopes. The CbB is very deep (>60 inches to bedrock), gently sloping and well-drained soil formed on friable glacial till overlying a loose substratum of glacial till or ice-contact stratified drift. Due to the high permeability of this soil, it does not adequately filter effluent and could cause groundwater pollution when used for septic tank absorption fields. The NpD is a deep well-drained soil on relatively steep slopes, and was formed in friable glacial till over a firm substratum derived from conglomerate, shale, or slate. Permanent vegetation cover is needed to control the high erosion potential of this soil. The seasonal high water table and potential frost action are the main limitations for construction or sites for septic tank absorption fields.

There are two wetland soil types mapped by the NRCS that comprise approximately 27% (12 acres) of the land area within 300 feet of Lily Pond's ordinary high water line (Figure 8).

Figure 8. Soils Mapped within 300 Feet of Ordinary High Water Line

Swansea muck (Sw) is mapped at the intermittent inlet stream along the northern edge of Lily Pond (culverted under King Street) and the wetlands bordering the southern edge of Lily Pond and the Herring Brook outlet are mapped as Freetown muck-ponded (Fp).

The Swansea muck is a very deep (i.e., 16-51 inches), very poorly drained organic muck underlain by gravelly sand to a depth > 60 inches, and occurs in low-lying areas on outwash plains and terraces. The seasonal high water table for this soil typically occurs from the surface to 12 inches deep. This soil is not suitable for building, cultivation, or septic systems due to the high seasonal water table, and has only a slight erosion hazard.

The Freetown series is very deep, very poorly drained soil formed in depressions, along streams and rivers, or in low-lying areas on uplands and outwash plains. The highly decomposed organic layer in this soil may go to a depth of 60 inches or more. The seasonal high water table for this soil typically occurs from the surface to 36 inches above the surface.

Other soils mapped within the watershed by NRCS are shown according to their respective drainage classes (Figure 9). These soils are formed primarily on glacial till and outwash sands and gravel that overlay Dedham granite bedrock (Generalized Surficial Geology and Bedrock Geology maps, Soil Survey of Norfolk and Suffolk Counties MA, 1989). This figure includes:

- Excessively well-drained to moderately well-drained Udorthents,
- well-drained soils in the Charlton-Hollis-Rock outcrop complexes,
- well-drained Canton fine sandy loam, Newport silt loam, Montauk fine sandy loam, Paxton fine sandy loam, and Newport-urban land complex,
- moderately well-drained Woodbridge fine sandy loam, Scituate fine sandy loam, and Pittstown silt loam,
- poorly-drained Ridgebury fine sandy loam, and
- very poorly-drained Swansea muck, Freetown muck-ponded, and Whitman fine sandy loam.

4.1.1.3 Shoreline Land Use-Land Cover and Wildlife Habitat

A one-day field reconnaissance was conducted to describe habitat characteristics of the shoreline and within 300 feet of the shoreline of Lily Pond. During this site visit ENSR biologists noted vegetation cover, wildlife habitat types, land use and topography adjacent to the pond, and wetlands were classified according to the USFWS classification system (Figure 10; Cowardin et al, 1979). Features that may contribute to degradation of water quality within Lily Pond (i.e., stormwater drainage pipes, eroded soils, impervious surfaces, etc.) were noted. In addition, land use-land cover within the watershed as mapped by Massachusetts Geographic Information Systems (MassGIS) was field verified (Figure 7).

Figure 9. Soils Mapped by NRCS According to Drainage Class

Figure 10. Vegetation Cover Types within and Adjacent to Lily Pond

Lily pond can be classified as a Lacustrine-littoral-Aquatic Bed-rooted vascular-submergent wetland (L2AB3; Cowardin et al, 1979). The dominant vegetation for this habitat is described in Section 4.3 Biological Characteristics. Much of the pond perimeter has a narrow band of Palustrine-Scrub Shrub-broad leaved deciduous wetland (PSS1; Cowardin et al, 1979) dominated by swamp loosestrife (*Decodon verticillata*). The only major wetland system adjacent to the pond is situated at the southern end where Brass Kettle Brook enters and Herring Brook exits Lily Pond (Photo #1, Appendix A). This wetland can be characterized as a Palustrine-Forested-dead/Scrub Shrub wetland (PFO5/SS; Cowardin et al, 1979) dominated by swamp azalea (*Rhododendron viscosum*), high-bush blueberry (*Vaccinium corymbosum*) sphagnum (*Sphagnum spp*.) and a variety of wetland sedges, rushes, and grasses. Aside from the dead red maples (*Acer rubrum*) and the channelized Herring Brook (Photo #2, Appendix A), this wetland appears largely undisturbed exhibiting mostly native vegetation except for one small patch of phragmites (*Phragmites australis*) developing on the western side of Herring Brook. A large proportion of the landscape to the west and southeast of Lily Pond is forested upland habitat. Forested areas are dominated by shagbark hickory (*Carya ovata*), american beech (*Fagus grandifolia*), and white pine (*Pinus strobus*) in the overstory, and sweet pepper bush (*Clethra alnifolia*), arrowwood (*Viburnum dentatum*) and bracken fern (*Pteridium aquilinum*) in the understory.

Anthropogenic land uses are also present within 300 feet of Lily Pond. Along the northeastern shoreline there are several residential homes situated on > ½ acre lots (Photo #3, Appendix A). To the north and northeast there is paved parking associated with the water intake station and water treatment residuals settling lagoons. The outlet for the settling lagoons currently drains into Lily Pond where it has created a small delta of sediment out into the pond (Photo #4, Appendix A) dominated by phragmites (Photo #5, Appendix A). Sedimentation associated with the settling lagoons, and runoff from parking areas and roofs of the water treatment facility are potential concerns to water quality in Lily Pond. Peppermint Brook and wetland complex wind through a series of low to high-density residential communities as well as receiving runoff from a number of paved roadways (Figure 2). For a complete plant list and locations of described habitat types, see Table 9 and Figure 10.

Letters were written to the Massachusetts Natural Heritage and Endangered Species Program (MNHESP) and the United States Fish and Wildlife Service's (USFWS) endangered species specialist to request a database review for endangered on or adjacent to Lily Pond (Appendix B). As of yet there has been no response from USFWS. A return letter from MNHESP dated 10/17/02 stated that there are no rare plants or animals or exemplary communities adjacent to the Lily Pond. However, an inspection of the MNHESP Natural Heritage Atlas showed that there are three areas within the watershed mapped as Priority Habitats of Rare Species/Estimated Habitats of Rare Wildlife.

Table 9. Vegetation Species Observed within 300 feet of Lily Pond.

Common Name	Genus	Species
Forested Uplands		
Shagbark hickory	*Carya*	*ovata*
White pine	*Pinus*	*strobus*
American beech	*Fagus*	*grandifolia*
American holly	*Ilex*	*americanus*
Sweet birch	*Betula*	*lenta*
Red oak	*Quercus*	*rubra*
White oak	*Quercus*	*alba*
Canadian hemlock	*Tsuga*	*canadensis*
Arrowwood	*Viburnum*	*dentatum*
Sweet pepper bush	*Clethra*	*alnifolia*
White aster	*Aster*	*sp.*
Bracken fern	*Pteridium*	*aquilinum*
Hay scented fern	*Dennstaedtia*	*punctilobula*
Pennsylvania sedge	*Carex*	*pennsylvanica*
Beech drops	*Epifagus*	*virginiana*
Boneset	*Eupatorium*	*perfoliatum*
Princess pine	*Lycopodium*	*obscurum*
Ground cedar	*Lycopodium*	*tristachyum*
Whorled loosestrife	*Lysimachia*	*quadrifolia*
Wintergreen	*Gaultheria*	*procumbens*
Wetland Habitats		
Red maple	*Acer*	*rubrum*
Black gum	*Nyssa*	*sylvatica*
Sweet pepper bush	*Clethra*	*alnifolia*
Pussy willow	*Salix*	*discolor*
Buttonbush	*Cephalanthus*	*occidentalis*
Black willow	*Salix*	*nigra*
Steeplebush	*Spirea*	*tomentosa*
Meadowsweet	*Spirea*	*latifolia*
Winterberry	*Ilex*	*verticillata*
Maleberry	*Lyonia*	*ligustrina*
Leucothoe	*Leucothoe*	*racemosa*
Royal fern	*Osmunda*	*regalis*
Cinnamon fern	*Osmunda*	*cinnamomea*
Sensitive fern	*Onoclea*	*sensibilis*

Table 9 (continued). Vegetation Species Observed within 300 feet of Lily Pond.

Common Name	Genus	Species
Wetland Habitats Continued		
Marsh fern	*Thelypteris*	*Palustris*
Eleocharis	*Eleocharis*	*acicularis*
Canada rush	*Juncus*	*canadensis*
Cattails	*Typha*	*latifolia*
Soft rush	*Juncus*	*canadensis*
Hypericum	*Triadenum*	*virginicum*
Swamp candles	*Lysmachia*	*terrestris*
Jewelweed	*Impatiens*	*capensis*
Lurid sedge	*Carex*	*lurida*
Mannagrass	*Glyceria*	*canadensis*
Glyceria	*Glyceria*	*obtusa*
Marsh bedstraw	*Galium*	*palustre*
Nodding bur-marigold	*Bidens*	*cernua*
Phragmites	*Phragmites*	*australis*
Purple loosestrife	*Lythrum*	*salicaria*
Sedge	*Carex*	*crinita*
Sedges	*Carex*	*spp*
Tussock sedge	*Carex*	*stricta*
Three-way sedge	*Dulichium*	*arundinaceum*
Wool-grass	*Scirpus*	*cyperinus*
Bluejoint	*Calamogrostis*	*canadensis*
Swamp loosestrife	*Decodon*	*verticillata*
Sphagnum	*Sphagnum*	*spp.*
Arrowhead	*Sagittaria*	*spp.*
Arrow arum	*Peltandra*	*virginica*
Sparganium	*Sparganium*	*spp.*

In addition, 35 potential vernal pools have been mapped within Lily Pond's watershed (Figure 11) which may provide breeding habitat for a number of amphibian and foraging habitat for other birds and mammals.

Wildlife species observed during ENSR's one-day field visit included Canada geese (*Branta canadensis)*, great blue herons (*Ardea herodias)*, mute swan (*Cygnus olor)*, double crested cormorants (*Phalacrocorax auritus*), american robins (*Turdus migratorius)*, a red shouldered hawk (*Buteo lineatus)* and a painted turtle (*Chrysemys picta*). A list of mammals, birds, amphibians, and reptiles from New England Wildlife: Habitat, Natural History, and Distribution (DeGraaf et. al. 2001) commonly found in habitat types observed on-site is provide in Table 10.

4.1.1.4 Summary

The watershed is heavily forested but large in comparison to Lily Pond surface area, with a substantial portion of the forested area zoned for residential property. These areas should be conservatively viewed as areas of potential future development. Safeguards and restrictions, such as those embodied in the Water Resource District (Section 14 of the Town of Cohasset Zoning By Laws), to protect against environmentally unfriendly development are considered necessary for long-term protection of Lily Pond water quality. Soils within the watershed are compatible with good water quality as long as they maintain their current stable vegetated state. High erosion potential is associated with these soils if exposed to precipitation. The habitat value of the watershed was considered high. The watershed supports a diverse upland and wetland flora and fauna communities and contains estimated habitat areas for rare wildlife and potential vernal pools.

Figure 11. Lily Pond Habitat for Rare Wildlife and Potential Vernal Pools

Table 10. Expected Wildlife on and Adjacent to Lily Pond.

Common Name	Genus	Species
Pond Habitat		
Canada geese	*Branta*	*canadensis*
Great blue herons	*Ardea*	*herodias*
Mute swan	*Cygnus*	*olor*
Double crested cormorants	*Phalacrocorax*	*auritus*
Wood duck	*Aix*	*sponsa*
Mallard	*Anas*	*platyrhynchos*
Blue-winged teal	*Anas*	*discors*
Osprey	*Pandion*	*haliaetus*
Painted turtle	*Chrysemys*	*picta*
Snapping turtle	*Chelydra s.*	*serpentina*
Northern water snake	*Nerodia s.*	*sipedon*
Bullfrog	*Rana*	*catesbeiana*
Green frog	*Rana*	*clamitans*
Stinkpot	*Sternotherus*	*odoratus*
Muskrat	*Ondatra*	*zibethicus*
Wetland Habitats		
Swamp sparrow	*Melospiza*	*georgiana*
Red-winged blackbird	*Agelaius*	*phoeniceus*
Green Heron	*Butorides*	*striatus*
Belted kingfisher	*Ceryle*	*alcyon*
Marsh wren	*Cistothorus*	*palustris*
Black-crowned night heron	*Nycticorax*	*nycticorax*
Common yellowthroat	*Geothlypis*	*trichas*
Northern waterthrush	*Seiurus*	*noveboracensis*
Canada warbler	*Wilsonia*	*canadensis*
Yellow warbler	*Dendroica*	*petechia*
Spotted turtle	*Clemmys*	*quttata*
Northern water snake	*Nerodia s.*	*sipedon*
Ribbon snake	*Thamnophis s.*	*sauritus*
Spring peeper	*Pseudacris*	*crucifer*
Green frog	*Rana*	*clamitans*
Bullfrog	*Rana*	*catesbiana*
Wood frog	*Rana*	*sylvatica*
Star nosed mole	*Condylura*	*cristata*

Table 10 (continued). Expected Wildlife on and Adjacent to Lily Pond.

Common Name	Genus	Species
Forested Upland Habitats		
American crow	*Corvus*	*brachyrhynchos*
American goldfinch	*Carduelis*	*tristis*
American redstart	*Setophaga*	*ruticilla*
American robin	*Turdus*	*migratorius*
American woodcock	*Scolopax*	*minor*
Barred owl	*Strix*	*varia*
Black-and-white warbler	*Mniotilta*	*varia*
Black-capped chickadee	*Parus*	*atricapillus*
Black-throated green warbler	*Dendroica*	*virens*
Brown thrasher	*Toxostoma*	*rufum*
Carolina wren	*Thryothorus*	*ludovicianus*
Chipping sparrow	*Spizella*	*passerina*
Downy woodpecker	*Picoides*	*pubescens*
Eastern wood-pewee	*Contopus*	*virens*
Gray catbird	*Dumetella*	*carolinensis*
Hairy woodpecker	*Picoides*	*villosus*
Northern cardinal	*Cardinalis*	*cardinalis*
White-breasted nuthatch	*Sitta*	*carolinensis*
Eastern American toad	*Bufo*	*americanus*
Eastern box turtle	*Terrapene*	*carolina*
Eastern garter snake	*Thamnophis*	*sirtalis*
Fowler's toad	*Bufo*	*woodhousii fowleri*
Gray treefrog	*Hyla*	*versicolor*
Red-spotted newt	*Notophthalmus v.*	*viridescens*
Redback salamander	*Plethodon*	*cinereus*
Spotted salamander	*Ambystoma*	*maculatum*
Wood frog	*Rana*	*sylvatica*
Northern black racer	*Coluber c.*	*constrictor*
Northern brown snake	*Storeria d.*	*dekayi*
Northern ringneck snake	*Diadophis*	*punctatus edwardsi*
Coyote	*Canis*	*latrans*
Eastern chipmunk	*Tamias*	*striatus*
Eastern mole	*Scalopus*	*aquaticus*
Gray squirrel	*Sciurus*	*carolinensis*
Masked shrew	*Sorex*	*cinereus*
Meadow vole	*Microtus*	*pennsylvanicus*

Table 10 (continued). Expected Wildlife on and Adjacent to Lily Pond.

Common Name	Genus	Species
Forested Upland Habitats Continued		
Northern short-tailed shrew	*Blarina*	*brevicauda*
Raccoon	*Procyon*	*lotor*
White-tailed deer	*Odocoileus*	*virginianus*

4.1.2 Lake Features

4.1.2.1 Lake Morphometric Features

Lily Pond is a kidney shaped lake with a bedrock outcrop near the center. A bathymetric map (Figure 12) was generated based on probing at 131 points along 19 transects (Figure 4) on July 31st and August 1st. A hypsographic curve was generated from depth contour areas and corresponding water depths (Figure 13). The average and maximum depths of Lily Pond were estimated from these data. On the day of sampling, Lily Pond had an average depth of 5.7 feet and a maximum depth of 8.0 feet.

The water volume within the pond was estimated at 86,836,856 gallons (11,608,398 ft^3) on the survey date. According to the water treatment facility's staff gage water level records (measured at 43.92 ft MSL), Lily Pond was at 81% useable capacity on the day prior to ENSR's bathymetric survey (see Figure 13 for schematic of volume calculation). Useable capacity is defined as the volume of the pond at or above the bottom elevation of the screened portion of the water intake structure (elevation 38 ft MSL; 96.6 million gallons). Water below the intake structure, water depth greater than six feet deep on the day of the survey, would be considered "dead storage" (i.e., volume in the 6 – 8 foot depth contour). On the day of the survey, the useable capacity was estimated at 81.2 million gallons, while dead storage was estimated at 5.6 million gallons. Adjusting the estimated useable capacity volume on the survey date to 100% (increasing useable volume by 19% or 15,426,193 gallons) and adding the volume of dead storage results in volume of Lily Pond at elevation 45 ft MSL of roughly 102,263,049 gallons (13,670,526 ft^3). This figure applies to the volume of water in the main pond basin only and does not reflect any additional storage provided by the extensive wetland system to the south associated with Herring Brook. The volume calculated for this investigation differs sharply from reported estimates of maximum capacity of 150.2 million gallons. This volume would require an average depth of 8 – 9 feet, while observed average depth during this investigation was 5.7 feet. Historical records from the Massachusetts Division of Fisheries and Wildlife have a recorded average and maximum depth of 5 and 7 feet respectively in 1912 (prior to the construction of the BBCS). Additional morphometric features of Lily Pond are provided with Table 11.

Figure 12. Pond Bathymetry

Figure 13. Hypsographic Curve for Lily Pond in August 1, 2002 – Approximately 81%. Useable Volume.

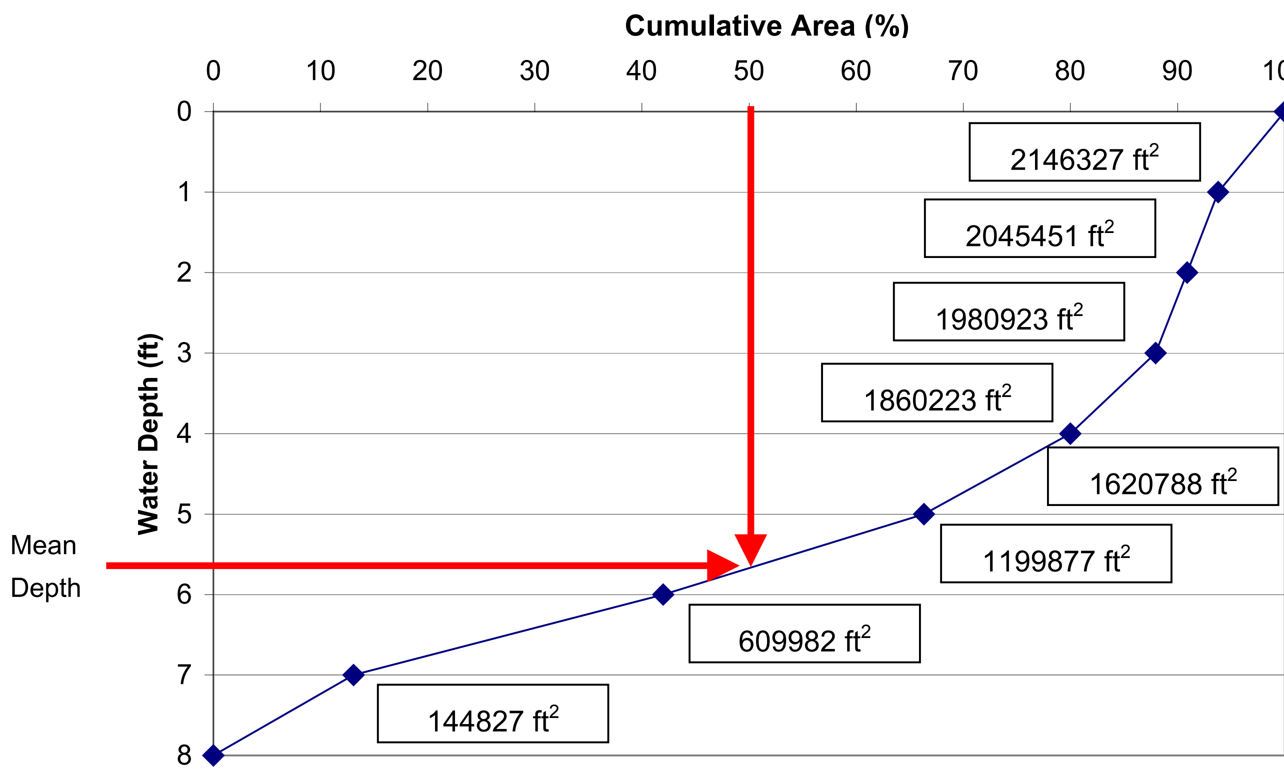


Table 11. Morphometric Features of Lily Pond.

Surface Area	51 acres; 21 hectares
Maximum Depth	8.0 feet; 2.4 meters
Mean Depth	5.7 feet; 1.7 meters
Volume in Lily Pond at surface elevation 45 ft MSL Useable capacity for drinking water at 45 ft MSL Dead storage – unusable volume	102.2 million gallons; 13,670,525 cubic feet 96.6 million gallons; 12,915,758 cubic feet 5.6 million gallons; 754,807 cubic feet
Fetch (East/West)	0.37 miles; 1,978 feet; 603 meters
Maximum Width (North/South)	0.36 miles; 1,909 feet; 582 m
Approximate Flushing Rate Assumes 100% useable capacity	 9.3 exchanges/year

Volume estimates are for main basin only and do not include storage provided in Herring Brook or associated wetlands.

4.1.2.2 Sediment

Benthic sediment type (e.g., sand or muck) and depth were recorded at 131 points along 19 transects (Figure 4). Benthic sediments were comprised mostly of muck overlying sand. Measured soft sediment depth ranged from less than a foot to greater than 14 ft. The intensive sediment survey was limited to a total depth of 10 ft (length of probe), so sediment depth estimates were determined as the difference of the surface water depth from 10 ft. A spot check of select points was made in key areas using a 20 ft probe on August 29, 2002. Two of these areas contained sediment depths greater than 14 ft (total depth greater than 20 ft probe length). Previous lake sediment experience has indicated that areas in the central portion of a waterbody grade off into deep muck rather uniformly within a central basin. Therefore deep muck deposits are likely to occur throughout the entire basin except at rocky outcrops.

Total sediment volume underneath the Pond is not calculable, as the muck was too thick to measure in much of the pond, but a minimum volume of 492,000 cubic yards (CY) is estimated. This suggests a minimum average soft sediment depth of 6 ft, but the soft sediment is not evenly distributed. Additional areas of sediment depth greater than 10 feet are likely. The shallow sediment depth southeast of the rock outcrop was observed, however. This shallow sediment depth is likely the result of bedrock ledge extending from the island southeast to the curved shoreline out to the hill on Reeds Corner.

The nature and location of sediment accumulations indicates internal origin for a majority of pond sediment. Dense rooted plant production over many years has provided large amounts of organic matter that settles to the bottom and gradually fills in the pond. Some organic matter is undoubtedly passed downstream from wetland areas in the watershed, but watershed inputs are not necessary to explain the accumulated organic muck. The sediment near the discharge of the settling lagoons indicates that these lagoons are contributing to the infilling of the Pond. Additional maintenance and greater treatment of the residuals supernatant appears necessary to avoid future impacts to Lily Pond.

4.1.3 Hydrology

The hydrology of Lily Pond is complicated since it combines both the drainage from the natural watershed as well as seasonal inputs via releases from the Aaron River Reservoir; while simultaneously being subject to the year-long water withdrawal demands for the Water Treatment facility. Two tributaries – Brass Kettle Brook and Peppermint Brook - (Figure 2) discharge to Lily Pond under normal conditions. Both tributaries have seasonal periods of little or no-flow with stagnant water within the channel. It is likely that these tributaries go completely dry for at least a portion of their watercourse under drought conditions. This was noted for Brass Kettle Brook in August.

A third ”tributary” to Lily Pond exists under certain hydrologic conditions. Herring Brook, the natural outlet of Lily Pond, can reverse flow direction and discharge to Lily Pond due to impoundment of water behind the true outlet control structure (the BBSC). The BBCS, located along Bound Brook at Beechwood Street, controls the water level (with a spillway elevation set between 43 to 45 ft MSL) within Lily Pond, the wetland system to the south of the Pond, and a portion of Bound Brook downgradient of its confluence with Herring Brook. High flows from spring runoff can be passed by pulling the gate (elevation 43 MSL) in the spring. Conversely closing the gate in the early summer leads to greater retention of water in Bound Brook (and Lily Pond). During the spring and summer (when water levels in Bound Brook exceeds 45 ft MSL) there will be spillage over the BBSC structure and hydrologic loss from the Lily Pond system (note – this was assumed to occur during 4-5 months per year).

The BBSC impoundment results in the seasonal storage of water in the wetland system located south of Lily Pond (for relationship of BBSC to Lily Pond intake structure and Aaron River Reservoir dam elevations see Figure 5). During these conditions, if the surface elevation of Lily Pond falls below 45 ft MSL (e.g., due to water withdrawal, evaporation), water may be drawn into Lily Pond from the bordering wetlands or from Bound Brook via Herring Brook. Lily Pond can also indirectly receive water from the Aaron River Reservoir (an additional water source for the Town of Cohasset) via controlled releases to Aaron River/Bound Brook. Based on relative pond elevation and season, the southern wetlands could be a source or a sink for water in Lily Pond. Therefore it was difficult to further quantify the amount of water entering Lily Pond without a more comprehensive hydrologic investigation considering all seasonal patterns, which was beyond the scope of the present study.

Therefore, available hydrologic data was assembled to provide an approximate hydrologic budget based on the simple assumptions of flow from the natural watershed (i.e., no contribution from Aaron River Reservoir). In terms of the hydrologic budget, ecosystem losses were assumed to be the sum of: (1) the losses due to spillage over the BBSC, (2) interception and diversion of Brass Kettle Brook water prior to its entry into Lily Pond, and (3) water demand by neighboring wetlands. Due to the uncertainty, the hydrologic budget should be used primarily for assessing relative watershed contributions and losses. This uncertainty will be reduced, at least partially, by the results of the *Sustainable Yield Study* commissioned by the Town of Cohasset Board of Water Commissioners and currently being conducted by GZA, although long-term stream gaging of the watershed tributary flows is also recommended.

4.1.3.1 Hydrologic Loading

An estimate of hydrologic loading was made under the assumption outlined above, assuming no contribution from Herring Brook. At no time during the ENSR field investigations was Herring Brook visually observed flowing into Lily Pond, but no attempt at measuring flow at depth was made. Using land use runoff coefficients, it was estimated that Basin 1 (Brass Kettle Brook) provides 68% (approximately 86 million ft^3/yr) of the total inflow to Lily Pond. Basin 2 (Peppermint Brook) provides 16% (approximately 21 million ft^3/yr), Direct Drainage provides 9% (approximately 11 million ft^3/yr), and precipitation provides the remaining 7% (approximately 9 million ft^3/yr) of the total annual hydrologic budget for Lily Pond without contribution of Herring Brook. The watershed yield values include both annual base and storm flow and are based on an average precipitation year. Coefficients and models used in this estimation are provided in Appendix C, Supporting Documentation.

The flushing rate is the number of times in a given year that the entire water volume could be replaced by hydrologic inputs. According to morphometric features and hydrologic data at the time of the survey, Lily Pond has a flushing rate of 10.8 times per year, at the time of the survey (i.e., no inflow from Herring Brook; 81% useable capacity). The respective detention times would be 0.09 years (34 days). The inverse of flushing rate is detention time or the average length of time that water remains in the pond. However, these values are highly dependent on inflow and do not take into account water withdrawal, which will increase the average flushing rate. At full useable capacity (i.e., elevation of 45 ft MSL), the flushing rate would be 9.3 times per year. Flushing rate and detention time in Lily Pond are not seasonally constant and will depend on weather patterns, periods of reversal of Herring Brook flow, and annual pattern of water withdrawal quantity. These values are important, however, to the manner in which the system processes pollutant inputs. Based on average conditions, the relative length of the detention suggests, on average, that pollutants do not stay in the pond long enough to fully impact water quality, but sufficient detention time is likely during dry summer seasons to allow full impact of inputs (i.e., uptake of nutrients by primary producers).

