LONG POND
ENVIRONMENTAL STATUS ASSESSMENT

Town of Tewksbury, Massachusetts

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Prepared for the Town of Tewksbury, MA

Provided By

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