Table 12 provides a breakdown and percent contribution by each variable. The contribution of Aaron Reservoir was not calculable based on available data. On an annual basis, 68% of the water system loss has not been accounted for. The ecosystem loss was determined arbitrarily by subtracting known outputs from the sum of all inputs. This value represents the amount of water loss due to Brass Kettle Brook flow by-passing the Lily Pond basin and draining to the wetland system associated with Herring Brook and Bound Brook, the water flowing over the BBCS during runoff (when water elevation > 45 ft MSL), and evapotranspiration from the wetland area associated with Herring Brook and Aaron River. Based on available data, the relative percentage of these losses could not be quantified.

Table 12. Lily Pond Annual Hydrologic Budget based on Full Capacity.

	Volume (gallons/yr)	Volume (ft^3/yr)	Volume (m^3/yr)	Percent Total Annual Budget
Inputs				
Surface & Base Flow				
Basin 1 – Brass Kettle Brook	643,310,478	85,998,101	2,435,195	68%
Basin 2 – Peppermint Brook	158,063,082	21,129,966	598,334	16%
Direct Entry	83,370,006	11,144,956	315,590	9%
Aaron Reservoir	undetermined	undetermined	undetermined	undetermined
Precipitation	65,847,531	8,802,534	249,260	7%
Total Input	950,591,239	127,075,556	3,598,379	100%
Output				
Evaporation	35,905,211	4,799,828	135,916	4%
Water Withdrawal	266,450,293	35,619,221	1,008,624	28%
Ecosystem Loss	648,235,735	86,656,507	2,453,839	68%
Total Output	950,591,239	127,075,556	3,598,379	100%

4.2 Chemical Characteristics

4.2.1 Surface Water Chemistry

Water quality monitoring locations are presented in Figure 6 and described in Table 4. Values for most parameters are presented in Table 13, except *in situ* dissolved oxygen, temperature, pH, and Secchi disk transparency, which are provided in Table 14. Total organic carbon was sampled separately in January 2003 and results are provided in Section 4.5. For calculation and summary purposes, ½ the detection limit was used for values reported below detection.

The temperature regime of an aquatic ecosystem is important in determining community structure. Massachusetts Surface Water Quality Standards for warm water fisheries state that temperatures should not exceed 28.3°C. Surface in-lake values ranged from 20.6 °C to 28.5 °C, (Table 13). The State water quality temperature standard was exceeded at surface locations at stations LP-2 and LP-4 during July. Tributary temperatures ranged from 11.5 °C to 20.9 °C (Table 13) during this study. The July sampling at BK-1 was not considered as a tributary since this station was more representative of in-lake conditions than tributary conditions. There is no Massachusetts Drinking Water Maximum Contaminant Level (MCL) for temperature.

Table 13. 2002 Water Quality Sampling Results

Water Quality Parameter	Units	BK-1	PB-1	LP-1S	LP-1B	LP-2S	LP-2B	LP-3S	LP-3B	LP-4S	LP-4B
		July 31, 2002									
Alkalinity	mg/L	10	56	12	10	8	12	8	8	8	12
Chloride	mg/L	23.7	176	26.8	27.3	26.7	27.3	26.0	25.1	26.6	29.0
Hardness	mg/L	12	96	NA	NA	NA	NA	4	NA	24	NA
Specific Cond.	umhos/cm	110	724	122	153	123	132	116	123	123	137
Fecal Coliform	#/100ml	BB	1100	<10	10	<10	<10	20	20	<10	<10
BOD5	mg/L	2	1	1	2	2	2	1	2	<1	2
Ammonium (as N)	mg/L	0.01	0.09	0.02	0.05	0.01	0.03	0.01	0.13	0.01	0.04
Nitrite (as N)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate (as N)	mg/L	<0.01	0.47	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
TKN (as N)	mg/L	0.7	0.5	0.2	0.6	0.6	0.1	0.5	0.7	0.6	0.6
Diss-Phosphorus	mg/L	0.02	0.04	<0.01	0.01	0.02	0.02	0.02	0.03	0.01	0.02
Total Phosphorus	mg/L	0.02	0.05	0.01	0.04	0.02	0.03	0.02	0.03	0.01	0.02
Arsenic	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Barium	mg/L	0.0095	0.0235	0.0072	0.0268	0.0071	0.0212	0.0143	0.0183	0.0078	0.0184
Cadmium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Chromium	mg/L	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Total Fe	mg/L	1.05	0.88	1.19	1.73	1.21	2.02	0.97	2.12	1.25	2.05
Lead	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Mercury	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Selenium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Silver	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

BB = Broken Bottle; NA = Not Analyzed

Table 13 (Continued). 2002 Water Quality Sampling Results.

Water Quality Parameter	Units	29-Aug-02							10-Oct-02							
		PB-1	LP-1S	LP-2S	LP-3S	LP-3B	LP-4S	LP-4B	BK-1	PB-1	LP-1S	LP-2S	LP-3S	LP-3B	LP-4S	LP-4B
Alkalinity	mg/L	56	10	12	8	8	12	10	<2	54	12	12	8	10	10	10
Chloride	mg/L	195	28.0	28.4	28.2	28.2	28.0	27.5	9	174	30	29.7	26.7	26.8	29.5	29.6
Hardness	mg/L	112	NA	NA	36	NA	36	NA	64	96	NA	NA	24	NA	20	NA
Specific Cond.	umhos/cm	871	155	151	148	148	149	149	182	556	112	101	106	108	117	112
Fecal Coliform	#/100ml	5800	<10	20	10	60	280	<10	20	80	NA	NA	<10	<10	<10	<10
BOD5	mg/L	<1	NA	NA	<1	1	1	1	1	<1	NA	NA	<1	<1	<1	<1
Ammonium (as N)	mg/L	0.11	0.03	0.04	0.06	0.06	0.04	0.05	<0.01	<0.01	<0.01	0.02	0.03	0.04	0.02	0.02
Nitrite (as N)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate (as N)	mg/L	0.30	<0.01	<0.01	0.02	0.03	<0.01	<0.01	<0.01	0.45	0.01	0.01	0.04	0.04	0.01	0.01
TKN (as N)	mg/L	0.6	1.1	0.9	0.9	0.9	0.8	0.9	0.2	0.4	0.3	0.4	0.9	2.4	0.8	0.7
Diss.-Phosphorus	mg/L	0.04	0.02	0.02	0.02	0.02	0.01	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.02
Total Phosphorus	mg/L	0.05	0.02	0.02	0.04	0.04	0.03	0.04	0.02	0.05	0.03	0.03	0.03	0.34	0.04	0.07
Arsenic	mg/L	<0.02	NA	NA	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	NA	NA	<0.02	<0.02	<0.02	<0.02
Barium	mg/L	0.0228	NA	NA	0.0122	0.0131	0.0053	0.0064	0.0659	0.0212	NA	NA	0.0132	0.0184	0.0094	0.0125
Cadmium	mg/L	<0.0002	NA	NA	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0005	NA	NA	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	mg/L	<0.002	NA	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	<0.002	<0.002	<0.002	<0.002
Total Fe	mg/L	1.0	1.6	1.5	1.2	1.2	1.7	1.4	0.18	0.36	1.2	1.3	3	1.3	1.3	1.5
Lead	mg/L	<0.001	NA	NA	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	NA	NA	<0.01	<0.01	<0.01	<0.01
Mercury	mg/L	<0.00004	NA	NA	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	NA	NA	0.00034	<0.00004	<0.00004	<0.00004
Selenium	mg/L	<0.02	NA	NA	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	NA	NA	<0.02	<0.02	<0.02	<0.02
Silver	mg/L	<0.002	NA	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	<0.002	<0.002	<0.002	<0.002

BB = Broken Bottle; NA = Not Analyzed

Table 14. 2002 In-situ Water Quality Results

Station		7/31/2002			8/29/2002			10/10/2002		
	Depth (ft)	Temp (°C)	DO (mg/L)	pH (SU)	Temp (°C)	DO (mg/L)	pH (SU)	Temp (°C)	DO (mg/L)	pH (SU)
LP1	Surface	27.1	7.2	7.1	21.1	7.0	6.8	16.0		6.3
	1	26.8	7.0	6.8						
	2	26.0	6.8	6.3						
	3	23.5	2.8	5.8						
	4	22.3	0.7	6.4	21.1	6.6	6.7			
	4.5	21.9	0.3	6.1						
LP-2	Surface	28.5	6.7	6.8	20.7	7.2	6.8	16.0		6.0
	1	28.2	6.7	6.8						
	2	27.3	6.6	6.7						
	3	24.8	5.9	6.8						
	4	23.1	2.6	6.7	20.7	5.8	6.8			
	4.5	22.8	2.6	6.9						
LP-3	Surface	25.5	4.3	6.4	20.6	3.9	7.9	14.0		5.8
	1	26.0	4.6	6.1						
	2	24.3	1.5	5.6						
	3	22.2	0.4	5.8	20.5	3.3	7.8			
	4	20.9	0.5	5.8				14.0		6.0
LP-4	Surface	28.3	6.8	6.8	20.8	7.5	7.1	15.5		6.3
	1	27.9	6.7	6.7						
	2	26.2	6.7	6.6						
	3	24.2	4.7	5.9						
	4	22.5	1.0	6.1						
	5	22.0	1.0	6.7	20.8	7.4	6.9	15.5		6.0
BK-1	Surface	27.4	4.5	6.3				11.5		4.8
PB-1	Surface	20.9	5.4	7.0	17.0	7.0	6.6	12.0		6.8

Secchi Disk Transparency (SDT)

Station	SDT (ft)	SDT (ft)	SDT (ft)
LP-1	3.1	2.0	2.5
LP-2	2.6	2.0	3.5
LP-3	2.0	3.0	2.5
LP-4	2.9	2.0	3.5

Dissolved oxygen (DO), as the name implies, is the amount of molecular oxygen dissolved in the water column. Values below 5.0 mg/L are generally considered undesirable for many species of aquatic life. Additionally, release of phosphorus from benthic sediments is often a concern under anoxic or low oxygen conditions (<1.0 mg/L). The Massachusetts Surface Water Quality Standard for Class A waterbodies is 6.0 mg/L. In-lake surface values ranged from 3.9 mg/L to 7.5 mg/L. Dissolved oxygen was below the state standard at LP-3 at all depths in July and August. Values below 6.0 mg/L were also recorded at all other in-lake stations below 3 ft in July. Dissolved oxygen in Peppermint Brook was below the state standard in July (5.4 mg/L). There is no Massachusetts Drinking Water MCL for dissolved oxygen.

Levels of pH in pond water are generally associated with corrosivity and can also control chemical availability of ammonia toxicity and metal solubility. The Massachusetts Surface Water Quality Standard range for pH is 6.5 to 8.3 SU. Although the pH of raw water is relevant to treatment needs, pH is typically adjusted during treatment and is not a serious concern in raw water. The pH levels in Lily Pond ranged between 5.6 and 7.1 SU, with most values within the 6.0 – 6.9 SU range. Massachusetts Drinking Water Secondary Maximum Contaminant Level (SMCL) ranges from 6.5 to 8.5 SU. Values in Lily Pond ranged from 5.6 to 7.9 SU. The minimum value was recorded at LP-3 at 2.0 ft in July. The maximum value was recorded at the surface at LP-3 on August 29, 2002. Biological activity (plant photosynthesis and algal blooms) will raise pH levels, but it is unusual to observe values well above 7 SU in southeastern Massachusetts. The pH in the tributaries ranged from 4.8 to 7.0 SU, suggesting no long term impact of any alkaline inputs, but a potential for impacts associated with acidic inputs since in-lake alkaline is low (see alkalinity discussion below).

Total alkalinity is a measure of buffering capacity or the ability of water to neutralize acids. Values ranged from 8 to 12 mg/L (measured as $CaCO_3$), which is typical for this coastal region of Massachusetts. The lowest values occurred at LP-2 and LP-3. Values greater than 20 mg/L are generally indicative of waters that are well buffered and are not highly susceptible to acid precipitation or other external acidic inputs. However, this part of Massachusetts is generally not well buffered as low alkalinity is generally related to bedrock geology. There is no alkalinity state standard for surface water or drinking.

Water clarity is linked to both dissolved and suspended solids concentrations, and can be affected by both fine sediment inputs and by algal biomass. Higher clarity is linked to better water quality for potable uses. Secchi disk transparency (SDT) is a measure of water clarity and is also a useful indicator of trophic state. This value is obtained by lowering a circular disk in the water column until it is no longer visible. The most critical time of year to evaluate SDT is during summer, when algal blooms most often occur and recreational use is highest. Measurements less than 2.0 meters (6.6 ft) are generally considered indicative of eutrophic conditions, although non-algal turbidity can also cause SDT values to decline to low levels. Contact recreation is not permitted under state law at values <1.22 m (4 ft). Values recorded in Lily Pond ranged from 0.6 to 1.1 m, within the undesirable range. SDT is likely limited by suspended solids from plant fragments and water color. Color was not measured during this investigation, but observations indicated that Lily Pond water is highly colored, resulting in a brownish or tea colored water. Color was measured in the 1986 CDM investigation, with values of 45-60 color units reported for Lily Pond, with higher values in the tributaries (see Table 1). There is no regulatory standard for the SDT of raw water; the turbidity standard is applied to finished water and relates to clarity.

Chloride is normally present in surface waters at low concentrations. It is naturally occurring from the weathering and leaching of rocks and soils. The addition of sodium chloride and calcium chloride for snow and ice removal, and discharges from industry and commercial properties can result in elevated concentrations in surface receiving waters. There is no state standard for surface waters of Massachusetts, but there is a state drinking water standard. Values above 250 mg/L are in excess of the Massachusetts SMCL. Concentrations within Lily Pond ranged from 25 to 30 mg/L within the acceptable range. Tributary values were higher, ranging from 24 to 195 mg/L. Peppermint Brook contained chloride in the highest concentrations overall, which is consistent with the location of a major highway (Route 3A) within the watershed.

Hardness is a measure of calcium and magnesium salts within the water. Waters with high concentrations of these salts are considered “hard”. There is no hardness state standard for surface waters or for drinking water as there are no known health effects associated with elevated levels. It is typically more of an aesthetic, or taste issue. Detergents, however, do not lather and can be less effective with higher salt concentrations. Hardness in Lily Pond was 24 mg/L on average (range 4 to 36 mg/L), and is considered “soft” water. Tributary values were higher (range 12 to 112 mg/L, average 76), and would be considered “moderately hard”. Peppermint Brook values were consistently higher than Brass Kettle Brook.

Specific conductance is a measure of waters ability to convey electrical current. Dissolved solids, such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum, are effective electrical conductors. Higher specific conductance values indicate higher concentrations of dissolved solids. Conductance is generally measured in micromhos per centimeter (µmhos/cm). There is no State standards for specific conductance for surface waters or drinking water. In this area, however, values less than 100 umhos/cm are generally indicative of infertile conditions (low nutrient availability) and values in excess of 300 umhos/cm are generally considered too fertile (excessive nutrient availability) or otherwise potentially contaminated. Values with Lily Pond averaged 129 umhos/cm, with a range from 101 to 155 umhos/cm. Tributary values were substantially higher, averaging 489 umhos/cm. Values within Brass Kettle Brook did not exceed 100 umhos/cm. Values within Peppermint Brook ranged from 96 to 871 umhos/cm.

Biological oxygen demand in 5 days (BOD5) is a measure of the oxygen consumption over a five day period by microorganisms for the decomposition of organic material. In general, the higher the BOD5 the greater rate of oxygen depletion, which can result in low oxygen values that can impair other aquatic biota. There is no BOD state standard for surface waters or for drinking water. BOD5 results were low for all sites on all dates, including tributary locations. Values ranged from less than the detection limit (<1 mg/L) to 2 mg/L.

Nitrogen is an essential nutrient for plant growth. High concentrations of nitrogen and phosphorus in the water column provide an ideal environment for algal growth. Although phosphorus tends to be the limiting nutrient in freshwater systems, high nitrogen concentrations indicate a fertile aquatic environment. There are several forms of nitrogen but only some are available for uptake by aquatic organisms. Ammonium and nitrate are the two forms of nitrogen that are most accessible; organic nitrogen is bound up in organic material and is unavailable. Ammonium is typically found in low concentrations since naturally occurring bacteria readily convert ammonium to nitrite then to nitrate in the presence of oxygen. Under anoxic conditions, such as those found in the hypolimnion (lower, cooler water layer of a stratified lake) during the summer months, ammonium is found in higher concentrations. Both ammonium and nitrate can be directly measured. Organic nitrogen is indirectly measured by taking the difference between total Kjeldahl nitrogen (TKN) and ammonium values.

Currently, there is not a numerical state standard for nutrient levels in water bodies for Massachusetts, although work towards establishing such standards is proceeding. The drinking water MCL for nitrate is 10 mg/L and 1 mg/L for nitrite. The acceptable range, values not indicative of eutrophic conditions, for nitrate nitrogen in this region is 0.3 – 0.6 mg/l, with < 0.3 mg/L ideal (Wetzel, 1983). Values between 0.6 – 1.0 mg/l indicate a deteriorating aquatic environment and > 1.0 mg/l indicates a poor aquatic environment or highly eutrophic conditions (Wetzel, 1975).

In-lake ammonium nitrogen values were generally low, with one value considered moderate at the bottom of LP-3B (0.13 mg/L). Similar values were recorded at the tributaries, with one moderate value at Peppermint Brook (0.11 mg/L) recorded in August. Nitrite nitrogen values were below detection (< 0.01 mg/L) at all stations during all sampling events. In-lake concentrations of nitrate nitrogen were with in the low range, ranging from below the detection limit (0.01 mg/L) to 0.04 mg/L. Levels in Brass Kettle Brook were below detection while values in Peppermint Brook ranged from 0.30 to 0.47 mg/L, within the acceptable range. TKN values were low to moderate, ranging from 0.1 to 1.1 mg/L in-lake and from 0.2 to 0.7 mg/L in tributaries.

Total phosphorus is a measure of organic and inorganic phosphorus. Dissolved phosphorus is most representative of the phosphorus immediately available for uptake by organisms. Phosphorus is commonly the least abundant nutrient and therefore controls primary productivity in freshwater systems. Massachusetts does not have numeric water quality or drinking water standards for phosphorus, although work towards establishing surface water quality standards is underway. However, it is widely accepted that a concentration above 0.03 mg/l provides an environment where biotic productivity can reach nuisance levels (Wetzel, 1975). Concentrations above 0.05 mg/l are excessive and concentrations above 0.10 mg/l are extreme and water quality impairment in lakes is inevitable. Concentrations below 0.03 mg/l are acceptable and concentrations below 0.01 mg/l are highly desirable.

In-lake total phosphorus concentrations ranged from 0.02 to 0.34 mg/L. The maximum value is not typical of the majority of 2002 Lily Pond samples. It was recorded at LP-3B and may be either the result of suspended materials in the sample. The dissolved phosphorus fraction of this sample was comparable to other sampling stations (0.03 mg/L). The average concentration of total phosphorus without the 0.34 mg/L outlier was 0.03 mg/L, which is considered moderate to high. Values at or above 0.03 mg/L are typically high enough to support nuisance algal blooms. Tributary values ranged from 0.02 to 0.05 mg/L, with higher values recorded at Peppermint Brook. In-lake dissolved phosphorus values ranged from 0.01 to 0.03 mg/L, with an average of 0.02 mg/L. Approximately 50% of the total phosphorus in Lily Pond is readily available for algal uptake.

The Federal Resources Conservation and Recovery Act (RCRA), which is a vehicle for hazardous/dangerous waste regulations, recognizes eight heavy metals (RCRA 8) as a target list to protect human health. These metals are arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Massachusetts Drinking Water MCLs are 0.05 mg/L for arsenic, 2.0 mg/L for barium, 0.005 mg/L for cadmium, 0.1 mg/L for chromium, 0.015 mg/L for lead, 0.002 mg/L for mercury, 0.05 mg/L for selenium, and 0.10 mg/L (SMCL) for silver. Iron, another metal naturally occurring in the environment necessary to flora for photosynthesis but toxic in high qualities, was also tested. The SMCL for iron in Massachusetts is 0.3 mg/L. There are no state specific standards for surface waters of Massachusetts, so the U.S. federal Ambient Water Quality Criteria (AWQC) for protection of freshwater aquatic species was used for comparison. These criteria were compared to Lily Pond metal concentrations at a hardness level of 24 (average of Lily Pond).

In-lake and tributary concentration of RCRA metals were low, all below the MCL or SMCL. Iron concentrations, however, exceeded the SMCL at all stations (in-lake and tributary) during all samplings with the exception of Brass Kettle Brook in October when the concentration was 0.18 mg/L. Iron concentrations exceeded the AWQC at all stations with the exception of PB-1 and LP-3S in July, and BK-1 and PB-1 in October. Iron values ranged from 0.18 to 3.0 mg/L and are well within the natural range for Massachusetts waters. These values indicate that there is plenty of iron present within Lily Pond so not to limit algal growth and treatment of iron is necessary prior to human consumption. Barium concentrations exceeded the AWQC at all sampled stations.

Total organic carbon in natural water is composed of both dissolved organic carbon (DOC) and particulate organic carbon (POC), most in the form of dead organic matter or detritus. The organic matter is a mixture of plant, microbial, and animal products in various stages of decomposition. It consists of compounds synthesized biologically and chemically from various degradation productions and of microorganisms and their remains in various states of decomposition (Wetzel, 2001). It is typically separated into two major components – non-humic substances and humic substances. Non-humic substances include carbohydrates, proteins, amino acids, fats, waxes, resins, pigments and other low molecular weight compounds. These substances are relatively easily degraded by bacteria, therefore the ambient lake concentrations of non-humic substances in natural waters is low. The majority of DOC (70-80%) in natural is composed of humic substances (Wetzel, 2001). Humic substances are naturally-occurring, dark-colored organic substances, with high molecular weight, which are extremely resistant to microbial decomposition. Accordingly, such substances tend to accumulate in the lake ecosystem and so show low turnover rates and little significant seasonal patterns. The ratio of DOC to POC is rather constant at 10:1 in most unproductively to moderately productive lakes but shift to a lower ratio (e.g., 6:1) for more productive lakes, particularly those with significant contributions from the littoral zone, such as Lily Pond.

In-lake TOC values ranged from 5.0 – 9.8 mg/L. Peppermint Brook TOC was similar to in-lake values, 6.2 mg/L, while Brass Kettle Brook TOC was higher 12.0 mg/L. The higher value in Brass Kettle Brook is likely to result from the heavily vegetated wetland system. TOC values measured in 2003 and any potential impacts to water quality as it relates to water treatment is provided in Section 5.5.

4.2.2 Sediment Chemistry

Sediments were sampled from four locations in the pond and analyzed for a variety of conventional parameters associated with dredging feasibility. The results of these analyses indicate that the sediments of Lily Pond are organic and rich in phosphorus, but they do not contain problematic concentrations of metals, PAHs, PCB, or pesticides. This is important because it indicates that the sediments do not pose an ecological risk within the pond, nor would they require special handling or disposal if removed from the pond (e.g., for dredging purposes). Further details are provided below and in Table 15.

Table 15. 2002 Sediment Sampling Results.

		Reference Thresholds		Sampling Stations			
Parameter	Method	MCP RCS-1 (ppm)	TEC (ppm)	LP-1 (ppm)	LP-2 (ppm)	LP-3 (ppm)	LP-4 (ppm)
Metals							
arsenic	6010B, SW-846	30	9.79	<8.2	<0.81	<1.5	<4.0
barium	6010B, SW-846	1,000		53.5	6.91	25.7	61.7
cadmium	6010B, SW-846	30	0.99	<2.5	<0.24	<0.44	<1.2
chromium (total)	6010B, SW-846	1,000	43.4	8.89	1.17	9.43	9.51
lead	6010B, SW-846	300	35.8	16	1.53	22.2	19.2
mercury	7471, EPA 1986	20	0.18	<0.332	<0.1	<0.125	<0.273
selenium	6010B, SW-846	400		18	<1.6	<2.9	<7.9
silver	6010B, SW-846	200		<2.5	<0.24	<0.44	<1.2
Total Petroleum Hydrocarbons	ASTM D3328	200		**419**			161
Polynuclear Aromatic Hydrocarbons							
acenaphthene	EPA 8270	20		<4.6			<3.8
acenaphthylene	EPA 8270	100		<4.6			<3.8
anthracene	EPA 8270	1,000	0.057	<4.6			<3.8
benzo(a)anthracene	EPA 8270	0.7	0.108	<1.8			<1.5
benzo(a)pyrene	EPA 8270	0.7	0.150	<1.8			<1.5
benzo(b)fluoranthene	EPA 8270	0.7		<1.8			<1.5
benzo(k)fluoranthene	EPA 8270	7		<1.8			<1.5
benzo(g,h,i)perylene	EPA 8270	1,000		<1.8			<1.5
chrysene	EPA 8270	7	0.166	<0.910			<0.760
dibenzo(a,h)anthracene	EPA 8270	0.7	0.033	<0.910			<0.760
fluoranthene	EPA 8270	1,000	0.423	<4.6			<3.8
fluorene	EPA 8270	400	0.077	<4.6			<3.8
indeno(1,2,3-cd)pyrene	EPA 8270	0.7		<1.8			<1.5
naphthalene	EPA 8270	4	0.176	<4.6			<3.8
2-methylnaphthalene	EPA 8270	4		<4.6			<3.8
phenanthrene	EPA 8270	100	0.204	<4.6			<3.8
pyrene	EPA 8270	700	0.195	<4.6			<3.8

Bold values indicate an exceedence of one or more thresholds in a detected compound.

Table 15 (continued). 2002 Sediment Sampling Results.

		Reference Thresholds		Sampling Stations			
Parameter	**Method**	**MCP RCS-1 (ppb)**	**TEC (ppb)**	**LP-1 (ppb)**	**LP-2 (ppb)**	**LP-3 (ppb)**	**LP-4 (ppb)**
Pesticides							
aldrin	EPA 8080	30		<0.197			<0.160
alpha-BHC	EPA 8080	50,000		<0.197			<0.160
beta-BHC	EPA 8080	10,000		<0.295			<0.240
delta-BHC	EPA 8080	10,000		<0.442			<0.349
gamma-BHC (Lindane)	EPA 8080	100	2.37	<0.197			<0.160
chlordane	EPA 8080	1,000	3.24	<34.4			<27.9
4,4'-DDD	EPA 8080	2,000	4.88	<0.541			<0.439
4,4'-DDE	EPA 8080	2,000	3.16	<0.197			<0.160
4,4'-DDT	EPA 8080	2,000	4.16	<0.590			<0.479
dieldrin	EPA 8080	30	1.9	<0.098			<0.080
endosulfan I	EPA 8080	50		<0.688			<0.559
endosulfan II	EPA 8080	50		<0.197			<0.160
endosulfan sulfate	EPA 8080	50		<3.245			<2.635
endrin	EPA 8080	600	2.22	<0.295			<0.240
endrin ketone	EPA 8080	600		<0.295			<0.240
endrin aldehyde	EPA 8080	600		<1.131			<0.918
heptachlor	EPA 8080	100		<0.147			<0.120
heptachlor epoxide	EPA 8080	60	2.47	<4.081			<3.314
methoxychlor	EPA 8080	30,000		<0.590			<0.479
toxaphene	EPA 8080	10,000		<34.4			<27.9
Polychlorinated Biphenyls			59.8				
PCB-1016	EPA 8080	2,000		<0.982			<0.787
PCB-1221	EPA 8080	2,000		<0.982			<0.787
PCB-1232	EPA 8080	2,000		<0.982			<0.787
PCB-1242	EPA 8080	2,000		<1.960			<1.570
PCB-1248	EPA 8080	2,000		<0.982			<0.787
PCB-1254	EPA 8080	2,000		<0.982			<0.787
PCB-1260	EPA 8080	2,000		<0.982			<0.787

Bold values indicate an exceedence of one or more thresholds in a detected compound.

Table 15 (continued). 2002 Sediment Sampling Results.

Parameter	Method	LP-1 (ppm)[1]	LP-2 (ppm)[1]	LP-3 (ppm)[1]	LP-4 (ppm)[1]
		Sampling Stations			
pH (SU)	4500-H-B SM 18TH	7.18	6.34	6.05	6.13
Percent Solids		10.01	69.4	28.8	12.1
Total Organic Carbon	EPA 415-1	28,000	27,000	22,000	32,000
Nutrients					
nitrate-N	EPA 352.1	110	26	66	181
total phosphorus	4500-P-E SM 18TH	5,167	128	302	708
Grain Size					
% finer than 4.75 mm (Sieve Size 4)		100.0	100.0	100.0	100.0
% finer than 2.00 mm (Sieve Size 10)		99.8	100.0	100.0	100.0
% finer than 0.850 mm (Sieve Size 20)		99.6	99.8	98.4	99.8
% finer than 0.425 mm (Sieve Size 40)		98.8	99.5	93.3	99.5
% finer than 0.300 mm (Sieve Size 50)		98.3	99.2	87.0	99.2
% finer than 0.180 mm (Sieve Size 80)		97.3	98.5	69.3	98.1
% finer than 0.075 mm (Sieve Size 200)		87.6	88.8	47.4	87.5
% > 3"		0.0	0.0	0.0	0.0
% Gravel		0.0	0.0	0.0	0.0
% Sand		12.4	11.2	52.6	12.5
% Silt		74.9	68.5	34.9	64.9
% Clay		12.7	20.3	12.5	22.6

Sediment values were compared to two thresholds: the Massachusetts Contingency Plan Reportable Concentration for the Soil 1 Category (MCP RCS-1; the most strict category for upland soils) and the Massachusetts consensus-based threshold effect concentrations (TECs; used as a screening level for risk to benthic organisms). Of the eight inorganic chemicals 17 PAHs, 20 pesticides and seven PCB fractions analyzed, only barium, chromium, lead, and selenium were detected. None of the detected values exceeded either the MCP or TEC thresholds. The only parameter that exceeded RCS-1 was total petroleum hydrocarbons (TPH) with an average value of 290 ppm (RCS-1 = 200 ppm). TPH is a cumulative measure of heterogeneous hydrocarbons and is considered a general indicator of anthropogenic (man-made) inputs due to fuels or combustion by-products, such as is often contained in highway runoff. However, TPH does not have an ecological risk-based standard since, due to the diversity of potential components of TPH (some with little or no toxicity), no correlation with adverse effects at low levels is noted. Further, TPH is generally hydrophobic and is associated with the organic carbon fraction in sediments. Due to the slight exceedance of the RCS-1 value, coupled with the large range of parameters examined, little weight should be attached to this RCS-1 exceedance. It is relatively safe to assume that sediment with concentrations generally below the MCP RCS-1 standard is “clean” and would have the greatest disposal options available, and would likely be the least expensive to dispose of.

While individual compounds (e.g. PAHs) were undetected at values above the screening threshold values, which is not unusual for sediment analysis due to very conservative screening values, it can be safely assumed are actually below the standard. This assumption is based on the consistent pattern of non-detections and lack of a discernible pollutant source.

Grain size analysis indicates that the majority of the sediment is in the silt and clay fraction (except LP-3, located in the outlet channel, is primarily sand and silt). It should be noted that the silt/clay fraction designation is based on particle size, not actual composition. The sediment appears to be mostly organic matter; thus the sediment would be considered gyttja type sediment. Sediments in Lily Pond were roughly 2-3% organic material, in the low range for sediment in ponds, but indicating that the material is well decomposed. Rock, cobble and gravel areas were observed near the shoreline but are not reflected by the grain size analysis. What lies beneath the thick organic muck layers was undeterminable with the method used to sample these areas in most cases. A mechanical coring device will be needed to determine the composition of the true pond bottom in deeper water/sediment areas. However, in most cases, this additional information is not needed to evaluate potential management options.

4.2.3 Nitrogen and Phosphorus Loading

Nitrogen and phosphorus loads to Lily Pond were derived by two separate methods: calculation from empirical models and calculation from a land use-based model calibrated with actual data. The land use model was calculated based on existing conditions during ENSRs investigation and then adjusted to reflect conditions of 100% useable capacity. The empirical formulas and assumptions made using the land use-based model (i.e., runoff coefficients etc.) are provided in Appendix C. With a limited seasonal data set (i.e., three sets of summer-fall dry weather samples), estimation from actual data using measured flow and concentration data was deemed non-representative and therefore was not performed. Although models are only representations of reality, they can provide insights into the magnitude and range of loading and temper judgments made based on a limited set of actual data. The approaches applied here provide a range of estimates, of nutrient loading and a sense for the potential uncertainty in loading estimates.

4.2.3.1 Nitrogen Loading

The total nitrogen load to Lily Pond estimated from the empirical model approach was 3,345 kg/yr (Table 16). This empirical model load is considered representative of the “effective” load of nitrogen to the lake; this is the amount of nitrogen most likely measurable in the water column over time.

The total nitrogen load to Lily Pond predicted by the land use model is 3,331 kg/yr (Table 17), comparable to the empirical model value. These loading estimates are lower than those estimate by CDM in 1986 (4,519 kg/yr), but is consistent with the smaller concentrations of nitrogen found in the 2002 samples. There are many assumptions that go into loading predictions, including the accuracy and treatment of data, choice of models, selection of export coefficients, and assignment of attenuation factors. Furthermore, loading does not occur at a constant rate and can vary substantially among seasons and years. As a consequence, the uncertainty of such estimates can be quite large and no single number should be relied upon too heavily. The range derived by these approaches appears representative of the probable range of actual loading to Lily Pond, but actual variability may be even greater.

4.2.3.2 Phosphorus Loading

The total phosphorus load to Lily Pond estimated from the average of several empirical models was 150 kg/yr (Table 16). Differences among estimates from various empirical models can sometimes provide insights into lake function. Note that the range of values for the five empirical models is fairly large (117 to 201 kg/yr), and that differences in estimates are derived mainly from variation in how the phosphorus retention coefficient (portion retained in the lake) is calculated. The Vollenweider retention coefficient value is roughly twice that of the Larsen-Mercier and Kirchner-Dillon retention coefficients. The Jones-Bachmann and Reckhow models

Table 16. Nitrogen and Phosphorus Load Estimate Derived from Empirical Models.

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE
TP	Lake Total Phosphorus Conc.	ppb	From data or model	30
L	Phosphorus Load to Lake	g P/m2/yr	From data or model	0.743412
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	38
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	30
I	Inflow	m3/yr	From data	3598378
A	Lake Area	m2	From data	205807.8
V	Lake Volume	m3	From data	387108
Z	Mean Depth	m	Volume/area	1.88092
F	Flushing Rate	flushings/yr	Inflow/volume	9.295541
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.789474
Qs	Areal Water Load	m/yr	Z(F)	17.48417
Vs	Settling Velocity	m	Z(S)	1.484937
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.210526
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.29575
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.246983
	ADDENDUM FOR NITROGEN			
TN	Lake Total Nitrogen Conc.	ppb	From data or model	740
L	Nitrogen Load to Lake	g N/m2/yr	From data or model	To be predicted
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	2.383074

LOAD ANALYSIS MODEL	ESTIMATED LOAD (kg/yr)
Phosphorus	
Mass Balance (no loss)	108
Kirchner-Dillon 1975	153
Vollenweider 1975	117
Reckhow 1977 (General)	201
Larsen-Mercier 1976	143
Jones-Bachmann 1976	137
Model Average (without mass balance)	150
Permissible Load	86
Critical Load	172
Nitrogen	
Mass Balance (no loss)	2663
Bachmann 1980	3345

Table 17. Nitrogen and Phosphorus Load Land Use Export Coefficient Model.

LOAD AND CONCENTRATION SUMMARY			
	NITROGEN		
	BASIN 1 Brass Kettle	**BASIN 2 Peppermint**	**BASIN 3 Direct Drainage**
OUTPUT (CU.M/YR)	2435195	598334	315590
OUTPUT (KG/YR)	1657	978	339
% WATERSHED LOAD	56%	33%	11%
OUTPUT (MG/L)	0.680	1.635	1.073
	PHOSPHORUS		
	BASIN 1 Brass Kettle	**BASIN 2 Peppermint**	**BASIN 3 Direct Drainage**
OUTPUT (CU.M/YR)	2435195	598334	315590
OUTPUT (KG/YR)	57.6	29.2	13.8
% WATERSHED LOAD	57%	29%	14%
OUTPUT (MG/L)	0.024	0.049	0.044

DIRECT LOADS TO LAKE	**N**	**P**
ATMOSPHERIC (KG/YR)	206.5	6.4
INTERNAL (KG/YR)	103.0	20.6
WATERFOWL (KG/YR)	47.5	10.0
WATERSHED LOAD (KG/YR)	2974.1	100.7
TOTAL LOAD TO LAKE (KG/YR) (Watershed + direct loads)	3331.0	137.7

use an implicit retention coefficient calculation based on hydraulic features of the lake (i.e., flushing rate and depth), while the others apply a retention coefficient based on measured phosphorus values. It is entirely possible that the year to year variation in phosphorus retention by Lily Pond spans the range represented in these models.

The total phosphorus load predicted from the land use model was 138 kg/yr (Table 17), similar to the empirical model predictions. Out of the predicted 138 kg/yr load, 101 kg/yr are from the watershed; other sources of phosphorus are not especially important to this pond. These estimates are lower than those prepared by CDM in 1986 (220 kg/yr), but are within the range of expected loads. As with the nitrogen loading estimates, the many assumptions inherent in the predictive process lead to substantial variability of estimates. Actual year to year variability is likely to be at least as great as the range of estimates.

The portion of the total annual load from the watershed includes any input to Lily Pond from septic systems. Septic system influence, in terms of phosphorus loading, is not likely to have impacts to surface waters located further than 100' from the source if systems are properly functioning. Phosphorus becomes bound in soil and utilized by plants readily. According to the SWSPP (Norfolk Ram Group 2002), there are 26 septic systems in Zone A of Cohasset, but the report did not specify where the systems were located. While it is difficult to quantify specific loading from septic systems without knowing the exact location of each system, a worse-case estimate can be calculated using basic assumptions. If it assumed that the 26 systems in Zone A are serving three people, all are failing (i.e., minimal attenuation), with a total phosphorus generation rate of 0.5 kg/p/yr and a total nitrogen rate of 4.0 kg/p/yr, the respective loading from these systems would be 35 kg TP/yr, with a 10% attenuation, and 312 kg TN/yr (no attenuation) for total nitrogen. This is the worse case scenario, as it was assumed that all systems were within 100' from surface waters and that all 26 systems were failing. A more realistic estimate of loading would be 10-25% of the worse-case loading (3.5-8.8 kg TP/yr and 31.2-78 kg TN/yr). In any event, stormwater contribution in this system is more important than septic influences at this time.

Chlorophyll and water clarity (as Secchi Disk Transparency) were predicted using phosphorus load and predicted in-lake phosphorus concentrations from both the empirical model and land use export model (Table 18). Predicted chlorophyll values ranged from 10.2 to 16.4 ug/L, with an average of 13.7 ug/L. Observed chlorophyll values ranged from 8.7 to 35.8 ug/L, with and average of 19.1 ug/L. Observed values were within the expected range (includes average predicted maxima = 45.7 ug/L), but on average measured chlorophyll was higher and may be due to particulate plant material in the water column (See Section 4.3.3 Phytoplankton). Water clarity was predicted on average to be 1.6 - 1.7 m. Average observed water clarity in Lily Pond as SDT was 0.8 m. This difference is likely due to color or non-algal turbidity. The predictions shown in Table 18 do not correct for water color or non-algal turbidity.

Table 18. Predicted Chlorophyll Concentrations and Water Clarity.

PREDICTED CHL AND WATER CLARITY		
MODEL	**Empirical Model**	**Land Use Export Model**
Mean Chlorophyll (ug/L)		
Dillon and Rigler 1974	11.9	10.2
Jones and Bachmann 1976	13.8	11.8
Oglesby and Schaffner 1978	16.4	14.5
Modified Vollenweider 1982	16.4	14.8
"Maximum" Chlorophyll (ug/L)		
Modified Vollenweider (TP) 1982	51.3	46.0
Vollenweider (CHL) 1982	44.6	38.9
Mod. Jones, Rast and Lee 1979	49.9	43.8
Secchi Transparency (M)		
Oglesby and Schaffner 1978 **(Avg)**	1.6	1.7
Modified Vollenweider 1982 **(Max)**	3.7	3.8

4.2.3.3 Discussion of Loading Limits

Using the loading estimates provided by CDM in 1986, predicted average chlorophyll is higher (20.0 ug/L) and average SDT was lower (1.3 m) than with ENSR's loading estimate. However, this load results in an in-lake phosphorus concentration of 48 ug/L, higher than concentrations observed in the 2002 investigation. This is not to suggest that either ENSR's or CDM's assessment is incorrect, it does suggest, however, that this system is dynamic and hydrology plays an important role in assessing in-lake nutrient concentrations and their biotic influence. Variability in this system is likely higher than most. Both models over-predict the average and maximum Secchi transparency, suggesting that the phosphorus load to Lily Pond is not the sole factor in maintaining water clarity (including CDM's loading estimate). However, the loading estimates generated by the empirical and land use models provide a reasonable approximation of what appears to be happening in Lily Pond and its watershed in terms of phosphorus.

Permissible and Critical limits for phosphorus loading were estimated for Lily Pond based upon an approach developed by Vollenweider (1968). The Permissible load is the amount of phosphorus that could enter a system without obvious or continual detrimental effects. As values exceed the Permissible load and get closer to the Critical load, nuisance algal blooms often become a problem. Lakes exceeding the Critical load usually experience serious productivity problems. Permissible and Critical phosphorus loads for Lily Pond were calculated to be 86 kg/yr and 172 kg/yr, respectively (Table 16).

The total phosphorus load to Lily Pond, estimated under the empirical model approach (150 kg/yr) and the land use model (138 kg/yr), exceed the Permissible limit. The load estimated with the empirical models and land use model is approaching to the Critical limit. The lake presently appears on the edge of eutrophic nutrient conditions for phosphorus, but algal blooms are not a serious problem. Light-limiting color, turbidity, and extensive rooted plant growth appear to aid in preventing nuisance algal blooms. Further binding of phosphorus by iron and/or humic substances may be further limiting phosphorus availability within the pond. However, algal blooms are possible if the present phosphorus loading continues and may become a serious issue if rooted plant growth is controlled.

Phosphorus is typically the limiting nutrient (i.e., nutrient in shortest supply) in fresh water systems and generally dictates algal productivity. Permissible and Critical loads and concentrations for phosphorus are estimated in an effort to determine loading rates while allowing for tolerable algal productivity. These limits, although calculable for nitrogen, are not very meaningful, as the Lily Pond system is phosphorus limited. The ratio of nitrogen:phosphorus in Lily Pond is 25:1, indicating that phosphorus is the limiting nutrient. Variation in nitrogen concentration, however, can shift algal community dominance. High concentrations of nitrogen favor green algae whereas lower concentrations of nitrogen favors blue-green algae, which are the most problematic for water supplies as they can cause taste and odor problem in high densities. Overall, nitrogen and phosphorus loading in this system is high.

4.3 Biological Characteristics

4.3.1 Fecal Bacteria

Coliform, a type of bacteria present in soils and plants as well as human intestines, naturally occurs in surface water. The measurement of fecal coliform is intended to eliminate coliform bacteria derived from soils and plants, emphasizing coliform derived from warm-blooded animals. However, fecal coliform does not differentiate between wastes from human and other warm-blooded animal sources, such as ducks, raccoons and family pets. Massachusetts State Surface Water Quality Standards state that the concentration of fecal coliform bacteria shall not exceed a geometric average of 20 organisms per 100 milliliters (ml) in any set of samples, nor shall 10% of the samples exceed 100 organisms per 100ml on an individual sampling basis. The Massachusetts MCL for total coliform is zero. Values within Lily Pond (Table 13) ranged from below the detection limit (<10 organisms/100mL) to 280/100 mL, resulting in a geometric means of 7, 21, and 5 organisms/100mL for July, August, and October respectively. Only one fecal coliform value was obtained from Brass Kettle Brook (BK-1) due to a broken bottle. Fecal coliform in Brass Kettle Brook was relatively low 20 organisms/100 mL on October 10, 2002. Values in Peppermint Brook were elevated and ranged from 80 to 5800 organisms/100 mL.

4.3.2 Chlorophyll *a*

Chlorophyll *a* is a photosynthetic pigment in algae, and terrestrial plants, which uses energy from sunlight to synthesize carbohydrates from carbon dioxide and water. The amount of chlorophyll present in the water provides a measure of the phytoplankton density (see description of "Phytoplankton" below). There is no regulatory standard for chlorophyll *a* of raw water, although values less than 10 ug/L are generally desirable. Concentrations ranged from 8.7 to 35.8 ug/L in Lily Pond (Table 19). The average in-lake chlorophyll concentration was 19.1 ug/L.

Table 19. 2002 Chlorophyll *a* Concentrations in Lily Pond.

Location	Sample Date	Phaeo (ug/L)	Chl a (ug/L)	Total Chl a (ug/L)
LP-1	7/31/2002	0.00	21.14	21.14
LP-4	7/31/2002	0.02	12.20	12.22
LP-3	8/29/2002	0.00	16.95	16.95
LP-4	8/29/2002	0.24	8.41	8.65
LP-3	10/10/2002	0.00	35.83	35.83
LP-4	10/10/2002	0.00	19.99	19.99

4.3.3 Phytoplankton

Phytoplankton samples were collected from two stations in Lily Pond on July 31, 2002. The phytoplankton of Lily Pond includes representatives of five algal divisions, with two common divisions not represented (Table 20). Numerically, the algal count was dominated by green algae (Chlorophyta) at LP-1 and not by any one division at LP-4. As cell size varies among phytoplankters, cell counts are converted to biovolume and then biomass to provide a better evaluation of relative abundance and importance to the aquatic system. Green algae dominated both samples in terms of biomass, although different genera of green algae were dominant in each sample. Diatoms were the next most abundant algal group in both samples.

Overall, biomass was moderate at 1,906 ug/L biovolume at LP-1 and 1,510 ug/L at LP-4. Values in excess of 10,000 ug/L are possible in lakes, and values <1000 ug/L are usually considered low for ecological purposes. However, even values >100 ug/L may be problematic in water supplies, depending upon which species are present and how the water is treated prior to distribution. In Lily Pond, most algae are larger-celled forms that would be filtered easily with only limited potential for clogging. Yet at the densities observed, filter run times might be reduced over what could be expected at much lower possible densities.

Table 20. 2002 Phytoplankton Density and Biomass in Lily Pond.

	Density (Cells/mL)		Biomass (ug/L)	
Taxon	**LP-1 7/31/02**	**LP-4 7/31/02**	**LP-1 7/31/02**	**LP-4 7/31/02**
BACILLARIOPHYTA				
Asterionella	11	0	2.2	0.0
Cocconeis	55	0	28.6	0.0
Eunotia	66	96	66.0	96.0
Gomphonema	11	0	11.0	0.0
Navicula	0	32	0.0	16.0
Nitzschia	0	64	0.0	94.4
Stenopterobia	0	16	0.0	57.6
Synedra	22	32	17.6	25.6
CHLOROPHYTA				
Ankistrodesmus	88	16	8.8	1.6
Cosmarium	0	16	0.0	12.8
Gloeocystis	0	64	0.0	345.6
Micrasterias	0	16	0.0	640.0
Mougeotia	44	0	44.0	0.0
Oedogonium	44	48	286.0	48.0
Scenedesmus	88	64	8.8	6.4
Schroederia	22	32	55.0	80.0
Sphaerocystis	1760	0	1232.0	0.0
Tetraedron	22	0	34.1	0.0
CHRYSOPHYTA				
Centritractus	0	16	0.0	9.6
Dinobryon	0	16	0.0	48.0
Mallomonas	110	32	55.0	16.0
Synura	22	0	17.6	0.0
CRYPTOPHYTA				
Cryptomonas	33	32	22.0	6.4
CYANOPHYTA				
Lyngbya	880	0	17.6	0.0
Oscillatoria	0	640	0.0	6.4

Table 20 (continued). 2002 Phytoplankton Density and Biomass in Lily Pond.

	Density (Cells/mL)		Biomass (ug/L)	
	LP-1 7/31/02	LP-4 7/31/02	LP-1 7/31/02	LP-4 7/31/02
SUMMARY STATISTICS				
DENSITY				
BACILLARIOPHYTA	165	240	125.4	289.6
CHLOROPHYTA	2068	256	1668.7	1134.4
CHRYSOPHYTA	132	64	72.6	73.6
CRYPTOPHYTA	33	32	22.0	6.4
CYANOPHYTA	880	640	17.6	6.4
EUGLENOPHYTA	0	0	0.0	0.0
PYRRHOPHYTA	0	0	0.0	0.0
RHODOPHYTA	0	0	0.0	0.0
TOTAL PHYTOPLANKTON	3278	1232	1906.3	1510.4
TAXONOMIC RICHNESS				
BACILLARIOPHYTA	5	5		
CHLOROPHYTA	7	7		
CHRYSOPHYTA	2	3		
CRYPTOPHYTA	1	1		
CYANOPHYTA	1	1		
EUGLENOPHYTA	0	0		
PYRRHOPHYTA	0	0		
RHODOPHYTA	0	0		
TOTAL PHYTOPLANKTON	16	17		
S-W DIVERSITY INDEX	0.64	0.84		
EVENNESS INDEX	0.53	0.68		

Most algae encountered were forms typically associated with aquatic plants, and many are known as attached (or periphytic) forms. Presence in samples is probably a function of disturbance of plants, leading to periphyton breaking free, and is a common occurrence. Many forms are also associated with the sediment, suggesting shallow conditions and resuspension of bottom materials at times. Possible taste and odor forms present included the blue-greens

Lyngbya and *Oscillatoria* and the golden algae *Mallomonas* and *Dinobryon*, but none of these were abundant. Diversity and evenness were moderate, suggesting no major ecological imbalance.

High chlorophyll (photosynthetic pigment) values obtained from water samples are not consistent with the observed algal community, and suggest that plant pieces were also collected in the samples. Much of the material observed floating in the lake is not algae, but plant material or detritus, and some of this is still in a live condition. Actual algal biomass is not high enough to yield the observed chlorophyll values.

4.3.4 Zooplankton

The zooplankton of Lily Pond was sampled by towing a net with a mesh aperture of 53 micrometers through 30 meters of water, resulting in a concentrated sample representing 948 liters of lake water. Samples were collected at two locations, LP-1 and LP-4, and examined at 40X to 100X magnification under brightfield optics to determine types, abundance and size of zooplankters present. Composition included one species of rotifer, three types of copepods, and seven genera of cladocerans (Table 21). Most forms are commonly associated with aquatic vegetation. Density, measured as either the number of individuals or biomass per liter, were very low, suggesting that the zooplankton are not a major component of the aquatic system. Average size was low to moderate, indicating limited grazing pressure on algae and limited potential as a fish food source. Diversity and evenness were moderate. There were more types of zooplankton and a higher density at LP-4 than at LP-1, but the difference was negligible from ecological and management viewpoints.

4.3.5 Aquatic Vascular Plants

Most of the Lily Pond sediment surface is covered with plants, with most growths extending upward substantially toward the water surface. Sediment included muck, sand, gravel, cobble, and rock (Table 22). Deep layers of muck was associated with deeper water depths. Though aquatic vegetation can be affected by several factors, including light, substrate, nutrient availability, macrophyte growth was not significantly limited by any of these factors in Lily Pond, with the exception of light at deeper areas. Historically Lily Pond has had to contend with extensive rooted plant growths. According the Massachusetts Fish and Wildlife Service, in 1912 Lily Pond had dense coverage (over half the surface area) of floating plants (watershield. *Brasenia* and white pond lily, *Nymphaea odorata*). This may have been the cause of the Pond's name.

Table 21. 2002 Zooplankton Density and Biomass in Lily Pond.

TAXON	Density (Cells/mL)		Biomass (ug/mL)	
	LP-1 7/31/02	LP-4 7/31/02	LP-1 7/31/02	LP-4 7/31/02
SUMMARY STATISTICS				
DENSITY				
PROTOZOA	0.0	0.0	0.0	0.0
ROTIFERA	1.2	1.2	0.2	0.2
COPEPODA	0.7	0.8	1.8	1.5
CLADOCERA	0.7	1.2	4.7	9.0
OTHER ZOOPLANKTON	0.1	0.0	0.5	5.0
TOTAL ZOOPLANKTON	2.6	3.2	7.2	15.7
TAXONOMIC RICHNESS				
PROTOZOA	0	0		
ROTIFERA	1	1		
COPEPODA	2	4		
CLADOCERA	4	7		
OTHER ZOOPLANKTON	1	1		
TOTAL ZOOPLANKTON	8	13		
S-W DIVERSITY INDEX	0.66	0.79		
EVENNESS INDEX	0.73	0.71		
MEAN LENGTH: ALL FORMS (MM)	0.38	0.51		
MEAN LENGTH: CRUSTACEANS	0.53	0.69		

Table 21 (continued). 2002 Zooplankton Density and Biomass in Lily Pond.

	Density (Cells/mL)		Biomass (ug/mL)	
TAXON	**LP-1 7/31/02**	**LP-4 7/31/02**	**LP-1 7/31/02**	**LP-4 7/31/02**
ROTIFERA				
Conochilus	1.2	1.2	0.2	0.2
COPEPODA				
Copepoda-Cyclopoida				
Cyclops	0.1	0.3	0.2	0.6
Mesocyclops	0.0	0.2	0.0	0.3
Copepoda-Calanoida				
Diaptomus	0.0	0.2	0.0	0.1
Other Copepoda-Nauplii	0.6	0.2	1.6	0.5
CLADOCERA				
Alonella	0.3	0.9	2.5	8.1
Bosmina	0.1	0.1	0.0	0.0
Chydorus	0.1	0.1	0.0	0.0
Daphnia ambigua	0.0	0.1	0.0	0.1
Diaphanosoma	0.0	0.1	0.0	0.0
Polyphemus	0.3	0.1	2.1	0.4
Sida	0.0	0.1	0.0	0.3
OTHER ZOOPLANKTON				
Chironomidae	0.0	0.0	0.0	5.0
Ostracoda	0.1	0.0	0.5	0.0

Table 22. Lily Pond 2002 Vegetation Coverage, Biovolume and Taxa with Relative Abundance.

Transect Point	Water Depth (ft)	Sediment Type	Cover	Biovolume	Species Composition Relative Abundance (%)											
					Cc	Uspp	Mh	Ni	No	Nv	Bs	Pb	Pp	Pc	FG	BG
A1	4.9	Muck / Rock	4	2	95	5										
A2	5.9	Muck	4	2	95	5	<5									
A3	5.9	Muck	3	3	95	5										
A4	5.5	Muck	3	3	90	5	5									
A5	6	Muck	4	3	85	10	5									
A6	4.1	Muck / Gravel	3	3	90	5		<5		5						
A7	3.9	Muck / Sand	2	1	50	50										
B1	1.5	Sand / Gravel	4	4	25	25	25				15	5	5			
B2	5.5	Muck	4	4	60	40	<5									
B3	5.5	Muck	4	4	40	40			20							
B4	5.2	Muck	4	4	75	25										
B5	5.6	Muck	4	3	60	40	<5									
B6	3.5	Muck / Sand / Rock	3	3	65	30			5							
C1	2	Rock	3	3	50	50										
C2	5.5	Rock / Sand / Hard pan	4	4	60	40	<5									
C3	5.8	Muck	4	3	60	40										
C4	5.5	Muck	4	4	50	20	30									
C5	4.5	Muck / Sand	4	3	45	40	10		5							
C6	2.9	Sand / Rock	4	4	30	30	10		30	<5						
D1	3	Rock	4	3	80	10			10							
D2	4.5	Muck / Sand / Rock	4	3	80	20										
D3	5.5	Muck	4	4	80	20										
D4	5	Muck	4	3	50	50				<5						
D5	5	Muck	4	3	50	50	5									
D6	6	Sand / Rock	4	4	50	50			<5							
E1	3.5	Muck/Rock	4	4	95	<5	<5									
E2	4	Rock / Muck	4	4	50	50										
E3	5	Muck	4	4	50	50				<5						
E4	5.5	Muck	4	4	60	40										
E5	5.8	Muck	4	4	50	50										
E6	3.9	Rock / Muck	4	3	50	50			<5							

Table 22 (continued). Lily Pond 2002 Vegetation Coverage, Biovolume and Taxa with Relative Abundance.

Transect Point	Water Depth (ft)	Sediment Type	Cover	Biovolume	Species Composition Relative Abundance (%)											
					Cc	Uspp	Mh	Ni	No	Nv	Bs	Pb	Pp	Pc	FG	BG
F1	3.9	Sand / Muck	2	1	60	20			20							
F2	4.5	Muck	3	2	70	30										
F3	6.3	Muck	4	2	60	40										
F4	6.3	Muck	4	3	70	30										
F5	6	Muck	4	4	70	30										
F6	5	Sand / Gravel	4	4	60	30	10		<5							
G1	3	Sand / Rock	4	4	40	20	5		30	5						
G2	6.5	Muck / Sand	4	4	60	30	10									
G3	7	Muck	4	2	50	25	25									
G4	7	Muck	4	2	60	40										
G5	6.5	Muck	3	2	70	30										
G6	7	Muck	3	2	70	30										
G7	6.4	Muck	4	3	60	30			10							
H1	3.5	Sand / Rock	4	4	50	30			15			5				
H2	6.5	Muck	3	2	60	40										
H3	6.5	Muck	1	1	90	10										
H4	6.8	Muck	1	1	90	10										
H5	7	Muck	4	2	60	30	10									
H6	7	Muck	4	2	60	40										
H7	6.5	Muck	4	3	70	30										
H8	6	Muck	4	3	40	40	20								<5	
I1	3.5	Muck / Sand	4	1	60	40										
I2	5.2	Muck	3	2	70	30										
I3	5.8	Muck	3	2	70	30										
I4	6.5	Muck	4	2	60	40										
I5	6.8	Muck	4	3	70	30										
I6	7	Muck	2	1	60	40										
I7	7.1	Muck	3	2	60	40										
I8	7	Muck	4	2	50	40			10							
J1	4	Sand / Rock	4	3	50	30	5		15							
J2	7	Muck	1	1	50	50										
J3	7	Muck	2	1	60	40										

Table 22 (continued). Lily Pond 2002 Vegetation Coverage, Biovolume and Taxa with Relative Abundance.

Transect Point	Water Depth (ft)	Sediment Type	Cover	Biovolume	Species Composition Relative Abundance (%)											
					Cc	Uspp	Mh	Ni	No	Nv	Bs	Pb	Pp	Pc	FG	BG
J4	7.3	Muck	1	1	50	50										
J5	7	Muck	4	2	70	30										
J6	6.2	Muck	4	3	60	30	10									
J7	5.5	Muck	4	3	70	30									<5	
J8	5.2	Muck	4	3	70	30										
J9	4.2	Muck	4	4	45	45						10				
K1	4.5	Muck	4	4	50	20			25	<5		5				
K2	4.5	Muck	4	4	40	30	10		10		5	5				
K3	6	Muck	4	4	70	30	<5									
K4	6.5	Muck	4	2	50	50										
K5	7.2	Muck	4	2	60	40										
K6	7.5	Muck	1	1	100											
K7	7.8	Muck	1	1	80	20										
K8	7.2	Muck	2	1	80	20										
K9	6.4	Muck / Sand	4	3	70	25	5									
L1	6.4	Muck / Sand	4	3	70	25	5									
L2	7	Muck	2	1	80	20										
L3	7.1	Muck	3	2	60	40										
L4	4.9	Sand / Rock	3	2	50	30	20									
L5	4.9	Sand / Rock	4	3	50	20	30									
L6	5.8	Muck	2	1	90		10									
L7	7.8	Muck	0	0												
L8	7	Muck	2	1	60	40										
M1	7.2	Muck	2	1	90	10										
M2	8	Muck	0	0												
M3	7.5	Muck	2	1	50	50										
M4	7.2	Muck	4	2	70	30										
M5	7	Muck	4	2	70	30										
M6	7	Muck	4	2	70	30										
M7	6.2	Muck	4	3	60	30	10									
M8	5.5	Muck	4	4	50	30	10		10							

Table 22 (continued). Lily Pond 2002 Vegetation Coverage, Biovolume and Taxa with Relative Abundance.

Transect Point	Water Depth (ft)	Sediment Type	Cover	Biovolume	Species Composition Relative Abundance (%)											
					Cc	Uspp	Mh	Ni	No	Nv	Bs	Pb	Pp	Pc	FG	BG
N1	5.5	Muck	4	4	50	30	10		10							
N2	6.5	Muck	4	3	60	35	5									
N3	6	Muck	4	3	60	30			10							
N4	6.2	Muck	4	2	60	30	10									
N5	6.2	Muck	4	2	60	40										
N6	6.4	Muck	4	2	60	40										<1
N7	5.5	Muck	4	3	70	30										
O1	5.5	Muck	4	4	70	30										
O2	5.5	Muck	4	3	60	40										
O3	5.8	Muck	4	3	60	30			10							
O4	4.8	Muck	4	3	60	20	20									
O5	4.5	Muck	4	3	10	60			15	15						
P1	3.5	Muck / Sand	4	4	40	40			10	10						
P2	5	Muck	4	4	50	30	20									
P3	5.9	Muck	4	3	70	30										
P4	6	Muck	4	3	70	30										
P5	3.5	Muck / Rock	2	1	90	10										
Q1	3.7	Sand / Rock	4	3	60	30	10							<5		
Q2	6.9	Muck	4	1	70	30										
Q3	7	Muck	4	1	70	30										
Q4	6.9	Muck	1	1	80	20										
Q5	7.1	Muck	1	1	100											
Q6	6.9	Muck	2	1	80	20										
Q7	7	Muck	1	1	40	60										
Q8	6.8	Muck	1	1	60	40										
Q9	6.8	Muck	3	2	55	45										
Q10	6.3	Muck	4	3	70	30										
Q11	4.5	Muck / Sand / Hard pan	4	4	60	30	10									
Q12	3.9	Muck / Sand / Hard Pan	4	4	45	20	20		10	5						
R1	3.1	Muck	4	4	40	20	20		15	5						
R2	4.9	Muck	4	3	50	40	10									
R3	5.5	Muck	4	3	50	40	10									

Table 22 (continued). Lily Pond 2002 Vegetation Coverage, Biovolume and Taxa with Relative Abundance.

Transect Point	Water Depth (ft)	Sediment Type	Cover	Biovolume	Species Composition Relative Abundance (%)											
					Cc	Uspp	Mh	Ni	No	Nv	Bs	Pb	Pp	Pc	FG	BG
R4	6.5	Muck	4	3	70	25	5									
R5	6.9	Muck	3	2	60	40										
S1	6.9	Muck	2	1	80	20										
S2	6.2	Muck	4	2	70	30	<5									
S3	6.1	Muck	4	2	50	40	10									
S4	6.1	Muck	4	3	40	35	25								<5	
S5	5.3	Muck / Sand	4	3	30	50	20									
S6	4	Muck / Sand	4	4	30	20	30		10	10						

Species code:

Code	Genus species	Common Name
Cc	*Cabomba caroliniana*	fanwort
Uspp	*Utricularia* (2 species noted)	bladderwort
Mh	*Myriophyllum heterophyllum*	variable watermilfoil, foxtail
Ni	*Nitella sp*	green macro alga
No	*Nymphaea odorata*	fragrant water lily
Nv	*Nuphar variegatum*	yellow pond lily, cow lily
Bs	*Brasenia Schreberi*	water shield
Pb	*Potamogeton bicupulatus*	snailseed pondweed
Pp	*Potamogeton pulcher*	spotted pondweed
Pc	*Potamogeton crispus*	curly-leaved pondweed
FG	Filamentous Green Algae	
BG	Blue Green Algae	

Overall percent cover was excessive (Figure 14). Approximately 77.8 percent of the total lake surface area had vegetation coverage greater than 75%; only 0.9% of the total lake surface area was devoid of plants. As a general rule, 20 to 40% plant coverage in the littoral zone is considered optimal for fisheries in northern tier lakes (Savino and Stein 1982). The entire area of Lily Pond is considered littoral, since water depths are not sufficiently great enough to limit light and rooted plant growths. In addition, high plant coverage and biovolume can clog water withdrawal intake structures; historically the Cohasset Water Treatment Plant has experienced this displeasure. Total percent biovolume followed a very similar pattern (Figure 15). Submerged vegetation reached the water surface in over 25% of the lake's surface area (biovolume > 75%).

There were 11 species identified during the July 2002 survey (Table 22). Three of which, fanwort (*Cabomba caroliniana*) variable watermilfoil (*Myriophyllum heterophyllum*) and curly-leaved pondweed (*Potamogeton crispus*), are non-native invasive species known to colonize areas at nuisance levels. Fanwort dominated the macrophyte community overall, with bladderwort, variable watermilfoil, and fragrant waterlilies also abundant. Taxa richness was the greatest near the water treatment plant (unofficial boat launch area).

The non-native species, fanwort, variable watermilfoil, and curly-leaved pondweed, are of concern as these species outcompete native vegetation and can form dense monocultures resulting in use impairment of the waterbody. Fanwort is native in the southeastern United States where it rarely grows to nuisance levels. This is not the case, however, in New England where fanwort outcompetes native plants and forms dense stands. Fanwort is generally found in slow moving water bodies such as lakes, ponds and quiet streams and rivers in three to ten feet of water. It can propagate vegetatively, with rhizomes or seeds. Fanwort dominated the plant community of Lily Pond. Average relative abundance was 62%. Fanwort was found at densities greater than 50% at 87% of the sampling locations.

Variable watermilfoil was widespread and relatively common in Lily Pond. Although it rarely achieved dominance, however, averaging 13% in relative abundance. Exceptions were noted in a few areas, but no pattern was obvious. Variable watermilfoil is a non-native species that reproduces by fragmentation, rhizomes, and seeds (although uncommon) and is commonly found in acidic waters. Fanwort likely keeps the density of milfoil to a minimum.

Curly-leaved pondweed is a non-native species that reproduces by rhizomes, turions, and seeds. It usually dies off in the New England area by mid-summer. It was noted near the rock outcrop island at only one point, at less than 5% of the total plant species composition. This species, like other non-natives, grows to nuisance levels. It is likely that the occurrence of this taxon would be greater had the survey been performed in June. However, fanwort may outcompete this species never allowing curly-leaved pond to dominate.

Figure 14. Lily Pond Macrophyte Coverage

Figure 15. Lily Pond Macrophyte Biovolume

There were two species of bladderwort observed in Lily Pond. Unfortunately these species were not in flower and identification to the species level is highly dependent on the presence of flowers. Some species of bladderwort are native, while others are introduced and can achieve nuisance levels. Bladderworts are carnivores, using bladders to capture tiny animals (zooplankton) and obtain nutrients directly from the water column; bladderworts do not root in the sediment. Bladderwort reproduces by fragmentation and seeds. Bladderwort was the second most abundant plant in Lily Pond. This plant rarely achieved dominance (only > 50% at 12% of the sampling locations), however.

4.3.6 Fish

A fish survey was not performed for this investigation. According to historic records of the Massachusetts Fisheries and Wildlife Service, Lily Pond was stocked with rainbow trout (*Oncorhynchus mykiss*) in 1901 and brook trout (*Salvelinus fontinalis*) in 1921. Both these species are cold water species and it is unlikely that they thrived in Lily Pond, considering it is a warm water system. Stocking by the State ceased shortly thereafter. Lily Pond was considered a drinking water supply and therefore not eligible for fisheries management. It is likely that Lily Pond contains warm water species common for the eastern region of Massachusetts that may include white perch (*Morone americana*), yellow perch (*Perca flavescens*), pumpkinseeds (*Lepomis gibbosus*), bluegills (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and bullheads (*Ameiurus spp*.).

The displacement of native plant species, particularly those with low-growing morphologies or high light requirements, and dominance by one plant species can negatively impact the fisheries community. It can result in population reductions or elimination of certain species of benthic invertebrates, alteration of cover for fish, and a reduction in food quality for herbivorous waterfowl (Shireman et al., 1982; Keast, 1984; Baker et al., 1993). Excessive plant densities have the potential to lead to excess survival of young of the year fish and subsequent intense competition for food resources, such that stunted populations or highly irregular year classes develop (Aggus and Elliot, 1975; Savino and Stein, 1982; Strange et al., 1975; Schneider, 1993). It is uncertain whether the excessive density of rooted plants, specifically fanwort, has negatively impacted the fish community in Lily Pond since no direct assessment of the fishery was conducted.

4.4 Trophic State Assessment

The numerical trophic state index (TSI) for lakes, developed by Carlson in 1977, was used to assess the relative trophic state of Lily Pond (Table 23). The TSI consists of physical (clarity), biological (chlorophyll), and chemical (total phosphorus) characteristics of the Pond. The average summer values are input into three predictive equations to provide a relative score that is compared against a range of values associated with lake trophic state. These trophic states range from the least productive (oligotrophic) to moderately productive (mesotrophic) to highly productive (eutrophic) classes. An oligotrophic waterbody is ones in which there is low nutrient inputs with corresponding low biological productivity. These lakes tend to be deeper, have very clear water and show little accumulation of biological material in the water column during the growing season. A mesotrophic waterbody is one that has moderate nutrient inputs with moderate biological productivity. These lakes have water clarity that can affected by algal blooms in summer, have productive zooplankton and fish communities, and water quality that supports both aesthetic and recreational water uses. Finally, a eutrophic waterbody in one that has excessive nutrient loading with excessive biological productivity. This level of biological activity can lead to frequent nuisance algal bloom, poor water clarity, loss of oxygen in the bottom waters, and often results in impairment of designated water uses.

The results of all three TSI scores are considered when arriving at a conclusion regarding trophic state. Data collected during the 2002 investigation was used in this assessment. Historic phosphorus concentrations seemed uncharacteristically high based on observations made in 2002 and therefore were not incorporated in this assessment. It would be beneficial, however, to have multiple years of data for such assessment as lake conditions vary annually due to variation in timing and magnitude of climatic events.

Based only on Carlson's TSI for total phosphorus, Lily Pond would be classified as mesotrophic. The other two lines of evidence for the TSI, Secchi disk transparency and chlorophyll indices, suggest a eutrophic status. Based on levels of three indicator parameters as well as the excessive rooted plant coverage and density, which is not accounted for in Carlson's TSI, Lily Pond would be classified as a eutrophic waterbody.

Table 23. Lily Pond Trophic State Index.

	Average Summer Value	Carlson TSI
SDT	0.8 m	63.2
Chl	19.2 ug/L	59.6
TP	30 ug/L	53.2

4.5 Evaluation of Water Treatment Impacts

Water quality in Lily Pond was found to be generally acceptable for a water supply. However, there are a few water quality variables that may increase the amount of treatment necessary to provide drinking water or may potentially cause undesirable by-products. These include color, total suspended solids, and total organic carbon content.

Color values, although not measured in this investigation, were measured at 45 to 60 units and were above the MCL. Excessive color increases the need for treatment. The source of color is derived primarily from naturally-occurring plant sources, including humic and tannic compounds. This is due to the large amount of forested and wetland areas found along tributaries and from the wetland located to the south of Lily Pond, which is an occasional source of water via Herring Brook. Color in Lily Pond, however, appears to be one factor in limiting algal growth through reduction of the photic zone (i.e., depth to which light penetrates). Reducing color in the pond may increase algal density, which may result in taste and odor problems in addition to increasing filter clogging potential. No effective means of reducing color in Lily Pond is feasible.

Total organic carbon (TOC) was measured in this investigation at two locations on the Pond and on the two tributaries. In-lake concentration ranged from 5.0 to 9.8 mg/L and tributary concentrations from 6.2 mg/L (Peppermint Brook) to 12.0 mg/L (Brass Kettle Brook). As discussed earlier, TOC in the Pond water is likely the result of natural processes such as microbially-mediated decay and breakdown of organic carbon, which is also the probable source of high color. Unfortunately disinfectants such as chlorine, used in water treatment processes, react with organic and inorganic material to form disinfectant by-products (DBPs) including total trihalomethanes (TTHM) which can be harmful to human health. This is not an uncommon concern for treated surface water supplies due to the ubiquitous nature of TOC in natural systems (Viessman and Hammer, 1985)

Reduction in the overall nutrient load to Lily Pond and/or reduction in the abundance of in-lake aquatic macrophytes would potentially reduce TOC concentration in the vicinity of the intake structure and therefore result in decreased DBPs. There is still likely to be significant DOC load based on wetland tributaries, however. Brass Kettle Brook is mostly forested land use and annual pulses of organic matter, due to direct deposition of autumnal leaf-fall to the stream as well as runoff through the leaf litter layer, would provide a significant loading of TOC to Lily Pond, regardless of any in-lake management.

The Lily Pond system has been historically productive, and has the morphometric features (i.e., shallow depth, organic substrate) to allow for extensive growth of macrophytes, and has nutrient loading values that have the potential to cause problems for the water supply. It is unlikely that even with the best watershed and in-lake management that in-lake TOC concentrations would be reduced such that no adverse effects to drinking water treatments would occur. However, there are management options available that can help mitigate the effect of a highly productive environment and are discussed in the feasibility portion of this document.

5.0 DIAGNOSTIC SUMMARY

Lily Pond is a natural water body classified as an outstanding resource water, Class A, Great Pond. It has been used as a water source for the Town of Cohasset since 1880. The lake is a small shallow lake approximately 51 acres with a mean and maximum depth of 5.7 and 8 feet, respectively. It is a kidney shaped waterbody with a bedrock outcrop island near the center of the pond. This pond has been shallow historically, with an average and maximum depth in 1912 reported as 5 and 7 feet respectively. Total water volume at full useable capacity is estimated to be approximately 102.2 million gallons.

The watershed of Lily Pond is approximately 1,603 acres. Much of this land is forested (64%). A substantial portion of this forested land is zoned residential and therefore has the potential for development but is protected as open space by a combination of State, natural preserves, and other similar land use restrictions. The high watershed:lake area ratio (31:1) suggests that in-lake water quality is highly dependent on the water quality of the watershed. Water quality from Peppermint Brook displays the characteristics of a highly developed sub-basin. Brass Kettle Brook has more desirable water quality, presumably due to the combination of an undeveloped watershed and the extensive wetland system providing natural attenuation of nutrients. These findings are based on limited sampling in the present program but are consistent with patterns noted by previous studies.

Hydrologically, Lily Pond is somewhat unique due to the non-tidal, bi-directional flow in the outlet stream. There are two tributaries that naturally flow to Lily Pond, Peppermint and Brass Kettle Brook. The outlet, Herring Brook, can also function as a tributary when the water level control structure along Bound Brook is allowed to hold back water. This structure reverses the flow of Herring Brook allowing water from the Aaron River Reservoir to enter Lily Pond. This reversal of flow provides the Town of Cohasset with an additional hydrologic input to its water supply if necessary. A simplified hydrologic budget was prepared based on contributions from the natural watershed without inputs from the Aaron River Reservoir. More data are necessary to determine the seasonal and annual input from the Aaron River Reservoir.

Observed nutrient levels in the pond are generally moderate and were below the level at which nuisance algal blooms are consistently a problem. However, these were limited observations confined to one season (late summer – fall) and may underestimate potential phosphorus availability in Lily Pond. The calculated phosphorus loading from several models indicated that Lily Pond is above the threshold “permissible” load and may be indicative of eutrophication.

This potential biological productivity is not fully indicated by the water column algal density as it is likely that the high density and biomass of rooted plants function as a significant sink for much of the nutrients entering Lily Pond. Watershed loading analysis suggests that a majority of the phosphorus potential draining to Lily Pond originates in the Brass Kettle Brook (57% of the TP watershed load) due to its size relative to other drainage basins. The absolute concentrations of nutrients entering the pond from this tributary are moderate (0.02 mg/L on average), however. While Peppermint Brook contributes less in terms of overall loading (29% of the TP watershed load), concentrations entering the pond are higher (0.05 mg/L on average). Peppermint Brook discharges through a small bordering vegetated wetland to the main lake basin providing minimal attenuation whereas the nutrient contribution of Brass Kettle Brook is mitigated by passage through much larger wetland systems. Additional data are necessary to obtain an assessment of the Aaron River Reservoir contribution that may play an important role in nutrient loading, especially on a seasonal basin when Brass Kettle and Peppermint Brook flows are minimal. These data reveal the importance of protecting the Brass Kettle Brook system from future development without appropriate safeguards, ensuring protection of water quality entering and leaving the Aaron River Reservoir, and utilizing best management practices to improve water quality from Peppermint Brook.

Sediments are primarily organic muck, with limited area of sand and rock found mostly along shoreline areas. Substantial in-lake organic deposits appear to be the result of long term plant production in the pond. Sediments have a high moisture content, with approximately 30% total solids on average. Hydrocarbons, PCBs, pesticides and metals were not detected or are present in the sediment at low levels; no ecological or human health concerns are indicated. Sediment disposal would not be restricted due to these characteristics.

The phytoplankton assemblage is relatively balanced and not particularly dense, but shows some potential to impair water potability especially with taste and odor forms. Algal growth appears to be limited at present by low light and phosphorus binding; competition with rooted plants may also be a factor. The zooplankton density and individuals size was small. Algal grazing and potential for fish food supply attributable to zooplankton are accordingly minimal.

The aquatic plant community of Lily Pond is dominated by an introduced species, fanwort (*Cabomba caroliniana)*, with two additional invasive species noted. Historically, this pond has had dense rooted aquatic vegetation, mostly in the form of watershield and pond lilies, however, it is not known when or how the exotic nuisance species arrived. Bladderwort (*Utricularia spp.*) is the second most dominant taxa. Rooted plant densities (> 75% coverage) were excessive over much of the lake bottom. Plant growth at this level causes multiple water use impairment and has resulted in blockage at the intake structure at the treatment plant in the past.

Assessment of the fish community was not performed, but data from other investigations suggest that the fish community is probably not thriving or balanced under these levels of macrophyte abundance. Rooted plant densities are high enough to adversely affect growth and limit spawning activities. Zooplankton density is also low, potentially providing only a limited food supply. Historically, Lily Pond was stocked with cold water fish (rainbow and brook trout) which probably did not flourish in this system, due to unfavorable natural water temperature and dissolved oxygen concentrations.

Based on an evaluation of physical, chemical, and biological characteristics, Lily Pond would be classified as eutrophic, particularly when its extensive rooted aquatic plant coverage and density is considered. Reductions in rooted plant density may not provide an improvement in trophic status, however. Nutrient concentrations are sufficient to fuel algal blooms and reducing rooted plant densities may free more nutrients and increase the likelihood of nuisance algal blooms. Therefore reduction in nutrient loads will be an important component in the overall pond management strategy.

Overall, Lily Pond appears to be in sub-optimal condition for its desired uses with marginal but acceptable water quality for drinking water. Modeling suggests that the phosphorus load exceeds the limit for optimal water clarity and quality, and is closer to the limit for more severe productivity problems. Algal blooms may be less frequent than predicted, however, probably as a consequence of light limitation and dense rooted plant growth. Rooted plant growths present the major impediment to optimal fish habitat and recreational uses, and are heavily dominated by a single exotic species with high nuisance potential. Major reductions in rooted aquatic plant growth, however, could result in algal productivity issues that may become more detrimental to the potable water usage. Management through the removal of soft sediment could control these plant growths at least on a localized basis, without increasing algal bloom frequency, near the intake structure. Substantial plant growth is probably unavoidable without pond management due to the expansive deposits of organic, nutrient-rich sediment and shallow water depths.

6.0 POND MANAGEMENT OBJECTIVES

Based on the original request for proposal, on subsequent meetings and discussions with the Board of Water Commissioners, and on ENSR's experience with the management of aquatic systems for water quality and potable water supply, the resultant objectives for the management of Lily Pond include:

- ***Protection of water supply quality and potability*** - Minimization of potential deleterious inputs from the watershed that could potentially compromise the potability or treatability of the raw water source for the Cohasset Water Treatment Plant, including nutrients, sediments, fecal bacteria (and associated pathogens), total trihalomethanes (TTHM) arising from interactions of chlorine with organic carbon, and anthropogenic compounds (e.g., metals, hydrocarbons, herbicides/pesticides). To improve water quality in Lily Pond, and to protect and enhance water potability, some degree of reduction in current loads and prevention of future undesirable loadings is desired.

- ***Potential enhancement of water supply operations*** – Enhancement of the ability of the Water Treatment Plant to freely draw water from the Pond via the present water intake is desired. A reduction in rooted aquatic vegetation biomass in the Pond is required. Replacement of exotic invasive species with a more balanced native assemblage, if feasible, is also preferable.

- ***Potential increase of water supply capacity*** - Creation of additional Pond volume by increasing the depth to allow increased reservoir storage capacity is desirable for long-term service of the Water Treatment Plant. This objective is also compatible with targeting a reduction in aquatic vegetation biomass.

- ***Enhance recreational/aesthetic aspects as feasible*** – The defined, limited recreational usage of the pond provides some value to the Town and local residents. As a secondary goal, any enhancement in recreational/aesthetic value that can be combined with addressing the primary three objectives listed above is desirable.

Continuing discussion of management objectives among the Board of Commissioners, town agencies, and interested parties to more clearly define goals and priorities is encouraged. The above objectives are the result of discussions held to date in which ENSR has been involved; additional objectives are certainly possible, and no absolute priority order has been established or intended in this report. The combination of watershed management, rooted plant control, increased storage capacity, and recreational enhancement is not mutually exclusive. There is considerable overlap in the suite of methods available to potentially achieve these objectives, although it is possible to address them either collectively or independently.

7.0 POND MANAGEMENT OPTIONS

The management options for Lily Pond can be broken down into two broad categories, watershed management and in-lake management. Applicable watershed management options will focus on pollutant loading in general, with particular emphasis on the control of watershed loading of nutrients, bacteria, toxics, and fine sediment additions. Most techniques are covered in detail in several watershed management manuals (e.g., Schueler 1987, Dennis et al. 1989, Schueler et al. 1992, Clayton and Schueler 1996), but are summarized here for the purpose of evaluating applicability to the Lily Pond watershed. In-lake management options will focus on rooted plant control, in-pond volume enhancement, and future monitoring of water quality. The most detailed reference on lake management/restoration methods is by Cooke et al. (1993), with additional useful information available in Baker et al. (1993), Hoyer and Canfield (1997), NYSDEC/FOLA (1990), McComas (1993), Westerdahl and Getsinger (1988a, 1988b), and WDNR (1989). Considerable information on control and management of nuisance macrophytes will be published in the Generic Environmental Impact Report (GEIR) for control of Eutrophication and Nuisance Aquatic Vegetation in Massachusetts. (Mattson et al., 2003). [Note: this report is currently published only as a draft document].

7.1 Watershed Management Options

Watershed management encompasses a wide variety of options dealing with pollutant reduction, best management practices (BMPs), land use controls, open space acquisition, watershed stakeholder home environmental practices, etc. Lily Pond watershed concerns and potential management options with regard to water potability have been recently addressed in the Surface Water Supply Protection Plan for Lily Pond and Aaron River Reservoir (SWSPP) by Norfolk Ram Group completed in June 2002. The purpose of the SWSPP was to compile and describe relevant watershed information with the aim and to identify, prevent, eliminate, and control actual or potential sources of contamination that could negatively impact the quality of the surface-based drinking water supply from Lily Pond and Aaron River Reservoir. Impacts from non-point source pollution were identified as the most immediate threat to water quality in these waterbodies. Based on these findings, a series of recommendations and prioritized action items were identified for improvement of existing water quality in Lily Pond and enhancement for present and future protection of the source drinking water (Norfolk Ram Group, 2002). Accordingly, most of the SWPP findings and recommendations are equally relevant and applicable to this present Lily Pond Limnology and Waters Edge Study.

7.1.1 Source Reduction

Source reduction refers to measures aimed at decreasing or eliminating existing or future pollutant loads to Lily Pond that emanate in the watershed. Some source reduction technique were eliminated outright as not especially appropriate for the Lily Pond watershed due to its characteristics (e.g., agricultural best management practices, streambank and buffer erosion control). Source reduction measures that are relevant for the Lily Pond watershed include stormwater management, on-site wastewater management, zoning and land use management, open space acquisition, watershed resident environmental practices, and management of settling basin residues.

7.1.1.1 Stormwater Management

Untreated stormwater runoff was identified by the SWSPP as one of the most immediate concerns to water quality in Lily Pond (Norfolk Ram Group, 2002). Untreated stormwater contains many roadway-associated pollutants including oils and grease, fuels and hydrocarbons, heavy metals, and road salts. In addition, stormwater runoff can often contains high amounts of nutrients (nitrogen and phosphorus) from fertilizers and animal wastes, pesticides and herbicides from lawn chemicals, and bacteria. Stormwater often contains a high total suspended solid load and transports soil and silt into the lake where deposition occurs. Finally, stormwater drainage system can be the conveyance for accidental spills and releases of hazardous materials due to traffic accidents or human error.

The SWSPP indicated that Lily Pond was particularly susceptible to stormwater runoff generated along nearby stretches of King Street, Pond Street, and the portions of Route 3A in the vicinity of Peppermint Brook. The results of the diagnostic portion of this study concur with this concern. Peppermint Brook tributary (sampling station PB-1) routinely exhibited the most elevated concentrations of nutrients (especially nitrate and total phosphorus), chloride, specific conductance, and fecal coliform among all sampling stations. These results are consistent with urban storm runoff from developed land use in the Peppermint Brook sub-watershed and Route 3A corridor which are in closely associated proximity of roadways to the Brook. Of additional concern is the relatively short distance from the confluence of Peppermint Brook with Lily Pond to the Water Treatment Plant intakes, since this increases the probability that the raw water source water quality could be compromised. This relationship increases the priority for this tributary to be closely monitored and for appropriate stormwater BMPs installed as quickly as feasible. Location of a stormwater treatment site downgradient of Route 3A is recommended since this would increase the effectiveness of containment and remediation of any spills that occur on that roadway, prior to their entry into Lily Pond.

To that end, the Town of Cohasset has already taken several important preliminary steps, partly due to the SWSPP process and partly due to the requirements of the impending Phase II Stormwater Management Program compliance deadline (March 2003). By this date, the Town must submit the implementation plan for identifying and treating stormwater in Lily Pond and elsewhere in Cohasset. One important step is the inventorying and mapping of catch basins along King Street, Pond Street, and Route 3A (see Appendix B, SWSPP). This will be a critical piece of information for responding successfully and containing a roadway spill or release. In addition, the Cohasset Board of Health has developed the Cohasset Stormwater Management Plan and Control Strategies (Board of Heath, 2000a). This plan provides a mechanism for identifying critical storm drain systems and installation of treatment consistent with MA DEP Best Management Practices (BMPs). Consistent with these initiatives, the Town of Cohasset has been actively seeking grants regarding stormwater mapping and BMP Implementation, particularly in the Peppermint Brook and Zone A tributary areas (Bartlett, pers. comm.)

Installation of stormwater BMPs will provide Lily Pond an improved measure of protection from stormwater inputs. However, it should be realized that current MA DEP Stormwater BMPs only indirectly treat stormwater for water quality. The most relevant stormwater BMP target criterion is reduction of influent TSS by 80%. While this reduction is useful in perhaps blocking bulk transport of sediment into the Pond, it also allows the remaining 20% of the particulate phase and 100% of the dissolved fraction of the stormwater to enter the pond. Many of the problematic pollutants are associated with the particulate phase (e.g., heavy metals, pesticides), but such pollutants as chloride, nitrate, and dissolved phosphorus are not effectively retained by BMPs. Thus, complete compliance with BMPs will not eliminate some of the stormwater loads from entering the Pond and additional measures might be considered.

7.1.1.2 On-Site Waste Water Management

A properly functioning on-site waste disposal system (e.g., septic system) can be an effective means of reducing pollutant loading to an aquatic ecosystem. On the other hand, an ineffective or failing system poses the risk of allowing nutrients and bacterial to be improperly treated and released to the environment. Of particular concern are those systems where septic effluent is breaking-out above ground and is transported to the lake or a tributary during storm events. Fortunately, the residential areas immediately around Lily Pond are all sewered, with only a small proportion of residences in the watershed of Lily Pond serviced by on-site waste disposal systems.

An inventory of the number of septic systems was not conducted as part of the Pond study. However, available information provides an approximate estimate of the relative numbers, their location, and their likely importance in determining water quality in Lily Pond. According to the SWSPP (Norfolk Ram Group, 2002), there are 5 listed septic systems installed prior to the Title V in 1978, 19 systems installed prior to the Title V enhanced requirements (1995), and 2 systems installed after 1995 in Zone A within the Town of Cohasset (26 systems total in Zone A of Cohasset). Zone A includes the 400’ area surrounding Lily Pond, portions of the 400’ area surrounding Aaron River Reservoir, 200’ surrounding Aaron River, 200’ surrounding Brass Kettle Brook, and 200’ surrounding Peppermint Brook. Most of these areas served by septic systems are clustered to the northeast of the Pond, within the Peppermint Brook sub-watershed basin. However, little of that watershed between Route 3A and the Pond is sewered (Tom Keefe, pers. comm).

Septic system influence, in terms of phosphorus loading, is much less likely to have impacts to surface waters located further than 100’ from the source. Phosphorus becomes bound in soil and utilized by plants readily. While there is no evidence to suggest that any major contaminant inputs are attributable to groundwater there, it is likely that a small portion of the pollution load of Peppermint Brook may be due to septic system loads (e.g., nitrate), particularly from pre-Title V systems. The number of potential septic systems, their distance from the Pond, and the intervening wetland areas south of Route 3A argue against this from being a major driver of water quality in Peppermint Brook.

Maintenance, inspection, and eventual up-grades of on-site waste disposal systems is the recommended management technique for the Lily Pond watershed. These issues are being currently addressed by the Cohasset Board of Health’s Cohasset On-Site Wastewater Management Plan (Board of Heath, 2000b). This innovative voluntary plan conveys important services to Cohasset homeowners whose septic systems pass Title V requirements. These services include 20-year loans for system upgrades for systems which fail at a future date, Title V inspections, annual evaluations and regular maintenance services, including pumping. This provides a strong incentive for septic system owners to come into compliance with Title V. Adherence to the goals and objectives of the Cohasset On-Site Wastewater Management Plan will be conducive to protection and enhancement of water quality in Lily Pond.

7.1.1.3 Water Treatment Settling Lagoon Inputs

The present configuration of the Cohasset Water Treatment Plant includes two lagoons used for the storage and treatment of settled water treatment residuals (“sludge”) and filter backwash water from the water purification process. These residuals typically contain a large proportion of the natural constituents in the raw source water along with a small amount of chemical additives (Flocculent 279. George Hawksley, pers. comm.) used to aid the flocculation and settling process. The supernatant of these settling lagoons drains directly to the Pond via an overland flow channel as described by the Water Department’s application for a National Pollution Discharge Elimination System (NPDES) permit. The dewatering operations in the lagoons have been noted as less than optimal due to the failure of the concrete and groundwater seepage through the cracks (Weston and Sampson Engineers, 2000). This has resulted in the accumulation of sludge in the lagoons, which needs to be periodically removed for the lagoons to be effective. [Note: the current amount of sludge contained by the lagoons was not determined nor was the cost of its removal]. A recent facility Capital Improvement Program (CIP) recommended various improvements and upgrades (Weston and Sampson Engineers, 2000).

In the area of the lagoon discharge, a delta of fine residuals has accumulated along the shoreline. The approximate length of this convex semi-circular delta is from 150-180 ft and extends about 50-60 ft into the Pond. Due to the aluminum sulfate (alum) content of the flocculent, these residuals have a distinctive appearance and crustose surface similar to clayey materials. The residual outflow delta has been colonized by *Phragmites* reeds in some areas. While the chemical quality of the supernatant and residual is not injurious to the Pond's water quality, the settled material represents some infilling of the Pond basin and a reduction in the storage capacity of the Pond. It is recommended that the Water Department consider additional detention or treatment of the supernatant prior to its discharge to the Pond to reduce the volume of suspended material that is settling out at the Pond shoreline. The sludge in the lagoons should be properly disposed of and, at the same time, the Water Department should consider reduction or elimination of the existing delta.

7.1.1.4 Zoning and Land Use Planning

This is a very important element in controlling watershed inputs to aquatic resources. A strong relationship exists between land use type and pollutant generation, with developed lands typically generating greater pollutant loads than non-developed lands. Lily Pond is extremely fortunate in having a very large proportion of the watershed protected by municipal zoning, open space and protected areas. In addition, Cohasset has a Water Resource Protection District that overlays all Cohasset land within the watershed and which entails additional land use restrictions and regulations regarding the use and storage of oil and hazardous materials (OHM). A good summary of the prohibited uses in the Water Resource Protection Districts is provided in Table 7-1 of the SWSPP (Norfolk Ram Group, 2002).

Significant parcels in Cohasset that are designated as open space in perpetuity or with a conservation restriction within the Lily Pond watershed include: the Wompatuck State Forest (operated by the Massachusetts Department of Environmental Management), the Trustee of Reservations' Whitney and Thayer Woods, and a number of smaller properties including the Barbara Churchill Conservation Areas, the Campbell Meadow, and the Andrus property. The Charlie Pape Reservation and Cohasset Water Department lands abutting the northwest shore of Lily Pond are currently not available for development. In addition, approximately 70% of the undeveloped land is wetland or non-accessible and cannot be developed, leaving approximately 600 acres of developable land. (Norfolk Ram Group, 2002). There are also similar water resource protection districts in Norwell and Scituate that protect land in the combined Lily Pond/Aaron Reservoir watershed and the Hingham portion of the Lily Pond watershed is largely open space (Norfolk Ram Group, 2002).

Further preservation of undeveloped land in the Lily Pond watershed is highly recommended, with particular emphasis on preserving areas of land that form buffer zones along the Pond tributaries or within the sub-watershed basins. The actual portion of watershed land that is available for preservation is not great, however, because of earlier land protection activities. The land draining to Brass Kettle Brook is largely protected by inclusion in Wompatuck State Park and the Whitney and Thayer Woods. Some of the watershed does contain industrially zoned areas, however, and the Cohasset Heights Landfill, which has been the subject of past investigations (i.e., CDM, 1984), a 2002 Cohasset Conservation Commission NOI, and active monitoring of landfill leachate and local groundwater. It should be noted that these groundwater pollutants pose a potential risk to the potability of Lily Pond surface water, but they are unlikely to result in adverse ecological effects in the Pond ecosystem.

In contrast to Brass Kettle Brook watershed, little open space exists in the more developed Peppermint Brook watershed. Since this sub-watershed accounts for a significant proportion of the nutrients and salts entering Lily Pond, control of development or acquisition of additional open space, if available, is recommended. In addition to the Brass Kettle Brook and Peppermint Brook watersheds, there is a small portion of the watershed that drains directly into Lily Pond (Figure 2). This area should also be considered a high priority for controlling inputs. In comparison to the other tributaries, however, the contaminant load from direct drainage is the smallest of the three basins due to its smaller area and lack of a flowing tributary.

7.1.1.5 Open Space Acquisition

Land use conversion involves purchasing properties that do or could contribute excessive amounts of pollutants and converting these properties to less deleterious land uses. For example, the Town of Cohasset might decide to purchase developable property and convert the land to open space, thus reducing potential pollutant generation from this parcel of land. This can be a very expensive proposition, but it may be practical for targeting specific properties that by their proximity to Pond or tributary or the nature of potential future use are more likely to generate pollutants which eventually discharge into Lily Pond.

In the case of Lily Pond, the Cohasset Water Department has been actively pursuing a policy of protection of the water supply by acquiring land or obtaining a deed restriction. This has also including the taking of land by eminent domain, in some cases. The Water Department has also identified and inventoried all developable land within Zone A in Cohasset with the intent of either purchasing or protection (by deed restriction) some of these properties in the next 3-5 years if they become available on the market (SWSPP, Norfolk Ram Group, 2002). This policy and action items will conserve and/or enhance the water quality in Lily Pond in the long-term and should be vigorously pursued.

7.1.1.6 Watershed Resident Environmental Practices

Resident environmental practices involve changing small-scale but important activities of watershed residents to improve water quality. Such changes may include conversion to non-phosphate detergents (already the case in MA), elimination of garbage grinders, limits on lawn fertilization, and eliminating illegal dumping in roadways and watercourses. Since most residences in close proximity to the Pond are sewered, conversion to non-phosphorus detergents and elimination of garbage grinders, will probably contribute a very small improvement in watershed loadings to the Pond (<<1%), but should be a consistent practice across the watershed. Inspection of the Pond shoreline and 300ft buffer zone indicate few instances where shoreline residences have an abutting maintained lawn. Most residences have a well-vegetated buffer zone of vegetation between them and the Pond. In a few instances, maintained lawns were abutting wetlands/swales that apparently drain to Lily Pond. The same precautions should also be practiced for these and all lawn areas within the Zone A. (i.e., the limited use or prohibition of quick-release fertilizers and lawn herbicide/pesticide treatments).

Home environmental practices can be brought about in two principal ways, through public education and/or the implementation of local bylaws and bans. Education is a critical first step and should precede any attempt at regulation. The most applicable modifications for Lily Pond would be adherence to a non-fertilizer buffer zone within 100 ft of the Pond and the use of slow-release fertilizers in the remainder of residences within Zone A. [Note: In January 2002, the Water Commission proposed revisions to the Zone A provisions including restrictions on the application in Zone A of quick release fertilizers or similar nutrient-containing soil additives that contribute disproportionately to nutrient runoff into Lily Pond and/or its tributaries].

Public education can be accomplished by mailing an informative brochure on watershed management to all residents in the watershed, through the use of video programs on local access television, or by holding public meetings for watershed residents. Public education relies heavily upon cooperation from residents and other watershed stakeholders, and is not likely to result in major improvements in water quality by itself. However, some level of improvement has been noted in other studies and the education process sets the stage for community involvement and cooperation. The importance of protecting their major water supply should be obvious to most Town residents. Public education is a recommended management technique for Lily Pond. Examples of educational fact sheets, brochures, and pamphlets that could be adopted for use in the Lily Pond watershed are provided in Appendix D.

7.1.2 Transport Mitigation

Transport mitigation refers to a variety of means by which pollutants generated in the watershed can be prevented from entering Lily Pond due to upgradient detention and treatment. These measures are often used when an undesirable land use or pollutant source, for whatever reason, cannot be directly reduced or eliminated. These measures include a number of watershed BMPs which can be used to reduce nutrients and sediments from entering the Pond. Such mitigation can encompass a large suite of options, ranging from those done on an individual houselots (e.g., rain barrels to detain roof runoff, small areas ("raingardens") to direct local runoff for detention and recharge) to more extensive treatment options that treat larger volumes of stormwater (e.g., wetland detention pond). For example, some of the larger options are likely to be considered for use in the treatment of stormwater arising from the Peppermint Brook system prior to entry in the Pond (e.g. treatment of runoff from Route 3A).

7.1.2.1 Buffer Strips

Buffer strips (or vegetated filter strips or grassed buffers) are areas of grass or other dense vegetation that separate a waterway from an intensive land use. These vegetated strips allow overland flow to pass through vegetation that filters out some percentage of the particulates and decreases the velocity of the storm water. Particulate settling and infiltration of water often occurs as the storm water passes through the vegetation. Buffer strips need to be at least 25 ft wide before any appreciable benefit is derived, and superior removal requires a width >100 ft. This can create land use conflicts, but creative planting and use of buffer strips can be a low cost, low impact means to minimize inputs to the aquatic environment.

This management technique is recommended for the Lily Pond watershed. According to the SWSPP (Norfolk Ram Group, 2002), all forestry practices at Wompatuck State Park and the Whitney and Thayer Woods are in accordance with 304 CMR 11.000 "Forest Cutting Practices" (Norfolk Ram Group, 2002) and are considered adequately regulated. Application is therefore likely to be limited to new development and cutting along the tributaries, but any retrofitting of existing developed areas could be of great benefit.

7.1.2.2 Catch Basins with Sumps and Hoods

Deep sump catch basins equipped with hooded outlets can be installed as part of a storm water conveyance system. Deep sumps provide capacity for sediment accumulation and hooded outlets prevent discharge of floatables (including non-aqueous phase hydrocarbons). Catch basins are usually installed as pre-treatment for other BMP's and are not generally considered adequate storm water treatment as a single stand-alone system. Volume and outlet configuration are key features which maximize particle capture, but it is rare that more than the coarsest fraction of the sediment/pollutant load is removed by these devices. This is a recommended management technique for the Lily Pond watershed, but is not expected to be sufficient by itself to make an appreciable difference. Rather, this will be an important pre-treatment mechanism for infiltration or detention strategies.

7.1.2.3 Oil/Grit Chambers

A number of oil/grit chamber designs are currently on the market. These self-contained units include an initial settling chamber for sediment removal, typically have hooded internal passages to remove oil and other floatables, and often incorporate some form of outlet pool to control exit velocity. Several rely on a vortex design to enhance sediment removal (e.g., Vortechnics, Storm Defender). Such systems are most applicable as pre-treatment for other BMPs, and are generally well suited as retrofits for relatively small areas in developed watersheds. Installing these devices as off-line systems may enhance pollutant removal, but their more common use as on-line pre-treatment devices can be very beneficial. This is a recommended management technique for the Lily Pond watershed given the threat that oils and other hydrocarbons could pose to water potability in the infiltration technologies.

7.1.2.4 Street Sweeping/Catch Basin Cleaning

Removal of pollutants before they are washed into Lily Pond could be accomplished by frequent street sweeping and catch basin cleaning. Both techniques provide only limited benefits by themselves, but could be effective tools in combination with other Best Management Practices. Truly effective street sweeping is accomplished with vacuum equipment, which costs in excess of $100,000/vehicular unit. Maintenance costs can also be substantial. Catch basin cleaning should be a semi-annual activity, but rarely is; restoration of catch basin capacity is essential to the proper function of drainage systems, and costs about $50/catch basin per year when basins are cleaned on a bulk basis. Street sweeping and catch basin cleaning are recommended management techniques for the Lily Pond watershed, as part of normal road maintenance and storm water drainage system management, but neither can be counted on as a primary pollutant control technique. Based on the proximity to Route 3A and the currently impacted water quality, the Peppermint Brook watershed should be prioritized for the street sweeping/catch basin cleaning.

7.1.2.5 Created Wetlands

Created wetlands are shallow pools that create conditions suitable for the growth of marsh or wetland plants. These systems maximize pollutant removal through vegetative filtration, nutrient uptake, soil binding, bacterial decomposition, and enhanced settling. Alternatively, a treatment system may combine created wetlands with detention ponds. Created wetlands are suitable for on-line or off-line treatment (assuming maintenance of adequate hydrology with off-line systems to support the wetland). Natural wetlands already fulfill this function in many portions of the Lily Pond watershed, but creation or enhancement of a small wetland could yield improvement in association with treatment of water in Peppermint Brook with regard to other options (see Section 7.1.2.7). Further site investigation would be required to further the feasibility of this option.

7.1.2.6 Detention

Detention ponds are essentially basins that are designed to hold a portion of storm water runoff for at least 12-24 hours. Pollutant removal is accomplished mainly through settling and biological uptake. Wet detention ponds are more effective than dry detention ponds as the latter have a greater risk of sediment re-suspension and generally do not provide adequate soluble pollutant removal. Although effective, the land requirement is typically large; the area should be at least 2% of the drainage area it serves, and preferably as much as 10% of that area. This technique is very useful in association with new development, and might be used in some retrofit scenarios, but it probably a difficult treatment option in the developed Peppermint Brook watershed due to space considerations.

7.1.2.7 Chemical Treatment

In-stream chemical treatment involves the dosing of stream flows with alum or other coagulants to bind phosphorus and coagulate sediments to promote settling. During this process, phosphorus permanently complexes with aluminum or another binding agent, rendering it unavailable for biological uptake by algae. This in-stream treatment technology has been successfully applied in other regions, especially Florida. A pilot application was performed on the primary tributary to a drinking water supply reservoir in Ohio, and another was conducted for the main inlet of a lake in Wellesley, MA, both with moderate success. The primary application of this technology has been for phosphorus removal where other BMPs were not viable. Phosphorus removal rates ranging from 50-95% have been reported. Removal rates ranging from 50-99% have also been documented for other pollutants such as suspended solids, nitrogen, color, and bacteria.

While expensive, this technique may be applicable to Lily Pond for treatment of stormwater flows in Peppermint Brook, which has been shown to be the watershed of greatest water quality concern and most affected by stormwater. The advantage of this approach is that it treats the stream as it directly enters the Pond, thus it is a direct reduction to the Pond nutrient budget (as opposed to the less quantifiable effect of stormwater treatments well upstream in the watershed). A dosing station would be needed to inject coagulant near the discharge of Peppermint Brook at King Street. Retention of the settled material would be managed through construction of a small detention or enhanced wetlands area. This method is costly and requires considerable maintenance, but the waterbody and application point in question is readily adjacent to the Water. In addition, the method could be reserved to treat storm flows only during a portion of the year (e.g., May – September) to reduce the impact of the nutrients and bacteria during the pond’s flora’s growing season and when dilution capacity is likely to be reduced. While expensive, this method might be an alternative technique if retrofitting stormwater treatment in the watershed is not feasible. This method was retained for further consideration and costing (see Section 8.1.2).

7.1.3 Summary of Watershed Management Options

Based on the consideration and discussion of the watershed management options above, the following options for source reduction are recommended but are considered adequately treated by the current programs and policies of the Town of Cohasset or through the Phase II Stormwater Management Program: storm water planning (inventory and planning), on-site waste water management, zoning and planning, and open space acquisition. For these options, the Town and Water Commission merely need to continue to administer and adhere to existing programs and bylaws. Watershed source inputs which needed to further addressed include: the Water Treatment Plant settling lagoons and watershed residential lawn care practices. The transport mitigation measures look to treat and improve stormwater during its passage from source to Pond. Virtually all may be applicable to the Peppermint Brook sub-watershed, with the site-specific selection of the most appropriate option basically dependent on land availability. Chemical treatment may be considered as a potential “end-of-pipe” approach to treating Peppermint Brook during storm events but needs to be further evaluated.

7.2 In-Lake Management Options - Rooted Plant Control

Currently, the most dominant ecological symptom of the general eutrophication of Lily Pond is the extremely dense coverage and biomass of rooted aquatic macrophytes. This section provides a short introduction into the general characteristics of macrophytes prior to a review of the major control strategies.

Macrophytes (vascular plants and visible algal mats) are generally grouped into classes called emergents (represented by pickerelweed and cattails), floating-leaved (water chestnut and water lilies), and submergents (pondweeds, milfoil, fanwort and waterweed), plus mats of filamentous algae. Understanding the factors that control plant growth is the first step in controlling weeds. Macrophytes reproduce by producing flowers and seeds and/or by asexual propagation from various fragments and shoots extending from roots. The primary means of reproduction is an extremely important feature of a plant, and will greatly affect the applicability of control methods.

Growth rates of macrophytes, especially exotic (i.e., non-native), nuisance species like fanwort and milfoil, can be very high, but is a function of suitable substrate and available light. Submergent plants will grow profusely only where underwater illumination is sufficient. Highly turbid lakes and reservoirs are unlikely to have dense beds of submerged plants. Significant reductions in algal blooms can also enhance light penetration and allow weeds to grow more extensively and densely. High silt loads to a lake can create a favorable plant substrate, but the silt loading may also create severe turbidity that limits growth. Rock, gravel and coarse sand provide limited rooting opportunity, while finer sands, silts and organic mucks can support substantial plant growths. Steep-sided lakes support a much smaller plant community as a consequence of both peripheral substrate and light limitations. A few plants, including water hyacinth, water lettuce, duckweed, and watermeal, can float on the surface with no roots in the sediment, nearly eliminating substrate and light as key control factors.

Most macrophytes obtain most of their nutrition via roots that extend into the sediment. This is an important ecological feature, as they can therefore be abundant in lakes in which nutrient concentrations in the water column have been reduced through watershed management or in-lake measures. When the sediments are either highly organic (very loose mucks) or inorganic (rock to coarse sand), macrophyte growth may be poor because it is more difficult for roots to take hold and to obtain nutrients in these sediment types. In these two extremes, emergent plants may replace submergents in shallow water because their more extensive root systems are better adapted to these conditions.

Setting goals for rooted plant control is a critical planning step and the choice of management technique(s) will be highly dependent upon those goals. A certain amount of plant growth is an ecological necessity in most lakes. Where fishing is the primary objective, substantial littoral bottom coverage is desirable, with some vertical and horizontal structure created by different species of plants to enhance the habitat for different fish species or life stages. For swimming purposes, having no macrophytes seems desirable from a safety perspective, but a low, dense cover in shallow lakes with silty bottoms can minimize turbidity, another safety concern.

For purposes of a drinking water supply, the macrophytes indirectly affect water quality due to the reduction of turbidity by stabilization of the bottom and dampening of wave energy or reduction in algal biomass due to competition for nutrients, However, it can also adversely impact the water supply by increasing the particulate organic carbon (POC) content of the water (i.e., dead vegetative fragments, suspended bottom materials, or similar floating organic detritus) by fragmentation and senescence, physically impairing water intakes, and leading to low dissolved oxygen in the bottom waters, which may increase anoxic release of phosphorus from the sediments. This latter situation is the case of the macrophytes in Lily Pond.

Perhaps the simplest axiom for plant management is that if light penetrates to the bottom and the substrate is not rock or cobble, plants will grow. A program intended to eliminate all plants is both unnatural and maintenance intensive, if possible at all. A program to structure the plant community to meet clear goals in an ecologically and ethically sound manner is more appropriate, although potentially still quite expensive.

Table 24 provides an overview of the techniques used to control rooted plants, with notes on the mode of action, advantages, and disadvantages of each technique. Additional details are provided in narrative form.

7.2.1 Benthic Barriers

The use of benthic barriers, or bottom covers, is predicated upon the principles that rooted plants require light and can not grow through physical barriers. Applications of clay, silt, sand, and gravel have been used for many years, although plants often root in these covers eventually, and current environmental regulations make it difficult to gain approval for such fill deposition. An exception may exist in the reverse layering technique (KVA, 1991), in which sand is pumped from underneath a muck or silt layer and deposited as a new layer on top of the muck or silt. This is technically a re-organizing of the sediments, not new filling. Although expensive on a large scale and not applicable where the muck is not underlain by suitable materials (as is the case for most of Lily Pond), this technique restores the natural lake bottom of some previous time without sediment removal.

Artificial sediment covering materials, including polyethylene, polypropylene, fiberglass, and nylon, have been developed over the last three decades. A variety of solid and porous forms have been used. Manufactured benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants.

In theory, benthic barriers should be a highly effective plant control technique, at least on a localized, area-selective scale. In practice, however, there have been many difficulties in the deployment and maintenance of benthic barriers, limiting their utility in the broad range of field conditions. Benthic barriers can be effectively used in small areas such as dock spaces and swimming beaches to completely terminate plant growth. The creation of access lanes and structural habitat diversity is also practical. Large areas are not often treated, however, because the cost of materials and application is high and maintenance can be problematic.

Benthic barrier problems of prime concern include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Additionally, benthic barriers are non-selective, killing all plants over which they are applied. Oxygen depression and related chemical changes under the barrier result in reductions in the density and diversity of the benthic invertebrate community, but recovery is rapid once the barrier is removed. One final problem is the tendency of products to come and go without much stability in the market. Few of the barrier materials on the market at any time continue to be available for more than 5 to 10 years; most need to be made in bulk to keep costs down, yet cost remains high enough to hinder demand and reduce bulk use.

Table 24. Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
1) Benthic barriers	♦ Mat of variable composition laid on bottom of target area, preventing plant growth ♦ Can cover area for as little as several months or permanently ♦ Maintenance improves effectiveness ♦ Not often intended for use in large areas, usually applied around docks, in boating lanes, and in swimming areas	♦ Highly flexible control ♦ Reduces turbidity from soft bottoms ♦ Can cover undesirable substrate ♦ Can improve fish habitat by creating edge effects	♦ May cause anoxia at sediment-water interface ♦ May limit benthic invertebrates ♦ Non-selective interference with plants in target area ♦ May inhibit spawning/feeding by some fish species
1.a) Porous or loose-weave synthetic materials	♦ Laid on bottom and usually anchored by sparse weights or stakes ♦ Removed and cleaned or flipped and repositioned at least once per year for maximum effectiveness	♦ Allows some escape of gases which may build up underneath ♦ Panels may be flipped in place or removed for relatively easy cleaning or repositioning	♦ Allows some growth through pores ♦ Gas may still build up underneath in some cases, lifting barrier from bottom
1.b) Non-porous or sheet synthetic materials	♦ Laid on bottom and anchored by many stakes, anchors or weights, or by layer of sand ♦ Not typically removed, but may be swept or "blown" clean periodically	♦ Prevents all plant growth until buried by sediment ♦ Minimizes interaction of sediment and water column	♦ Gas build up may cause barrier to float upwards ♦ Strong anchoring makes removal difficult and can hinder maintenance

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
1.c) Sediments of a desirable composition	♦ Sediments may be added on top of existing sediments or plants. ♦ Use of sand or clay can limit plant growths and alter sediment-water interactions. ♦ Sediments can be applied from the surface or suction dredged from below muck layer (reverse layering technique)	♦ Plant biomass can be buried ♦ Seed banks can be buried deeper ♦ Sediment can be made less hospitable to plant growths ♦ Nutrient release from sediments may be reduced ♦ Surface sediment can be made more appealing to human users ♦ Reverse layering requires no addition or removal of sediment	♦ Lake depth may decline ♦ Sediments may sink into or mix with underlying muck ♦ Permitting for added sediment may be difficult ♦ Addition of sediment may cause initial turbidity increase ♦ New sediment may contain nutrients or other contaminants ♦ Generally too expensive for large scale application
2) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering/disposal ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Plants and seed beds are removed and re-growth can be limited by light and/or substrate limitation	♦ Plant removal with some flexibility ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging ♦ Usually very expensive

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
2.a) "Dry" excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment	♦ Eliminates most aquatic biota unless a portion left undrained ♦ Eliminates lake use during dredging
2.b) "Wet" excavation	♦ Lake level may be lowered, but sediments not substantially dewatered ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve most aquatic biota	♦ Usually creates extreme turbidity ♦ Tends to result in sediment deposition in surrounding area ♦ Normally requires intermediate containment area to dry sediments prior to hauling ♦ May cause severe disruption of ecological function ♦ Usually eliminates most lake uses during dredging
2.c) Hydraulic removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and limits impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle extremely coarse or debris-laden materials ♦ Requires sophisticated and more expensive containment area ♦ Requires overflow discharge from containment area

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
3) Dyes and surface covers	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting plant growth ♦ Dyes remain in solution until washed out of system. ♦ Opaque sheet material applied to water surface	♦ Light limit on plant growth without high turbidity or great depth ♦ May achieve some control of algae as well ♦ May achieve some selectivity for species tolerant of low light	♦ May not control peripheral or shallow water rooted plants ♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water ♦ Covers inhibit gas exchange with atmosphere
4) Mechanical removal	♦ Plants reduced by mechanical means, possibly with disturbance of soils ♦ Collected plants may be placed on shore for composting or other disposal ♦ Wide range of techniques employed, from manual to highly mechanized ♦ Application once or twice per year usually needed	♦ Highly flexible control ♦ May remove other debris ♦ Can balance habitat and recreational needs	♦ Possible impacts on aquatic fauna ♦ Non-selective removal of plants in treated area ♦ Possible spread of undesirable species by fragmentation ♦ Possible generation of turbidity
4.a) Hand pulling	♦ Plants uprooted by hand (“weeding”) and preferably removed	♦ Highly selective technique	♦ Labor intensive
4.b) Cutting (without collection)	♦ Plants cut in place above roots without being harvested	♦ Generally efficient and less expensive than complete harvesting	♦ Leaves root systems and part of plant for re-growth ♦ Leaves cut vegetation to decay or to re-root ♦ Not selective within applied area

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
4.c) Harvesting (with collection)	♦ Plants cut at depth of 2-10 ft and collected for removal from lake	♦ Allows plant removal on greater scale	♦ Limited depth of operation ♦ Usually leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Not selective within applied area ♦ More expensive than cutting
4.d) Rototilling	♦ Plants, root systems, and surrounding sediment disturbed with mechanical blades	♦ Can thoroughly disrupt entire plant	♦ Usually leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Not selective within applied area ♦ Creates substantial turbidity ♦ More expensive than harvesting
4.e) Hydroraking	♦ Plants, root systems and surrounding sediment and debris disturbed with mechanical rake, part of material usually collected and removed from lake	♦ Can thoroughly disrupt entire plant ♦ Also allows removal of stumps or other obstructions	♦ Usually leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Not selective within applied area ♦ Creates substantial turbidity ♦ More expensive than harvesting

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
5) Water level control	♦ Lowering or raising the water level to create an inhospitable environment for some or all aquatic plants ♦ Disrupts plant life cycle by dessication, freezing, or light limitation	♦ Requires only outlet control to affect large area ♦ Provides widespread control in increments of water depth ♦ Complements certain other techniques (dredging, flushing)	♦ Potential issues with water supply ♦ Potential issues with flooding ♦ Potential impacts to non-target flora and fauna
5.a) Drawdown	♦ Lowering of water over winter period allows desiccation, freezing, and physical disruption of plants, roots and seed beds ♦ Timing and duration of exposure and degree of dewatering are critical aspects ♦ Variable species tolerance to drawdown; emergent species and seed-bearers are less affected ♦ Most effective on annual to once/3 yr. basis	♦ Control with some flexibility ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ Impacts vegetative propagation species with limited impact to seed producing populations	♦ Possible impacts on contiguous emergent wetlands ♦ Possible effects on overwintering reptiles and amphibians ♦ Possible impairment of well production ♦ Reduction in potential water supply and fire fighting capacity ♦ Alteration of downstream flows ♦ Possible overwintering water level variation ♦ Possible shoreline erosion and slumping ♦ May result in greater nutrient availability for algae

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
5.b) Flooding	♦ Higher water level in the spring can inhibit seed germination and plant growth ♦ Higher flows which are normally associated with elevated water levels can flush seed and plant fragments from system	♦ Where water is available, this can be an inexpensive technique ♦ Plant growth need not be eliminated, merely retarded or delayed ♦ Timing of water level control can selectively favor certain desirable species	♦ Water for raising the level may not be available ♦ Potential peripheral flooding ♦ Possible downstream impacts ♦ Many species may not be affected, and some may be benefited ♦ Algal nuisances may increase where nutrients are available
Chemical controls			
6) Herbicides	♦ Liquid or pelletized herbicides applied to target area or to plants directly ♦ Contact or systemic poisons kill plants or limit growth ♦ Typically requires application every 1-5 yrs	♦ Wide range of control is possible ♦ May be able to selectively eliminate species ♦ May achieve some algae control as well	♦ Possible toxicity to non-target species of plants/animals ♦ Possible downstream impacts; may affect non-target areas within pond ♦ Restrictions of water use for varying time after treatment ♦ Increased oxygen demand from decaying vegetation ♦ Possible recycling of nutrients to allow other growths
6.a) Forms of copper	♦ Contact herbicide ♦ Cellular toxicant, suspected membrane transport disruption ♦ Applied as wide variety of liquid or granular formulations, often in conjunction with polymers or other herbicides	♦ Moderately effective control of some submersed plant species ♦ More often an algal control agent	♦ Toxic to aquatic fauna as a function of concentration, formulation, and ambient water chemistry ♦ Ineffective at colder temperatures ♦ Copper ion persistent; accumulates in sediments or moves downstream

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls			
6.b) Forms of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid)	♦ Contact herbicide with limited translocation potential ♦ Membrane-active chemical which inhibits protein synthesis ♦ Causes structural deterioration ♦ Applied as liquid or granules	♦ Moderate control of some emergent plant species, moderately to highly effective control of floating and submersed species ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on use for water supply, agriculture and recreation ♦ Safety hazards for applicators
6.c) Forms of diquat (6,7-dihydropyrido [1,2-2',1'-c] pyrazinediium dibromide)	♦ Contact herbicide ♦ Absorbed by foliage but not roots ♦ Strong oxidant; disrupts most cellular functions ♦ Applied as a liquid, sometimes in conjunction with copper	♦ Moderate control of some emergent plant species, moderately to highly effective control of floating or submersed species ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to zooplankton at recommended dosage ♦ Inactivated by suspended particles; ineffective in muddy waters ♦ Time delays on use for water supply, agriculture and recreation
6.d) Forms of glyphosate (N-[phosphonomethyl glycine)	♦ Contact herbicide ♦ Absorbed through foliage, disrupts enzyme formation and function in uncertain manner ♦ Applied as liquid spray	♦ Moderately to highly effective control of emerged and floating plant species ♦ Can be used selectively, based on application to individual plants ♦ Rapid action ♦ Low toxicity to aquatic fauna at recommended dosages ♦ No time delays for use of treated water	♦ Non-selective in treated area ♦ Inactivation by suspended particles; ineffective in muddy waters ♦ Not for use within 0.5 miles of potable water intakes ♦ Highly corrosive; storage precautions necessary

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls			
6.e) Forms of 2,4-D (2,4-dichlorophenoxyl acetic acid)	♦ Systemic herbicide ♦ Readily absorbed and translocated throughout plant ♦ Inhibits cell division in new tissue, stimulates growth in older tissue, resulting in gradual cell disruption ♦ Applied as liquid or granules, frequently as part of more complex formulations, preferably during early growth phase of plants	♦ Moderately to highly effective control of a variety of emerged, floating and submersed plants ♦ Can achieve some selectivity through application timing and concentration ♦ Fairly fast action	♦ Variable toxicity to aquatic fauna, depending upon formulation and ambient water chemistry ♦ Time delays for use of treated water for agriculture and recreation ♦ Not for use in water supplies
6.f) Forms of fluridone (1-methyl-3-phenyl-5-[-3-{trifluoromethyl} phenyl]-4[IH]-pyridinone)	♦ Systemic herbicide ♦ Inhibits carotenoid pigment synthesis and impacts photosynthesis ♦ Best applied as liquid or granules during early growth phase of plants	♦ Can be used selectively, based on concentration ♦ Gradual deterioration of affected plants limits impact on oxygen level (BOD) ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna	♦ Impacts on non-target plant species possible at higher doses ♦ Extremely soluble and mixable; difficult to perform partial lake treatments ♦ Requires extended contact time
6.g Forms of triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid)	♦ Systemic herbicide, registered for experimental aquatic use by cooperators in selected areas only at this time ♦ Readily absorbed by foliage, translocated throughout plant ♦ Disrupts enzyme systems specific to plants ♦ Applied as liquid spray or subsurface injected liquid	♦ Effectively controls many floating and submersed plant species ♦ Can be used selectively, more effective against dicot plant species, including many nuisance species ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna ♦ Fast action	♦ Impacts on non-target plant species possible at higher doses ♦ Current time delay of 30 days on consumption of fish from treated areas ♦ Necessary restrictions on use of treated water for supply or recreation not yet certain

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Biological Controls			
7) Biological introductions	♦ Fish, insects or pathogens which feed on or parasitize plants are added to system to affect control ♦ The most commonly used organism is the grass carp, but the larvae of several insects have been used more recently, and viruses are being tested	♦ Provides potentially continuing control with one treatment ♦ Harnesses biological interactions to produce desired conditions ♦ May produce potentially useful fish biomass as an end product	♦ Typically involves introduction of non-native species ♦ Effects may not be controllable ♦ Plant selectivity may not match desired target species ♦ May adversely affect indigenous species
7.a) Herbivorous fish	♦ Sterile juveniles stocked at density which allows control over multiple years ♦ Growth of individuals offsets losses or may increase herbivorous pressure	♦ May greatly reduce plant biomass in single season ♦ May provide multiple years of control from single stocking ♦ Sterility intended to prevent population perpetuation and allow later adjustments	♦ May eliminate all plant biomass, or impact non-target species more than target forms ♦ Funnels energy into largely unused fish biomass and algae ♦ May drastically alter habitat ♦ May escape to new habitats upstream or downstream ♦ May not always be sterile; population control uncertain ♦ Grass carp currently not permitted for use in MA
7.b) Herbivorous insects	♦ Larvae or adults stocked at density intended to allow control with limited growth ♦ Intended to selectively control target species ♦ Milfoil weevil is best known, but still experimental	♦ Involves species native to region, or even targeted lake ♦ Expected to have no negative effect on non-target species ♦ May facilitate longer term control with limited management	♦ Population ecology suggests incomplete control likely ♦ Oscillating cycle of control and re-growth likely ♦ Predation by fish may complicate control ♦ Other lake management actions may interfere with success

Table 24 (continued). Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Biological Controls			
7.c) Fungal/bacterial/viral pathogens	♦ Innoculum used to seed lake or target plant patch ♦ Growth of pathogen population expected to achieve control over target species	♦ May be highly species specific ♦ May provide substantial control after minimal inoculation effort	♦ Largely experimental; effectiveness and longevity of control not well known ♦ Infection ecology suggests incomplete control likely ♦ Possible side effects not well understood
7.d) Selective plantings	♦ Establishment of plant assemblage resistant to undesirable species ♦ Plants introduced as seeds, cuttings or whole plants	♦ Can restore native assemblage ♦ Can encourage assemblage most suitable to lake uses ♦ Supplements targeted species removal techniques	♦ Largely experimental at this time; few well documented cases ♦ Nuisance species may eventually outcompete established assemblage ♦ Introduced species may become nuisances

Successful use is related to selection of materials and the quality of the application. As a result of field experience with benthic barriers, several guidelines can be offered:

- Porous barriers will be subject to less billowing, but will allow settling plant fragments to root and growth; annual maintenance is therefore essential
- Solid barriers will generally prevent rooting in the absence of sediment accumulations, but will billow after enough gases accumulate; venting and strong anchoring are essential in most cases
- Plants under the barrier will usually die completely after about a month, with solid barriers more effective than porous ones in killing the whole plant; barriers of sufficient tensile strength can then be moved to a new location, although continued presence of solid barriers restricts recolonization.
- Proper application requires that the screens be placed on the sediment surface and staked or securely anchored. This may be difficult to accomplish over dense plant growth, and a winter drawdown can provide an ideal opportunity for application. Late spring application has also been effective, however, despite the presence of plant growths at that time, and barriers applied in early May have been removed in mid-June with no substantial plant growth through the summer. Scuba divers normally apply the covers in deeper water, which greatly increases labor costs. Bottom barriers will accumulate sediment deposits in most cases, which allows plant fragments to root. Barriers must then be cleaned, necessitating either removal or laborious in-place maintenance.

For application to Lily Pond, benthic barriers could be a possibility for localized relief of macrophytes. They are usually most effective at creating open areas at swimming areas or around docks and landing areas. Bottom barriers offer a smaller scale, localized approach to managing plant nuisances and would have minimal consequences on the overall lake ecosystem. Similarly, bottom barriers could be a means to control rooted plant growths near the water treatment intakes. One major concern is the relatively mucky bottom sediments found in most of Lily Pond, however. Application of bottom barriers in such sediment will reduce the effective half-life of the treatment, since the benthic barrier is likely to settle through the muck, with fine silt material passing through the meshes and providing substrate for aquatic plants. Efforts to annually retrieve and clean the benthic barriers on a regular basis (one means of prolonging the effectiveness) could lead to high water turbidity and may be physically impracticable. If terms of the short-term localized relief from plants, other more cost-effective means are available (e.g., non-mechanical removal). Accordingly, benthic barriers are not recommended for Lily Pond.

7.2.2 Dredging

7.2.2.1 Introduction

Dredging works as a plant control technique when either a light limitation on growth is imposed through increased water depth or when enough “soft” sediment (muck, clay, silt and fine sand) is removed to reveal a less hospitable substrate (typically rock, gravel or coarse sand). The only exception may be suction dredging, whereby a target species can be reduced or possibly eliminated by removing whole plants and any associated seed banks. Suction dredging might more appropriately be considered a form of harvesting, however, as plants are extracted from the bottom by SCUBA divers operating the suction dredge and sediment is often returned to the lake.

The amount of sediment removed, and hence the new water depth and associated reduced light penetration to bottom sediments, is critical to successful long-term control of rooted, submerged plants. There appears to be a direct relation between water transparency, as determined with a Secchi disk, and the maximum depth of colonization (MDC) by macrophytes. Canfield et al. (1985) provided equations to estimate MDC in Florida and Wisconsin from Secchi disk measurements:

State	Equation
Florida	$\log MDC = 0.42 \log SD + 0.41$
Wisconsin	$\log MDC = 0.79 \log SD + 0.25$

where SD = Secchi depth in meters

Using the Florida equation (chosen for application for Lily Pond due to the highly colored water), growths would be expected to a depth of 2.3 m, or 7.7 ft in Lily Pond. Diminished cover and biovolume values are typically observed at depth over 7 ft, consistent with the calculation (see Table 22, Section 4.3.5). Therefore, it would be expected that keeping a water depth of > 8 ft would significantly control macrophyte abundance in Lily Pond.

If the soft sediment accumulations that are supporting rooted plant nuisances are not especially thick, it may be possible to create a substrate limitation before a light-limiting depth is reached. If dredging exposes rock ledge or cobble, and all soft sediment can be removed, there will be little rooted plant growth. Yet such circumstances are rare to non-existent; either the sediments grade slowly into coarser materials, or it is virtually impossible to remove all fine sediments from the spaces around the rock or cobble. Consequently, at least 25% regrowth is to be expected when light penetrates to the bottom.

The following section provides a summary of the available and applicable dredging technologies that were considered for Lily Pond. Dredging projects are complicated projects and generally involve consideration and selection of three distinct processes:

- Dredging/Sediment Removal,
- Sediment Dewatering, and
- Reuse/Disposal of Sediments.

Each of these processes can be performed by multiple methods. The following summarizes the technologies that were considered for this project.

7.2.2.2 Available Dredging Technologies

Dredging in lakes is generally performed by application of either one of two methods – hydraulic dredging or mechanical dredging. The following is a brief description of each method.

<u>Hydraulic Dredging</u>

Hydraulic dredging is performed by removing water and sediment in a “slurry” from the lake bottom. The sediment and water is then separated by one of several means and the water returned to the lake. A hydraulic dredge typically consists of barge-mounted cutter head that feeds excavated sediment to barge-mounted pump unit. One or more booster pumps may be employed if the distance to the dewatering area is large or if the elevation change is great. Hydraulic dredges typically operate at flows of approximately 2,000 gallons per minute and a solids concentration of approximately 10%. The dredge “slurry” is piped from the dredge to the dewatering area.

<u>Mechanical Dredging</u>

Mechanical dredging is performed by physically removing lake sediments with excavation equipment such as clamshells, drag lines, excavators, and front-end loaders. Removed sediments are then transported to a temporary drying site (or reuse site if already sufficiently dewatered) with standard earth moving equipment (i.e., dump trucks). Mechanical dredging may be performed in either wet (i.e., sediment under water) or dry (i.e., water removed from lake) conditions. However, the physical characteristics of the sediment limit how mechanical dredging may be performed. Sandy sediments with low organic content are best suited for mechanical dredging in wet conditions because they have relatively low in-place water content and dewater rapidly when excavated. These sediments are relatively easy to handle with earth moving equipment. On the other hand, sediments with high silt and organic content are generally difficult or impossible to handle in wet conditions because they have a high in-place water content and retain a great deal of water when excavated. These sediments are better suited to dredging in dry conditions.

7.2.2.3 Available Dewatering Technologies

Several methods are used to dewater the sediment including the following: Lagoon, Mechanical (Filter Belt Press), and In-Place. These methods are described below.

Lagoon Dewatering

Lagoon dewatering involves separating sediments from water via physical settling in a series of ponds. Lagoon dewatering operations for hydraulic dredges are typically conducted in two steps:

- Primary settling in a relatively large basin (usually greater than 12 hour residence time), and
- Secondary settling in a relatively small basin (usually 1 to 2 hour residence time) with the aid of chemical coagulants (e.g., polymers, aluminum sulfate, etc.).

The primary phase of settling removes the majority of sediment. The main purpose of the second phase is to remove colloidal particles to provide a good quality discharge stream. Sediments are left in the lagoons following dredging operations until they have dried via evaporation and percolation sufficiently for their intended reuse.

Lagoon dewatering for mechanical dredge operations is typically conducted in one step, because the sediment from this type of operation has much lower water content than hydraulic dredges. The main purpose of the lagoon for a mechanical dredge operation is to provide a place for the sediments to dry.

Lagoon dewatering operations require a large area relative to the area of the lake to be dredged, and can be difficult to site. Ideally a dewatering lagoon should be sized to contain the entire volume of sediments to be dredged in a season. Otherwise, when the lagoons reach capacity, dredging operations must be discontinued for a month or more until the sediments are desiccated and removed. Dividing the primary pond into multiple units can help to minimize the downtime, but the overall volume of the containment area is still the limiting factor for the speed of the project.

Mechanical Dewatering

Mechanical dewatering involves separation of sediments from water using machinery such as belt filter presses, similar to the process used for Hardy Lake in Waltham, Massachusetts. Polymer coagulants are commonly used in this process to enhance filtrate quality and to produce a more consolidated filter cake. Mechanical dewatering would typically be used in conjunction with a hydraulic dredging operation. A typical operation would include the following components, in order:

- One hydraulic dredge,
- Small “knock out” tank for the removal of cobbles and gravel,

- Large batch tank to even flows from hydraulic dredge to filter presses (typically dredges operate a much higher flow rates than presses),
- Polymer addition and mixing system,
- Two to four filter presses operating in parallel,
- Conveyor belt system to load filter cake from presses directly to dump trucks, and,
- Return line to the lake for filtrate.

The primary advantage of mechanical dewatering over other methods is the small area required for the operation. The mechanical equipment capacity will generally limit the overall production rate with this dewatering method. The overall speed of projects using mechanical dewatering can be slower than other operations because the hydraulic dredges cannot operate full time. However, the speed of this operation is superior to operations using small capacity lagoons. In the past, the cost of mechanical dredging was prohibitive, due to the relatively low throughput of the operation. However, the technology has advanced to the point where it is competitive with other methods, especially where space is limited.

In-Place Dewatering

In-place dewatering involves temporarily removing the water from a lake to allow the sediments to dry. Once sufficiently dry the sediment is removed using standard earthmoving practices. The main challenge for such an operation is to draw down and maintain lake surface water levels at an elevation below the desired dredging depth. A number of strategies are typically used for these projects including:

- Gravity drawdown,
- Pumping,
- Coffer-damming, and
- By-pass channels.

In-place drying times vary depending on the sediment composition, with more organic sediments taking longer to dry than mineral soils. Drying times could be as long as several months and are extremely dependent on weather conditions. A significant disadvantage of this method is that the dewatering operation will be breached by a storm event, re-filling the lake, and re-wetting the sediment.

7.2.2.4 Reuse/Disposal of Sediments

The third part of a successful dredging project is the cost-effective disposal or, hopefully, reuse of the dewatered sediments. The nature and characteristics of Lily Pond sediments (Section 4.2) indicate that they would be suitable for disposal in a variety of situations and would not require disposal as hazardous materials at a licensed landfill. Potential alternatives for the reuse of the dredged material from Lily Pond are could include:

- General use as a topsoil (without amendment),
- General use as a topsoil amendment (mixed with sand),
- Topsoil amendment for landfill closure projects,
- Use in composting, and/or various construction operations (with amendment), and
- Daily Cover at landfills.

Given the general acceptability of the dewatered sediment, a wide variety of reuses are possible. However, the distance to the application which would be critical to the costs of the project, due to the costs due to trucking. Accordingly, local applications and reuse would be preferred.

7.2.2.5 Applicability of Dredging for Rooted Plant Control in Lily Pond

Dredging to reduce aquatic plant abundance in Lily Pond appears warranted, but needs to be fully considered. Experience with dredging for rooted plant control has had mixed results. As with dredging for algal control, failures are invariably linked to incomplete pre-dredging assessment and planning. Control through light limitation appears more successful than control through substrate limitation, largely as a function of the difficulty of removing all soft sediment from shallow areas. Dry dredging projects appear to result in more thorough soft sediment removal, mainly because equipment operators can visually observe the results of dredging as it takes place. As will be discussed in detail later, water level drawdown is not a viable option for Lily Pond (see Section 7.2.5). Hydraulic dredging in areas with dense weed beds can result in frequent clogging of the pipeline to the slurry discharge area, suggesting the need for some form of temporary plant control (most often herbicides or harvesting) prior to hydraulic dredging. Application of such a herbicide is not a viable option in Lily Pond (see Section 7.2.6).

The potential for serious negative impacts by dredging on the lake and surrounding area can be considerable. Many of these problems are short-lived, however, and can be minimized with proper planning. It should be kept in mind, however, that dredging represents a major re-engineering of a lake, and should not be undertaken without clear recognition of its full impact, positive and negative. This typically involves significant environmental permitting, including local, State, and sometimes Federal permits.

Dredging of Lily Pond to control rooted plants would involve creating a substrate limitation in nearshore areas and removing sediment down to a water depth of approximately 10ft elsewhere. This would involve taking up to 5+ feet of soft sediment in some locations. There is not a consistent hard substrate aside from some ledge and boulders along the northwest-southeast axis of the Pond and some sandy substrate near the outlet. Therefore, dredging for plant control would be primarily aimed at light limitation.

Dredging would provide several benefits to Lily Pond. The first would provide a means of controlling and significantly reducing the rooted aquatic macrophytes in the Pond. The second would be a significant increase in the volume of the Pond (e.g, greater than 10% or more). There would also be removal of nutrients in the top sediments in sections of the Pond, which are most likely to be enriched due to anthropogenic sources. Finally, removal of macrophytes from the near surface area is likely to enhance the recreational uses of the Pond, particularly with regard to fishing and non-motorized boating. Based on the potential benefits, dredging was retained for further evaluation as a pond management option (see Section 8.0). Due to the characteristics of the Pond with regard to hydrologic regime and sediment characteristics, hydraulic dredging was selected as the most appropriate method to pursue for sediment removal. This option is discussed further in Section 8.2.2.

7.2.3 Light Limitation with Dyes and Surface Covers

Environmentally-applied dyes may be sometimes used in rooted plant control efforts. Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow. They tend to reduce the maximum depth of plant growth, but have little effect in shallow water (<4 ft deep). They are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which a stem could reach the lighted zone). In lakes with high transparency but only moderate depth and ample soft sediment accumulations, dyes may provide open water where little would otherwise exist. Repeated treatment will be necessary, as the dye flushes out of the system. Dyes are typically permitted under the same process as herbicides, despite their radically different mode of action. Based on the potential incompatibility of the dyes with potable water production and the pre-existing coloration of the water due to natural humic and tannic compounds which already produces this effect, to some degree, dyes are not a viable management option for Lily Pond.

Surface shading has received little attention as a rooted plant control technique, probably as a function of potential interference with recreational pursuits which are a goal of most rooted plant control programs. Polyethylene sheets, floated on a lake surface for two to three weeks may be sufficient to eliminate many species for the summer if the sheets were applied in spring before plants grow to maturity. This procedure could be a useful and inexpensive alternative to traditional methods of weed control in small areas such as docks and beaches or the Lily Pond intake area, and could be timed to yield results with minimal negative impacts to system ecology. The potential interference of surface covers with recreation is not a liability for Lily Pond. However, surface covers would only be used on a localized basis much like bottom barriers and not provide significant reduction of the pond flora.

7.2.4 Mechanical Removal

There are many variations on mechanical removal of macrophytes. Table 24 breaks these varied techniques into hand pulling, cutting without collection, harvesting with collection, rototilling, and hydroraking. Suction dredging, addressed in the dredging section, could also be included here, as it is primarily intended to remove plant biomass. Other classification systems are undoubtedly applicable; this is a diverse collection of methods linked by the commonality of physically attacking the targeted plants. These techniques are often cited as being analogous to mowing the lawn (cutting or harvesting), weeding the garden (hand pulling), or tilling the soil (rototilling or hydroraking), and these are reasonable comparisons. Mechanical management of aquatic plants is not much different from managing terrestrial plants, except for the complications imposed by the water.

Hand pulling is exactly what it sounds like; a snorkeler or diver surveys an area and selectively pulls out unwanted plants on an individual basis. This is a highly selective technique, and a labor intensive one. It is well suited to vigilant efforts to keep out invasive species that have not yet become established in the lake or area of concern. Hand pulling can also effectively address non-dominant growths of undesirable species in mixed assemblages, or small patches of plants targeted for removal. This technique is not suited to large scale efforts, especially when the target species or assemblage occurs in dense or expansive beds, such is the case in Lily Pond.

Hand pulling can be augmented by various tools, including a wide assortment of rakes, cutting tools, water jetting devices, nets and other collection devices. McComas (1993) provides an extensive review of options. Use of these tools transitions into the next two categories, macrophyte cutting and harvesting. Suction dredging is also used to augment hand pulling, allowing a higher rate of pulling in a targeted area, as the diver/snorkeler does not have to carry pulled plants to a disposal point.

Cutting is also exactly what it appears to be. A blade of some kind is applied to plants, severing the active apical meristem (location of growth) and possibly much more of the plant from the remaining rooted portion. Regrowth is expected, and in some species that regrowth is so rapid in certain seasons that it negates the benefits of the cutting in only a week or two. If the plant can be cut close enough to the bottom, or repeatedly, it will sometimes die, but this is more the exception than the rule. Cutting is defined here as an operation which does not involve collecting the plants once they are cut, so impacts to dissolved oxygen are possible in large scale cutting operations.

The more complete cutting technique involves the use of mechanized barges normally associated with harvesting operations, in which plants are normally collected for out-of-lake disposal. In its use as a cutting technology, the “harvester” cuts the plants but does not collect them. A recent modification in this technique employs a grinding apparatus that ensures that viable plant fragments are minimized after processing. There is a distinct potential for dissolved oxygen impacts as the plant biomass decays, much like what would be expected from most herbicide treatments.

Harvesting may involve collection in nets or small boats towed by the person collecting the weeds, or can employ smaller boat-mounted cutting tools which haul the cut biomass into the boat for eventual disposal on land, or can be accomplished with larger, commercial machines with numerous blades, a conveyor system, and a substantial storage area for cut plants. Offloading accessories are available, allowing easy transfer of weeds from the harvester to trucks that haul the weeds to a composting area. Choice of equipment is really a question of scale, with most larger harvesting operations employing commercially manufactured machines built to specifications suited to the job. Some lake associations choose to purchase and operate harvesters, while others prefer to contract harvesting services to a firm that specializes in lake management efforts.

Cutting rates for commercial harvesters tend to range from about 0.2 to 0.6 acres per hour, depending on machine size and operator ability, but the range of possible rates is larger. Even at the highest conceivable rate, harvesting is a slow process that may leave some lake users dissatisfied with progress in controlling aquatic plants. Weed disposal is not usually a problem, in part because lakeshore residents and farmers often will use the weeds as mulch and fertilizer. Also, since aquatic plants are more than 90 percent water, their dry bulk is comparatively small. Key issues in choosing a harvester include depth of operation, volume and weight of plants that can be stored, reliability and ease of maintenance, along with a host of details regarding the hydraulic system and other mechanical design features.

Rototilling and the use of cultivation equipment are newer procedures with a limited track record. A rototiller is a barge-like machine with a hydraulically operated tillage device that can be lowered to depths of 10 to 12 feet for the purpose of tearing out roots. Also, if the water level in the lake can be drawn down, cultivation equipment pulled behind tractors on firm sediments can achieve 90 percent root removal. Potential impacts to non-target organisms and water quality are substantial, but where severe weed infestations exist, this technique could be appropriate.

Hydroraking involves the equivalent of a floating backhoe, usually outfitted with a York rake which looks like certain farm implements for tilling or moving silage. The tines of the rake attachment are moved through the sediment, ripping out thick root masses and associated sediment and debris. A hydrorake can be a very effective tool for removing submerged stumps, water lily root masses, or floating islands. Use of a hydrorake is not a delicate operation, however, and will create substantial turbidity and plant fragments. Hydroraking in combination with a harvester can remove most forms of vegetation encountered in lakes.

Most mechanical plant removal operations are successful in producing at least temporary relief from nuisance plants and in removing organic matter and nutrients without the addition of a potentially deleterious substance. Plant regrowth can be very rapid (days or weeks). Harvesting may reduce plant diversity in some cases, and resultant open areas are candidates for colonization by invasive species, but most potential problems can be avoided by proper program planning.

Aquatic plant harvesting on a whole lake scale does not appear to make sense for Lily Pond for a number of reasons. The typical motivation to conduct harvesting is to clear selected areas for active recreational activities such as motor boating, personal watercraft, or swimming, and these reasons are not applicable to Lily Pond, except near the intake area. Harvesting will not provide a long-term solution for the aquatic macrophytes since the relatively shallow pond bottom is likely to be easily recolonized, especially since the predominant invasive species (fanwort) spreads by vegetative methods and fragmentation would lead to new plant growth. The use of a full-scale harvester would require a diesel-powered vessel that could have water quality concerns due to small leaks or spills of fuel and hydraulic systems. Finally, there could be an increase in the turbidity due to resuspension of bottom sediments and/or algae growth sponsored by released nutrients.

Localized non-mechanical harvesting can be used in Lily Pond to control rooted plants in selected areas on a maintenance basis. Macrophyte harvesting has been conducted at Lily Pond by a commercial firm (ACT, Sutton, MA) for short-term relief of macrophyte abundance near the intakes (1997, 1998). This involved the commercial harvesting of a small portion of the pond (on the order of 3-5 acres) or roughly a 400 ft radius around the intakes and out to the small island (pers. comm. George Hawksley). This appeared to be effective for a portion of or all of the growing season, but does not significantly decrease macrophyte abundance in future seasons (as indicated by the heavy abundance currently existing in this area). It also does not address the issue of wind/wave concentration of semi-attached macrophytes such as bladderwort (*Utricularia*), which appears to be responsible for a least a portion of the blockage in the past (pers. comm. George Hawksley).

Rather than rely on commercial harvesters, for which there is often a significant mobilization cost, small-scale harvesting equipment that could be dragged behind a rowboat (i.e., rakes, or cutterbars) would be a means to assure that water plant intakes are not blocked by impinging plant material. Often this method is not recommended because of the associated fragmentation of the vegetative material and further spreading of invasive species. In the case of Lily Pond, the further spread of the invasive fanwort is relative moot since the species is already found in profusion in all areas of the Pond.

This method would need to be conducted with care since harvesting of plants in the area of greatest concern, (i.e., near the intakes) could potentially lead to elevated concentrations of coarse to fine plant fragments and suspended bottom material being drawn into the plant raw water supply. Alternative means of harvesting (e.g., hand pulling or diver assisted) are not recommended due to the soft sediments and poor visibility in the Pond. Perhaps this limited non-mechanical harvesting could be conducted during a period when the intakes are not in use (drawing on existing water supplies) for short-term relief of the plant blockage concern.

7.2.5 Water Level Control

Historically, water level drawdown has been used in waterfowl impoundments and wetlands for periods of a year or more, including the growing season, to improve the quality of wetlands for waterfowl breeding and feeding habitat. It has also been a common fishery management method. Until a few decades ago, drawdowns of recreational lakes were primarily for the purpose of flood control and allowing access for clean ups and repairs to structures, with macrophyte control as an auxiliary benefit. While this technique is not effective on all submergent species, it does decrease the abundance of some of the chief nuisance species, particularly those that rely on vegetative propagules for overwintering and expansion. If there is an existing drawdown capability, lowering the water level provides an inexpensive means to control some macrophytes. Based on the available scientific literature, drawdown is considered an effective means to control and reduced the abundance of fanwort, the dominant macrophyte presently in Lily Pond.

The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level. In the case of Lily Pond, the upper surface elevation is controlled by the height of the BBCS, while the ultimate potential depth of the drawdown is likely to be determined by the bottom elevation of the water intake structure or the minimum depth of the channel of Herring Brook.

Several factors affect the success of drawdown with respect to plant control. While drying of plants during drawdowns may provide some control, the additional impact of freezing is substantial, making drawdown a more effective strategy during late fall and winter. However, a mild winter or one with early and persistent snow may not provide the necessary level of drying and freezing. The presence of high levels of groundwater seepage into the lake may mitigate or negate destructive effects on target submergent species by keeping the area moist and unfrozen. The presence of extensive seed beds may result in rapid re-establishment of previously occurring or new and equally undesirable plant species. Recolonization from nearby areas may be rapid, and the response of macrophyte species to drawdown is quite variable.

Desirable side effects associated with drawdowns include the opportunity to clean up the shoreline, repair previous erosion damage, repair docks and retaining walls, search for septic system breakout, and physically improve fish spawning areas. The attendant concentration of forage fish and game fish in the same areas may be viewed as a benefit of most drawdowns, although not all fishery professionals agree. The consolidation of loose sediments and sloughing of soft sediment deposits into deeper water is perceived as a benefit in many cases, at least by shoreline homeowners.

Undesirable possible side effects of drawdown include loss or reduction of desirable plant species, facilitation of invasion by drawdown-resistant undesirable plants, reduced attractiveness to waterfowl (considered an advantage by some), possible fishkills if oxygen demand exceeds re-aeration during a prolonged drawdown, altered littoral habitat for fish and invertebrates, mortality among hibernating reptiles and amphibians, impacts to connected wetlands, shoreline erosion during drawdown, loss of aesthetic appeal during drawdown, more frequent algal blooms after refill in some cases, reduction in water supply, impairment of recreational access during the drawdown, and downstream flow impacts. Careful planning can often avoid many of these negative side effects, but managers should be aware of the potential consequences of any management action.

Desirable flood storage capacity will increase during a drawdown, but associated alteration of the downstream flow regime may have some negative impacts. Once the target drawdown level is achieved, there should be little alteration of downstream flow. However, downstream flows must necessarily be greater during the actual drawdown than they would be if no drawdown was conducted. The key to managing downstream impacts is to minimize erosion and keep flows within an acceptable natural range.

Inability to rapidly refill a lake after drawdown is a standard concern in evaluating the efficacy of a drawdown. There must be enough water entering the lake to refill it within an appropriate timeframe while maintaining an acceptable downstream flow. In northern lakes, the best time for refill is in early spring, when flows typically peak as the snowpack melts and rainfall on frozen ground yields the maximum runoff.

Impairment of water supply during a drawdown is a primary concern of groups served by that supply. Certainly the critical factor for Lily Pond is the depth of the bottom elevation of the water intake for the Water Treatment Plant. The water level in wells with hydraulic connections to the lake will decline, with the potential for reduced yield, altered water quality and pumping difficulties. Drawdowns of Cedar Lake and Forge Pond in Massachusetts resulted in impairment of well water supplies (Wagner, pers. obs.), but there is little mention of impairment of well production in the reviewed literature.

Carefully planned water level fluctuation can be a useful technique to check nuisance macrophytes and periodically rejuvenate wetland diversity. Planned disturbance is always a threshold phenomenon; a little is beneficial, too much leads to overall ecosystem decline. The depth, duration, timing and frequency of the drawdown are therefore critical elements in devising the most beneficial program.

While drawdown is clearly an inexpensive option for providing control of peripheral rooted plant growths, several concerns were identified regarding the ability to conduct a drawdown of Lily Pond. These concerns include: the depth of effective drawdown (as determined by BBCS or depth in Herring Brook), potential impairment of the intake operation, depth of target macrophyte beds, potential dewatering of wetlands associated with Bound Brook south of Lily Pond, ease of refilling, and impacts to water quality both during drawdown and following refilling. Moreover, reduction in the abundance of fanwort may not alleviate macrophyte concerns in the Pond, as other native or drawdown-resistant species will likely re-colonize the drawdown zone. In addition, the potential impacts to invertebrates, amphibians, reptiles and fish have raised concerns in recent years with permitting agencies. To fully evaluate the potential impacts of drawdown, further investigations would be require. Given the fairly long list of potential concerns outlined above, however, drawdown appears to be an infeasible option for Lily Pond.

7.2.6 Herbicides

Killing nuisance aquatic weeds with chemicals is one of the oldest methods used to attempt their management. Other than perhaps drawdown, few alternatives to herbicides were widely practiced until relatively recently. There are few aspects of aquatic plant control which breed more public controversy than chemical control of macrophytes through the use of herbicides, which are a subset of all chemicals known as pesticides. However, it is prudent to consider potential chemical solutions to such problems as infestations of non-native species that grow to nuisance proportions, just as we seek potential physical and biological solutions. Current pesticide registration procedures are far more rigorous than in the past, with the result that there is a fairly restricted suite of approved chemicals for application. These chemicals, and the various alternative commercial formulations (while still retaining the basic active ingredients), have been used in countless waterbodies and settings with acceptable results. While no pesticide is considered unequivocally “safe”, a premise of federal pesticide regulation is that the potential benefits derived from use outweigh the risks when the chemical is used according to label restrictions. However, in the case of Lily Pond, the option of herbicides is further restricted. Due to its status as a drinking water supply, the control of aquatic weeds through herbicide use is not permissible without a permit from the MA DEP, according to Massachusetts regulations 310 CMR 22.20B(8). There is very low potential that such a permit for placing chemicals in a sole source drinking water supply would be obtainable without considerable restrictions in the water usage (at least for some period). This is a daunting prospect due to lack of alternative potable water supply for the Town of Cohasset during treatment or in the case of an application accident. Further, the introduction of such chemicals into Lily Pond could be unacceptable to the local water users. Due to these factors, use of herbicides in Lily Pond was not further considered.

7.2.7 Biological Introductions

Significant improvement in our future ability to achieve lasting control of nuisance aquatic vegetation may come from plant-eating or plant-pathogenic biocontrol organisms, or from a combination of current procedures such as harvesting, drawdown, and herbicides with these organisms. Biological control has the objective of achieving control of plants without introducing toxic chemicals or using machinery. It suffers from one ecological drawback; in predator-prey (or parasite-host) relationships, it is rare for the predator to completely eliminate the prey. Consequently, population cycles or oscillations are typically induced for both predator and prey. It is not clear that the magnitude of the upside oscillations in plant populations will be acceptable to human users, and it seems likely that a combination of other techniques with biocontrols may be necessary to achieve lasting, predictable results.

Biological controls include herbivorous fish such as *Ctenopharyngidon idella* (the grass carp), insects such as the aquatic weevil (*Euhrychiopsis lecontei*), and experimental fungal pathogens. Aside from consumptive approaches (grazing, parasitism), it is also possible to exert competitive pressures, limiting invasive species by maintaining a healthy native assemblage.

The grass carp is a non-native fish (imported around 1962) known to be a voracious consumer of many forms of macrophytes. It has a very high growth rate. This combination of broad diet and high growth rate can produce control or even eradication of plants within several seasons. However, grass carp do not consume aquatic plant species without preference. These fish prefer plant species such as *Elodea*, *Potamogeton* spp., and *Hydrilla*. Low stocking densities can produce selective grazing on the preferred plant species while other less preferred species, including milfoil, may even increase. Overstocking, on the other hand, may eliminate all plants, contrary to the ecological axiom of oscillating population cycles described previously.

Grass carp are not approved for introduction in Massachusetts. Consequently, while some success has been achieved elsewhere, this is not an option for Lily Pond at this time. Additionally, the use of grass carp is likely to drastically alter the ecology of a lake. Stocked to reduce vascular plant density, grass carp typically cause a shift toward algal blooms and increased turbidity that becomes a self-sustaining alternative lake condition. This condition is likely to be unsuitable for water potability concerns and may be more objectionable than the original rooted plant density.

The use of insects to control rooted plants has historically centered on introduced, non-native species, especially eurasian watermilfoil. Despite some successes, the track record for biological problem-solving through introduced, non-native species is poor (as many problems seem to have been created as solved), and governmental agencies tend to prefer alternative controls unless there is no practical choice. However, the use of native species in a biomanipulative approach is usually acceptable. Combining biological, chemical and mechanical controls is the basis of integrated pest control, and takes advantage of as many avenues of control as possible for maximum effectiveness. The development of native insects as aquatic plant controls is still in its infancy and insect larvae that target fanwort are not well understood. At this time, biological introductions do not seem a feasible option for Lily Pond, since the success rate and cost are not favorable enough to recommend this approach over the alternative means of plant control at this time.

7.2.8 Summary of Rooted Plant Control

Based on the discussion and considerations of the major forms of rooted plant control, five methods were eliminated as not appropriate for Lily Pond. These include benthic barriers, artificial shading, water level control, herbicides, and biomanipulation. Dredging and non-mechanical aquatic weed removal were retained for further consideration as management tools.

8.0 POND MANAGEMENT RECOMMENDATIONS

Based on the current state and characteristics of the Pond and its watershed, the applicability and feasibility of various treatment options, and the existing programs and initiatives of the Town of Cohasset, ENSR has selected several management options for Lily Pond. These are divided into those related to the watershed (Section 8.1) and those pertaining to in-lake management (Section 8.2).

8.1 Watershed Input Control Recommendations

Water quality conditions in Lily Pond are generally marginal but acceptable for its intended primary use as a water supply. Loading to Lily Pond is high for a number of water quality variables, and should be reduced for greater protection of future water potability and potential enhancement of other water uses. Water quality in the pond is diminished with respect to water clarity and nutrient levels. Resultant impacts are manifest in the excessive nuisance macrophyte community that impairs both water treatment operations as well as recreational uses of the Pond.

The diagnostic study indicated that the size and hydrologic contribution of the three basins in the Lily Pond watershed do not necessarily correspond to their importance with regard to nutrient loading. Brass Kettle Brook provides 68% of estimated watershed hydrologic contribution, while Peppermint Brook contributes 16% and direct drainage 9%; the remainder comes from direct precipitation. However, Peppermint Brook is responsible for a disproportionate amount of the total phosphorus 33%) with direct delivery to the Pond. Further, even though quantitatively more important (57%), the ecological impact of nutrient loads arising in the Brass Kettle Brook watershed to Lily Pond is likely much less. This is due to attenuation of nutrients by passage of the Brook through the large wetlands located at the confluence. Under circumstances of high pond water elevation (e.g., during spring runoff period), these nutrients are also likely to be rapidly exported from the system via Herring Brook due to the location of the Brass Kettle Brook near the outlet. This indicates that watershed management should focus on the Peppermint Brook watershed as a first priority, although reductions in nutrient and/or contaminant loading anywhere in the watershed is beneficial to Pond water quality. Accordingly, a number of actions to reduce the level of watershed loadings were identified as potentially useful and recommended for Lily Pond.

8.1.1 Land Use Control

Fortunately, future potential development in the watershed of Lily Pond and its upstream hydrologic source, the Aaron River Reservoir, is likely to be limited, due to the high percentage of protected land and open space. The Town of Cohasset initiatives currently in place (i.e., the Cohasset Stormwater Management Plan and Control Strategies, the Cohasset On-Site Wastewater Management Plan) and the policy of the Water Department to actively pursue the acquisition of developable parcels and additional open space in the watershed, should act collectively to reduce nutrient loads from the watershed below present levels. Any additional development in the watershed, particularly those in Zone A or the Water Resource District, should be carefully evaluated for impacts to the Pond and must be accompanied by appropriate watershed management actions if the Pond is to be protected. Watershed management improvements must outpace development if the pond water quality is to be enhanced. Development need not be prevented outright, but must be held to the highest standards of environmental protection. All of the programs and initiatives identified above are highly consistent and support of protection and enhancement of Lily Pond water quality.

8.1.2 Stormwater Management

Stormwater management, particularly in the Peppermint Brook watershed, has been identified by this study as well as the SWSPP (Norfolk Ram Group, 2002) as a priority item. Providing detention or infiltration areas, or creating constructed wetlands for the purpose of treating runoff should compensate for impacts from older development, streets and highways, and other unregulated or less regulated buffer zone in the Peppermint Brook watershed. Specific ranges and average improvements in water quality provided by the suggested stormwater management techniques are outlined in Table 25.

In general, all storm water discharge pipes should be routed into detention or infiltration facilities, where space allows. Sizing should accommodate at least a storm event with a two-year recurrence interval, and preferably an event with a ten-year recurrence interval (the so-called 2-year and 10-year storms). Where space does not allow the terminal discharge to be passed into a detention/infiltration facility, catch basins in the drainage system should be augmented with leaching basins.

It may not be necessary to augment all catch basins; one or more leaching basins can sometimes be placed slightly upgradient of the discharge pipe, and can infiltrate much of the runoff if properly sized and constructed. Off-line overflow leaching basins are preferred, in which the first flush of runoff can be captured without additional input from subsequent runoff (i.e., once the leaching chamber is full, runoff is diverted to the original discharge). Provisions

Table 25. Range and Average Values (in parentheses) for Expected Removal (%) for Key Pollutants by Selected Management Methods, Compiled from Literature Sources and Actual Projects.

Stormwater Management Options	TSS	TP	Soluble P	Total N	Soluble N	Metals
Street sweeping	5 – 20	5 – 20	< 10	5 – 20	< 10	5 – 20
Catch basin cleaning	5 – 10	1 – 10	< 1	1 – 10	< 5	5 - 10
Buffer strips	40 – 95 (50)	20 – 90 (30)	10 – 80 (20)	20 – 60 (30)	0 – 20 (5)	20 – 60 (30)
Catch basins	1 – 20 (5)	0 – 10 (2)	0 – 1 (0)	0 – 10 (2)	0 – 1 (0)	1 - 20
Modified catch basins	25 (25)	(10)	(0)	(10)	(0)	(20)
Porous Pavement	40 – 80 (60)	30 – 60 (40)	(0)	40 – 80 (50)	(0)	40 – 90 (60)
Sediment/floatables traps	20 – 80 (25)	0 – 20 (10)	0 – 1 (0)	0 – 20 (10)	0 – 1 (0)	10 – 30 (20)
Vegetated swale	60 – 90 (70)	(30)	(15)	(25)	(0)	(70)
Infiltration trench/chamber	75 – 90 (80)	40 – 70 (60)	20 – 60 (50)	40 – 80 (60)	0 – 40 (10)	50 – 90 (80)
Infiltration basin	75 – 80 (80)	40 – 70 (60)	20 – 60 (50)	40 – 80 (60)	0 – 40 (10)	50 – 90 (80)
Sand filtration	80 – 85 (80)	(60)	(40)	(35)	(0)	50 – 70 (60)
Organic filtration	80 – 90 (80)	(70)	(50)	(50)	(5)	(70)
Dry detention	14 – 87 (70)	13 – 56 (27)	0 (0)	10 – 60 (31)	0 – 52 (20)	0 – 66 (36)
Wet detention	32 – 99 (70)	12 – 91 (49)	8 – 90 (53)	6 – 85 (34)	0 – 97 (43)	13 – 96 (63)
Construction wetland	14 – 98 (70)	0 – 97 (68)	0 – 65 (30)	23 – 30 (26)	1 – 95 (45)	0 – 82 (54)
Pond/Wetland combination	20 – 96 (76)	24 – 92 (70)	1 – 80 (40)	0 – 83 (38)	9 – 70 (28)	6 – 90 (58)
Chemical treatment	30 – 90 (70)	30 – 90 (70)	50 – 95 (80)	20 – 80 (50)	0 – 30 (10)	30 – 90 (65)

of the MA Storm Water Policy pretreatment before infiltration, and designs should adhere to the corresponding specifications; usually deep sumps and hooded overflows for existing catch basins provide sufficient pretreatment.

Application of these stormwater management BMPs are recommended for application over the entire Lily Pond watershed, but the greatest benefit will be associated with improvements in the Peppermint Brook watershed, specifically treatment of runoff coming off of Route 3A. For improvement in stormwater quality up to 5 parcels/sites could be targeted for improvement. At an average generic, but conservative cost of $20,000 per parcel/site this would involve a capital cost of approximately $100,000. The cost of these sites may differ widely based on the nature of the BMPs and associated engineering and/or permits. Identification of these sites and determination of the best BMPs for use in this area should coordinated with the Phase II Stormwater Management Program. As can be seen in Table 26, in addition to structural improvements, regular or expedited cleaning of streets and catch basins is another effective way to reduce stormwater loadings to Lily Pond. Typically, a program of BMPs and increased maintenance can provide improvements on the order of 10-30% reduction of pollutants, depending on the treatments used.

In addition to these watershed upgrades and retrofits, chemical treatment of Peppermint Brook as it enters Lily Pond was also evaluated further. As discussed previously, this is an “end-of-pipe” treatment that is costly but more directly effective in reducing nutrient and sediment loading to the Pond. A preliminary cost estimate was prepared to compare the potential benefits of other stormwater treatment methods. The cost elements for this option are described below.

Chemical treatment of Peppermint Brook would involve establishment of a permanent dosing station at or near the King Road crossing. This dosing station would be used to dose (inject) chemicals (i.e., alum-based polymers) directly into Peppermint Brook to help flocculate TSS and nutrients during stormwater flows and retain the settled material prior to its entry into Lily Pond. Water Treatment Plant personnel would have excellent access to the dosing stations due to its proximity, but a secure structure would be needed to prevent vandalism. Storage of bulk concentrations of flocculent chemicals would be at the Treatment Plant.

An initial water quality and stormwater flow study of Peppermint Brook would be needed for design treatment and sizing purposes. The findings of this study would be used to (1) determine the most effective flocculent and the appropriate dose (i.e., jar-testing); (2) to establish a relationship between stream height and flow in Peppermint Brook, to allow calculation of how much flocculent chemical is necessary for a given flow volume; and (3) determine the resulting volume of settled residuals based on % of storm flow treated. This study would need to capture several storm water events to gauge the range of water quality and settling conditions. The estimated cost of this investigation is $20,000.

Design and construction of a permanent dosing station would be expected to cost on the order of about $100,000 (based on analysis of a similar station for the Town of Wellesley for application on a small brook). The station would use a water level indicator (stilling pipe) and/or transducer to estimate depth/flow to determine dosage amount. A telephone or dedicated landline could be used to allow direct real-time monitoring of station performance at the Water Treatment Plant (installation of line and software estimated at $15,000). Operational costs for maintenance and service of the dosing station are estimated at up to $10,000 per year, but as chemical dosing would be preferentially conducted during spring to fall actual, operational costs would be minimal during the winter months. Providing for retention and retrieval of the settled material would involve construction of a detention basin within or near the end of the channel downstream of King Street. This could be accomplished by deepening of the channel and constructing an earthen berm or other containment (e.g., gabion weirs) at the lake end. The actual design would be based on the amount of settled material produced per year (based on the results of the initial water quality flocculent testing study). Given the small area available, the settled solids would have to be removed annually, so access is required for heavy equipment for annual maintenance removal. Design and construction of this basin was roughly estimated at $30,000 (the size would be refined by the initial study). Annual maintenance by the Water Department (or similar Town agency) was estimated at $3,000 (1-2 day clean-out event). Environmental permitting and compliance for the project (Notice of Intent, Water Quality certificate) was estimated at $15,000. Adding 15% for unexpected cost contingencies, gives an approximate estimate of $204,000 (including the initial water quality and testing study) and an annual maintenance program of approximately $13,000.

The potential benefit of the chemical dosing station is indicated in Table 25, based on literature sources. Accordingly, it was assumed that total phosphorus could be reduced by up to 60% in the Peppermint Brook tributary at Lily Pond. While this is significant reduction in the streams nutrient load, it needs to be compared to the flow-weighted contribution of the tributary. Using the nutrient watershed loading model described in Section 4.2.3, the implementation of chemical treatment would result in a reduction in Lily Pond's nutrient budget from 138 kg TP/yr to 120 kg TP/yr. This would result in only modest gains in the water transparency and reducing the in-lake concentration, although this source of nutrients is much more likely to be expressed biologically due to its delivery directly to the lake. It is likely that similar levels of reduction of nutrient loads are feasible through more conventional stormwater management that once established, would have much smaller annual operation and management costs. Given the high cost associated this option, potential concerns regarding the ability to size a sufficient basin to retain the majority of settled floc in the space available, and potential aesthetic concerns given the visibility of settled material from King Street, this option was ultimately not recommended for Lily Pond.

8.1.3 Lawn Fertilization Educational Program

Another recommended watershed input reduction control option is an educational program to instruct and educate watershed residents to reduce or eliminate fertilizers in sensitive buffer areas adjacent to the Pond or its tributaries. The use of slow-release fertilizers and/or prohibition of quick-release fertilizers is recommended. There is abundant educational material from a variety of sources (MACC, NALMS, others) that cover this subject material, so that relatively little new materials will need to be developed. A cost-effective approach would be to put this information on the Town or Water Commission website for town-wide coverage, with a limited number of brochures copied and directly mailed (along with explanatory letter) to residences falling within the watershed Zone A limits or other areas, as appropriate. The estimated cost of this option is relatively minimal (<$2,000). However, the amount of beneficial reduction in nutrients is also likely to be very modest with a reduction of less than 1% of the nutrient load to the Pond likely. Despite this small potential decrease, this option is recommended as another means to keep watershed residents aware of their land use relationship with Lily Pond and to encourage good environmental stewardship. This informational brochure could also be used by the Cohasset Water Commission in their ongoing watershed protection education program. Examples of educational fact sheets, brochures, and pamphlets that could be adopted for use in the Lily Pond watershed for lawn fertilizer and other home maintenance areas are provided in Appendix D.

8.1.4 Improved Settling Lagoon Discharge Performance

The last watershed input reduction recommendations relates to the current discharge from the water treatment residual settling lagoons at the Water Treatment Plant. The direct discharge of supernatant to the Pond is leading to a build-up of a sediment delta below the discharge that is encroaching upon the Lily Pond shoreline and leading to a reduction in Pond volume. As noted earlier, these sediments are composed of natural silts and clays along with a small portion of flocculation chemicals and do not pose an adverse risk to biota or flora in the Pond. This delta area is poorly colonized by vegetation aside from Phragmites reeds and is somewhat aesthetically unappealing.

Evaluating the effectiveness of the settling lagoons and seeking a greater reduction in the amount of TSS leaving the lagoons is recommended. Monitoring of the lagoon discharge would provide a means of evaluating performance. Removal of some or the entire sediment delta is also recommended and is consistent with other recommended in-lake options to increase the volume of the Pond. At this point in time, no costs have been identified with this option. It is considered a future option for the Water Department to evaluate. Re-evaluation of the design and engineering are consistent with the recommendation of the Capital Improvement Program (Weston and Sampson, 2000).

8.2 In-Lake Management Recommendations

Two in-lake management recommendations were identified as part of the Pond Management Plan. These involve two different ways of reducing plant biomass, but with very different scales of application. The first, non-mechanical harvesting, is considered the inexpensive, "low-tech" and short-term solution for reducing the plant biomass near the intake. The second, a proposed hydraulic dredging of approximately 27% of the pond's bottom area, is the expensive, "high-tech" and long-term solution to this problem. These two methods are discussed below.

8.2.1 Non-Mechanical Harvesting of Macrophytes

The removal of macrophytes by non-mechanical means is an inexpensive and appropriate solution for reducing plant coverage and biomass in localized areas. The area of concern for the treatment is the portion of Lily Pond adjacent to the water intakes. As has been described earlier in detail, the use of Lily Pond as a drinking water supply precludes the use of herbicides or shading chemicals in this area and the nature of the bottom sediments make application of benthic barriers ineffectual. Use and mobilization of a large-scale mechanical harvester is not cost-effective to treat this relatively small area. Accordingly, the use of small boat-mounted harvester equipment (i.e., rake or cutting tool) is recommended. While this method will not permanently eliminate vegetation, it would keep the intake area free of blockage.

There are many commercial products that can be towed behind a small rowboat. These have been reviewed by McCormas (1993) and include cutterbars, rakes, and other collection devices. Depending on the equipment, the typical cost is relatively inexpensive (i.e., < $1,500). On the other hand, this technique is often labor-intensive and needs to be conducted several times during the season. Waiting until peak biomass is reached (and or intake blockage occurs) until initiating harvesting may prove difficult or impossible. This activity does not need any specialized training and could be conducted by Water Treatment Plant personnel (or summer interns). Some small area on shore will be needed to place the harvested plant material while it dessicates and decays (which may generate odors), but there should be no issues associated with disposal of the resulting organic matter. Since this method can generate plant fragments and substantial turbidity, it should be coordinated with periods when the Plant intake is not active. In addition, a fine-mesh net could be placed over the intake to prevent plant fragments from entering. An estimated cost of $1,500 for cutting equipment and an annual outlay of $1,500 for maintenance harvesting is estimated.

Potential Wetland Impacts

This option generally does not entail any negative impacts to the identified interests of the Wetland Protection Act, although generation of excessive turbidity could impact the "prevention of pollution" interest, but should not if reasonably conducted. A possible benefit for "protection of fisheries" (i.e., improvement of aquatic habitat) could be realized by its application. For application to Lily Pond, no contiguous wetland areas were identified as potential impacted, although the action is within a defined resource area (Lily Pond). A Notice of Intent (NOI) permit application through the Cohasset Conservation Commission may be required, but should probably be initially pursued as a simple Request for Determination of Applicability (RDA) request.

8.2.2 Hydraulic Dredging of Lily Pond

Among the methods available to control rooted plant density, dredging of the pond to create a light limitation of macrophytes will probably be the most effective at significantly reducing plant abundance and biomass. Based on the pond and sediment characteristics, hydraulic dredging is the most effective option. However, because of the need for adequate dewatering and disposal areas, engineering design, and environmental permitting, the long-term benefits of the sediment removal have to be carefully weighed against the feasibility, costs and short-term impacts. The first step in scoping such a project is the determination of the total amount of sediment to be removed. Therefore, the depth and area of proposed dredging need to be selected. In many cases, these parameters are based on a relative optimization of the benefits of increased depth and reduced vegetation vs. cost and environmental concerns.

8.2.2.1 Identification of Proposed Dredging Depth and Area

Evaluation of the in-pond light characteristics indicates that a minimum depth of at least 8 ft would be required to control the existing fanwort populations. However, given the fluctuations in surface water elevation that can occur in Lily Pond over the summer (or even in drought years), it is recommended that a 10 ft water depth be achieved, if possible. It should be recognized that achieving 10 ft in water depth would not necessarily eliminate all vegetation, as species tolerant of low light (e.g., *Chara*, stoneworts) may occur. However, these forms grow close to the bottom and have minimal biomass as compared to the fanwort. Therefore, there would be significant improvement in the amount of open water, reduction in the organic biomass liable to clogging or impair water treatment, increase in the useable storage of the Pond, and an improvement in boating and fishing uses.

The second element determining total sediment to be removed is the area to be dredged – with a potential range of options from the entire Pond to a small portion (e.g., only the intake structure and a channel to deeper water). Determination of this area depends on many factors such as the potential impacts to lake biota and ecosystem function, potential impacts to adjacent areas (including wetlands), impacts to potable water quality, the size and capacity of the dewatering and disposal areas, interference with other uses of the Pond, distance to neighboring residences, truck traffic, and overall costs and benefits.

As a starting point, the extreme example of dredging of the entire pond to an average depth of 10 ft was considered. This would entail removal of a minimum > 350,000 CY at a cost likely to exceed $5M. In addition to the high cost, other undesirable features include concerns regarding the dewatering and disposal of such a volume of sediment, potential to change the entire pond ecosystem from macrophyte to phytoplankton-dominated system with decreased flushing rate, the potential for silt and resuspended material to enter wetlands in the south, potential difficulty in dredging rocky areas in the southeast quadrant of the lake, potential enhancement of Peppermint Brook stormwater impact (through loss of filtering macrophytes between confluence and intake) and permitting difficulties. In some cases, this would be counter-productive to the achievement of the management objectives, especially protecting water quality. Based on these factors, a complete dredging of the pond is not warranted.

On the other hand, a partial dredging of Lily Pond would achieve or be consistent with all stated pond management objectives including:

- ***Protection of water supply quality and potability*** – reduction in the amount of nutrient-rich organic sediments and reduction in the supply of organic carbon in the Pond will help protect water potability,
- ***Potential enhancement of water supply operations*** – A reduction in rooted aquatic vegetation biomass in the Pond will improve the ability of the Water Treatment Plant to freely draw water from the Pond via the present water intakes,
- ***Increase of water supply capacity*** - Creation of additional Pond volume by increasing the depth would increase the reservoir storage capacity by approximately 15.2 million gallons and reverse the gradually infilling of the Pond, and
- ***Enhance recreational/aesthetic aspects as feasible*** – the creation of more open water along shoreline and in-lake should improve the quality of the fisheries and enhance fishing and boating uses.

The portion of the Pond to be treated was considered with respect to improving intake access and performance, reduced likelihood in an ecosystem shift to a phytoplankton-dominated system, avoidance of impacts to wetland areas and in-lake areas with shallow ledge, avoidance of the Peppermint Brook confluence, proximity to likely dewatering areas near the facility, and other factors. Based on these considerations, a partial dredging of approximately 75,000 CY in the northeastern quadrant of the Pond was selected as meeting all of the pond management objectives without significant impacts. The location of this proposed area for sediment removal is shown in Figure 16.

Figure 16 11x17

The proposed dredging would increase the water depth to 10 ft in an area of approximately 603, 850 sq. ft (13.9 acres) located between the central rock outcrop and the Water Treatment Plant. Removal of sediment to this depth would produce several benefits and would:

- reduce light levels at bottom to below that sufficient to support dense fanwort populations. This light level would reduce macrophyte densities to the 0-25% range and likely would lead to either elimination of plants or replacement with low-growth forms (e.g., charophytes),
- increase the volume of the lake significantly by providing an estimated additional 15.2 MG of potential storage or approximately 15% of the potential full pool volume (102 MG),
- reduce operational costs at the Water Treatment Plant by removing macrophyte biomass from the proximity of the intake structure, thus preventing future blockage and reduced maintenance costs (i.e., no need for aquatic vegetation harvesting). This should also reduce the amount of particulate organic carbon (POC) entering the intake and reduce the production of undesirable drinking water by-products, thus increasing the potability of the water,
- remove nutrients in the upper sediment layers that have been most affected by anthropogenic influences. This would reduce the potential nutrient enrichment from internal cycling of phosphorus from the top sediment layers. Based on the dredging of 13.9 acres of sediment an estimated 6 kg of TP/yr could potentially be removed from the pond nutrient budget, and
- enhance the quality of the secondary recreational uses of fishing and boating. The creation of a defined open water area of 13.9 acres combined with remaining macrophyte beds improves fishery habitat with reduction of the in-pond biomass on edge habitat and would improve fishing and boating access.

In addition to the benefits outlined above, the proposed dredging also takes into consideration and avoids or mitigates several potential impacts that are often associated with dredging. The mitigation for potential impacts includes:

- dredging of a greater portion (or the entire pond) could lead to a shift to a phytoplankton-dominated ecosystem due to increased nutrient supply (remove competing macrophytes) with increased frequency of significant nuisance algal blooms that could lead to reduced run times for water filtration equipment (due to clogging filters) and taste and odor problems,
- avoidance of impacts to abutting wetland areas. The dredging is confined to area to the northwest quadrant with a buffer zone between it and the good quality wetlands located to the south of the Pond. Due to the nature of the proposed hydraulic dredging, little or no wetland impacts are expected for the bordering vegetative wetlands (BVWs) associated with the large Bound Brook wetland complex to the south of the Pond from the in-lake operations and negligible shoreline impacts due to mobilization or disposal will occur. Since this activity will be within a resource area (pond basin, land under water), a wetland notice of intent will be required,

- hydraulic dredging, properly conducted, does not typically produce significant turbidity in the waterbody. This would allow dredging to be conducted year-round, as needed. The location of the dredging could be adjusted to avoid temporal events (e.g., avoiding shoreline during early summer to avoid disruption of fish spawning),
- centralization of the location of the dredging area near the Water Treatment Plant provides an accessible and viable location for sediment dewatering activities. The paved and open area to the south of the plant provides a potential location for temporary dewatering units (2-4 filter belt presses), the fractionation tank, as well as viable truck access. The proximity of the water treatment residual settling lagoons might be useful as a potential way to detain and treat the supernatant prior to its discharge back to the pond,
- location of the proposed dredging area leaves an internal pond a buffer of dense macrophytes between the intakes and the confluence of Peppermint Brook. Thus, the in-pond vegetation partially mitigates the direct impact of stormwater flows and associated poor water quality (i.e., TSS, bacteria, toxics, etc.),
- the proposed location also avoids dredging in areas where a high concentration of boulders and ledge has been noted on the bottom to the southeast of the central island,
- the central inland will act as a permanent “buoy” and should aid in the accuracy of the positioning of the dredging transects, and
- finally, selection of this area should also minimize potential noise and aesthetic complaints from shoreline residents during operations.

There are also some additional concerns regarding the implementation of dredging in Lily Pond that were identified as needing to be further addressed. These include:

- There is a potential for thermal stratification and seasonal anoxia in the area proposed for dredging. By increasing the depth to 10 feet there would be a potential for reduced oxygen near the bottom and reduced aquatic habitat.
- The additional storage capacity created by the proposed dredging is below the current intake’s bottom screen elevation. To access water in dredged area, the present intake structure will need to be modified and/or a new intake/pipe constructed, and
- If dredging operations significantly increase the turbidity, then dredging may need to be restricted spatially or temporally to colder months when pool elevation is higher. As noted earlier, this is not usually a characteristic of hydraulic dredging.

8.2.2.2 Identification of Dewatering Option

Mechanical dewatering was selected as the method of choice for the dewatering of dredged materials from Lily Pond. This selection was based on the relative scarcity or restricted access to large open (non-vegetated) and flat areas for conversion to settling lagoons near Lily Pond, the effectiveness of mechanical dewatering in handling fine silty material (M. Kennedy, pers. comm.), and the availability of a location for several filter belt press units (in area south of the Plant). Depending on the projected duration and disposal options, between 2 to 4 filter belt traffic that would be necessary to take the resultant filter cake from the presses and transport it to disposal areas. In addition, the potential for routing the supernatant through the residual settling lagoons may be a means of further improving water quality. However, this is contingent upon a lack of impacts to the lagoons normal operations. This would need to further pursued with the Water Department.

8.2.2.3 Identification of Dredge Disposal/Reuse Options

The proposed dredging program will result in the creation of approximately 38,000 - 56,000 CY of filter cake; estimated by conservatively assuming a de-watered moisture content of 50 – 75% and 75,000 CY of pond sediment removed. Based on the sediment characteristics described in Section 4.2.2, this material should not have any restrictions on reuse. Potential disposal/reuse options include use as topsoil or topsoil amendment, use in compositing or as construction fill, and daily cover at landfills. Potential usage is often dependent on the amount and timing of the material available. Given the uncertain schedule of funding for implementation of dredging, identification of potential disposal destinations is somewhat uncertain. More flexibility could be gained regarding disposal, if an arrangement can be made to temporarily stockpile dewatered material in the Charlie Pape Reservation lands, but this option needs further investigation. Based on typical disposal plans elsewhere, local facilities that could be contacted for potential disposal include the local contractors and landscape firms, the Cohasset Department of Public Works, and local landfills. Other potential destination could include golf courses (e.g., Cohasset Country Club) or remediation projects with a need for clean fill (e.g., former Naval Air Station at Weymouth). Further information and identification of the final disposal destination would be finalized as part of the design, specifications and environmental permitting.

8.2.2.4 Evaluation of Potential Impacts of Dredging Project

The following criteria were used for evaluating the potential impacts of the proposed dredging plan: technical feasibility, project cost, project duration, relative water quality impact, relative aquatic fauna impact, relative wetland impact, relative traffic impact, aesthetic impacts, and relative upland impact. The following is a brief description of how each criterion was evaluated for the proposed dredging project.

Technical Feasibility

The proposed dredging plan was deemed technically feasible, based on the method selected, known properties of the sediment and engineering judgement. Technically infeasible alternatives (i.e., dry dredging under drawdown conditions) were not further considered for selection.

Project Cost

The project team estimated the overall cost of the proposed dredging including design, construction, operation, and site restoration. Based on similar projects, the project team estimated a $12/ CY (in-lake) cost for this alternative. The costs associated with transporting the sediments to the reuse site were not included in the removal cost due the uncertainty of its locations, but were estimated at an additional $6/CY. This provides an overall planning estimate of $18/CY or, given the approximate 75,000 CY of sediment to be removed from Lily Pond, an approximate cost estimate of $1.35 M. Engineering and environmental permits are likely to be an additional $100,000 for an estimated project total of $1.45 M. This number would be further refined during preliminary design and permitting, but provides an informed order-of-magnitude estimate.

Project Duration

The project team estimated the total project duration based on dredge equipment, sediment dewatering rates, and filter belt equipment capacity. ENSR talked with Lars Garthe (Dredging Division Manager) Mobile Dredging and Pumping Company of Chester, PA, about how they did a similar lake dredging project at Hardy Pond (Waltham, MA) including mechanical dewatering. They consider the dewatering step as the potential rate-limiting step, but that dredging of a higher organic content sediment is quicker than a sandier substrate since the former dewaters better. Using standard inland dredge equipment, they can dredge at approximately 600 to 800 CY/day under typical favorable working conditions. With regard to the proposed Lily Pond dredging project, this translates into a project duration of from 90 to 125 day, so one working season is theoretically possible. However, this does not take into consideration mobilization/demobilization, set up and shoreline preparation, other pre-and post-dredging activities, nor any down time for either hydraulic dredge or dewatering belt filter presses or other delays (e.g., weather-related). Therefore, a conservative estimate would be at least some portion of two years. Accordingly, the project team estimated a period of two construction seasons to complete the dredging, dewatering and disposal of sediments, and restoration of the dewatering site.

Relative Water Quality Impact

The project team assessed the relative impact to in-lake water quality during dredging operations. The project was qualitatively estimated to have low, medium or high impact to pond water quality, based on the turbidity the proposed dredging method causes. (e.g., alternative options involving drawdown would be considered to have high impact). The project team rated this alternative's relative water quality impact as medium. Since the project uses hydraulic dredging, dredging-related turbidity will be minimized. The main potential for water quality impacts with this alternative is related to the quality of the dewatering return water. The return water from the on-shore dewatering process will need to be returned to the Pond away from the intake. However, the use of polymer coagulants should produce a relatively good water quality of the return water. Additionally, the filtrate could be pumped to either the Plant residual settling basins or a temporary settling area created with floating turbidity barriers within Lily Pond (but remote from the intakes).

ENSR judged that it will be possible to withdraw Pond water via the surface water intake when the hydraulic dredge is active except during periods when the dredge is relatively near intake. A floating turbidity barrier should be installed around the intake, but generally hydraulic dredges, because they act like a vacuum cleaner (i.e., drawing in water), do not generate much turbidity. If it is assumed that a 75 ft distance from the intake is a sufficient distance for not detecting significant turbidity arising from the dredging operation and an average of 5 ft of bottom sediment is taken, then roughly 1,650 CY will need to be removed during periods when the intakes are inactive. This sediment volume would translate into approximately 3 - 4 days of dredging at the dredging rates identified above (possibly less if longer work hours can be arranged) when the intake would need to be turned off and/or an alternative intake location (e.g., via portable pump and pipeline) used for the raw water source. Additional turbidity barriers may be installed to shield the water intakes during periods when wave or wind action concentrates turbidity at the northeast corner (or dredging temporarily halted).

Relative Aquatic Fauna Impact

An evaluation was made of the relative impacts to aquatic fauna, particularly fish and turtles, for the proposed project. Loss of aquatic fauna can be potentially high for any dredging operation, due to the nature of the activity. However, dredging programs that would segregate the active work area to a small portion of the lakes were rated as having a low impact to fauna.

Accordingly, the project team rated the proposed dredging project's relative aquatic fauna impact as low. Hydraulic dredging will only affect a small percentage of the lakes at one time, allowing much of the lakes' fauna access to the majority of the lake at all times. However, dredging operations by their nature can have a significant impact on benthic fauna (e.g., benthic invertebrates), but these communities typically rebound to pre-disturbed levels within 1-2 seasons.

Relative Wetland Impacts

An evaluation was made of the relative impacts to bordering vegetated wetlands (BVWs), especially those located along the southern Lily Pond shoreline and within the Bound Brook wetlands hydrologically connected via Herring Brook. The project team qualitatively rated the project as having a low, medium or high BVW impact based on the magnitude and duration of in-pond activity, associated turbidity, and an potential modifications of wetland interests. The quantity of work within buffer zone was also factored into this rating.

The project team rated this alternative's relative BVW impact as low. Hydraulic dredging will not result in excess turbidity and silts. The location of the project will not directly impact wetlands or their hydrology nor does it require significant construction within BVW buffer zone. Placement of filter belt presses and increased truck traffic at the Plant will require additional measures for protection of the Pond resource (erosion control and on-site spill containment, etc), but existing surfaces can be used. Any dewatered dredge material that is stockpiled will be enclosed by appropriate erosion and sedimentation controls.

Relative Traffic Impact

The project team qualitatively evaluated the relative traffic impacts for the project. The team deemed alternatives involving multiple moves of sediment near the project site as having a higher potential for traffic impacts. The project team rated the projects relative traffic impact as moderate. Some impacts of noise and traffic are possible due to the increased number of truck trips enter/exiting the Water Treatment Plant King Street entrance. Depending if the dewatered material is stockpiled at the Plant or in adjacent areas, multiple handling could be possible, but this will occur in areas not subject to normal traffic.

Aesthetic Impacts

The project team qualitatively evaluated the potential aesthetic impact of the project, including odor, noise and visual impacts. The project team rated this alternative's aesthetic impacts as low. Potential aesthetic impacts include visual and noise impact of dredging equipment and dewatering facilities, the latter being largely screened by vegetation and the Water Treatment plant, so visual impacts will be minimized. Noise impacts will be limited to dredge operation hours and the proposed dredging location minimizes visual impact on shoreline residences on the northeast shoreline of Lily Pond.

Relative Upland Impacts

The project team evaluated the relative disturbance of undeveloped upland areas associated with the project. The project team rated each alternative as having a low, medium, or high relative impact to undisturbed upland areas, based on the work required within such areas. The project team rated this proposed plan as having a relative upland impact as low. This alternative would not require significant development of vegetated upland. Potential stockpiling in the Pape Reservation (to be determined) would be a temporary measure.

Environmental Permitting

Dredging is a complicated and highly regulated activity, and the proposed project is no exception. Based on the size of the project (>10 acres), the scope (work within the WPA resource area), nature (dredging of 75,000 CY), and duration of the project it is anticipated it will require a MEPA Environmental Impact Report (EIR), a full Notice of Intent from the Cohasset

Conservation Commission, and the Massachusetts Department of Environmental Protection (MA DEP) Water Quality Certificate. As noted earlier, it is expected that the cost of obtaining this environmental permits is likely to cost a minimum of $100,000.

8.2.3 Water Quality Monitoring of Lily Pond

As part of the overall Pond Management plan, continued regular water quality monitoring of Lily Pond and its tributaries is recommended. This need has been largely address by the adoption of the Long-Term Sampling Plan for quarterly surface water monitoring recommended by the SWSPP (Section 4.3, Norfolk Ram Group, 2002) and fits in with other current monitoring efforts around the watershed. Currently, the Water Department is obtaining additional information regarding the annual sustainable yield of Bound Brook through a study that should further refine the hydrologic budget. The proposed set of water quality parameters described in SWSPP Table 4-3 is good, but total and dissolved phosphorus and nitrogen fractions (nitrate, ammonia, TKN) should be monitored at all stations to allow better definition of nutrient loads.

Sampling under wet conditions during spring and dry conditions in late summer is recommended as part of the quarterly schedule. This will allow sampling of spring runoff as well as characterization of the ecosystem during the period of maximum biological activity and biomass. Sampling of Brass Kettle and Peppermint Brooks near their respective inlets to Lily Pond is recommended, plus near-surface and near-bottom locations at the deepest point of the Pond, and Herring Brook outlet. At all stations, temperature dissolved oxygen, specific conductivity, and pH should be field monitored. Key water quality variables for the tributaries, the Pond, and outlet are turbidity, total suspended solids, chloride fecal coliform, total phosphorus and dissolved phosphorus and nitrogen fractions (nitrate, ammonia, TKN). Within the pond, water clarity (Secchi disk transparency) and dissolved oxygen and temperature depth profiles should be added to this list.

Assuming that all field sampling effort and water quality parameters listed in the SWSPP Table 4-3 are already addressed elsewhere (pers. comm. – J. McNabb), the additional water quality parameters recommended for Lily Pond (central location, shallow and deep) and two tributaries would cost an additional $3,000/yr. The proposed quarterly monitoring is highly recommended for keeping tabs on potential adverse impacts to Lily Pond water quality. On the other hand, a good monitoring database is also important for documenting potential future improvements in the water quality as a result of the recommended Pond management activities discussed above.

8.3 Implementation Steps and Costs

A summary of recommended actions and potential benefits for Lily Pond is provided in Table 26. Implementation actions, timeline, and associated costs for each of the recommended items is provided in Table 27. The following activities, with associated costs, are viewed as necessary to the implementation of the recommended management program:

1. Carefully review all existing and future development plans within the watershed for consistency with the Wetland Protection Act, the Storm Water Policy, the Rivers Protection Act, the Cohasset Stormwater Management Plan and Control Strategies, the Cohasset On-Site Wastewater Management Plan, and the NPDES program. These are normal functions of Town Commissions, but, if made necessary by the complexity of the proposed projects, any outside professional assistance for the Commissions is normally funded by the developer.

2. Develop an education package for restrictions and environmentally sound applications of lawn chemicals. This could be developed using existing brochures with minimal adaptation to Lily Pond watershed. Development of these brochures could be targeted for early spring 2003 for potential distribution at town meeting or for timely education prior to spring lawn maintenance.

3. Evaluate opportunities for retrofitting existing land parcels in the Peppermint Brook watershed with storm water management devices. This pond water quality investigation has identified this tributary as the one of concern and generally defined the types of land uses that need attention. Additional site specific investigation is encouraged to select the most appropriate locations. It is difficult to estimate the level of funding needed without a more detailed evaluation of stormwater routing along 3A, but this is likely to be identified by the Phase II Stormwater Regulations. Most simple detention/leaching facilities will carry a cost of $10,000 to $30,000. If it is assumed that up to five such facilities would be installed at an average cost of $20,000, the capital cost would be $100,000. Adding fees for investigation, design and monitoring, a cost estimate of $140,000 is appropriate. Non-point source pollution control grants are available through the EPA and DEP to fund this type of activity. This would be a gradually implemented program, with multiple opportunities for grants and cooperative arrangements.

4. Evaluate the existing discharge of the water treatment residual settling basins at the Water Treatment Plant and review methods to reduce the amount of TSS in discharge. This evaluation would be conducted by the Water Department staff. This evaluation should also consider excavation and removal of existing settled residual delta from Pond shoreline.

Table 26. Summary of Recommendations and Potential Benefits.

Recommendation	Reason/Issues	Potential Benefit
Watershed Management		
Land Use Restrictions	Increased or unplanned development can lead to a decline in water quality	Controlled development can protect water quality of Lily Pond and/or reduce impacts.
Storm Water Management	Storm water quality is poor and threatens Lily Pond potability. Storm water likely provides a substantial portion of the watershed nutrient loading.	Mitigating stormwater entering Lily Pond will improve water quality and reduce threat of spills/releases to the Pond.
Lawn Fertilizer Education	Improper lawn fertilizer application can increase nutrient loading to the pond, reducing water quality.	Educating residents on lawn care alternatives may decrease fertilizer application rates or encourage use of less damaging products resulting in improved water quality.
Settling Lagoon Improvement	Settling lagoons are currently discharging water treatment residuals to the Pond. A sediment delta has formed within the pond.	Improving the lagoons would improve water quality discharged to the lake, and reduce sedimentation rate, protecting pond storage capacity.
In-Lake Management		
Non-Mechanical Harvesting	Excessive rooted plant growths, resulting in clogged intake structure, high organic content in the pond, and poor aesthetics.	Relieve clogging of intake problems. Decrease overall organic content and decrease sedimentation from plant decay.
Hydraulic Dredging	Shallow water and nutrient rich sediment allows for extensive rooted plant growth and reduced storage capacity.	Reduce density of aquatic vegetation, decreasing likelihood of intake obstruction and increasing storage capacity.
Water Quality Monitoring	Continuing need to monitor water quality and quantity entering Lily Pond.	Create a large database for trend analysis from which future management alternatives can be evaluated Track efficacy of stormwater management.

Table 27. Implementation Actions, Timeline and Associated Costs

Action Item	Timeframe	Expected Cost	Notes
Watershed Management Controls			
Review development plans	Ongoing	Internal	Review by town boards for application to watershed
Develop lawn fertilization package	Spring 2003	$2,000	Via Water Commission public education program
Evaluate settling basin discharge mgmt	Summer 2003	Internal	Water Department internal review
Storm water management retrofits (prioritize sites on Peppermint Brook)			
Site specific investigation	Summer 2003	Internal	Coordinate with Phase II Stormwater Inventory
Plan/permit 5 sites	End of 2003	$40,000	Engineering and permitting costs
Implementation	End of 2004	$100,000	Installation capital cost
In-Lake Management Methods			
Conduct hand harvesting near intakes	Summer 2003	$3,000	Equipment plus annual maintenance (labor) costs
Dredging option	As feasible	$1.45 M	Cost based on estimated 75,000 CY removed
Conduct water quality monitoring	Ongoing	$3,000	Continue as SWSPP or contracted effort

5. Purchase simple non-mechanical harvesting equipment for periodic maintenance for plant control around intake area. Conduct harvesting as needed as short-term relief measure to prevent seasonal plant biomass blockage. An estimate of $3,000 is made for one-time purchase of equipment ($1,500) with annual labor estimated at $1,500.

6. Pursue options for conducting hydraulic dredging project within Lily Pond. An estimated 75,000 CY are targeted to be removed from northwest shoreline, with sediments dewatered near the Water Treatment Plant, and disposed offsite, away from Lily Pond. An estimated cost of $1.35 is provided for excavation, dewatering, transportation, and restoration of work areas. In addition, design and permitting for proposed dredging is expected to cost on the order of $100,000. This option is likely to be dependent on available funding and may take 1-2 years to fully develop. Further investigations of potential destinations for dewatered pond sediments and explore opportunities for temporarily stockpiling material in local open space lands should be conducted in the interim.

7. Continue quarterly water quality monitoring of Lily Pond and two tributaries on a seasonal basis as part of the Long Term monitoring proposed in the SWSPP and adopted by the Water Commission. Provided the SWSPP long-term sampling plan is conducted as indicated (Section 4.3, Norfolk Ram Group, 2002), the enhanced monitoring program for Lily Pond, its two tributaries, and outlet (5 stations) for the additional water quality parameters described above would cost about $3,000/yr.

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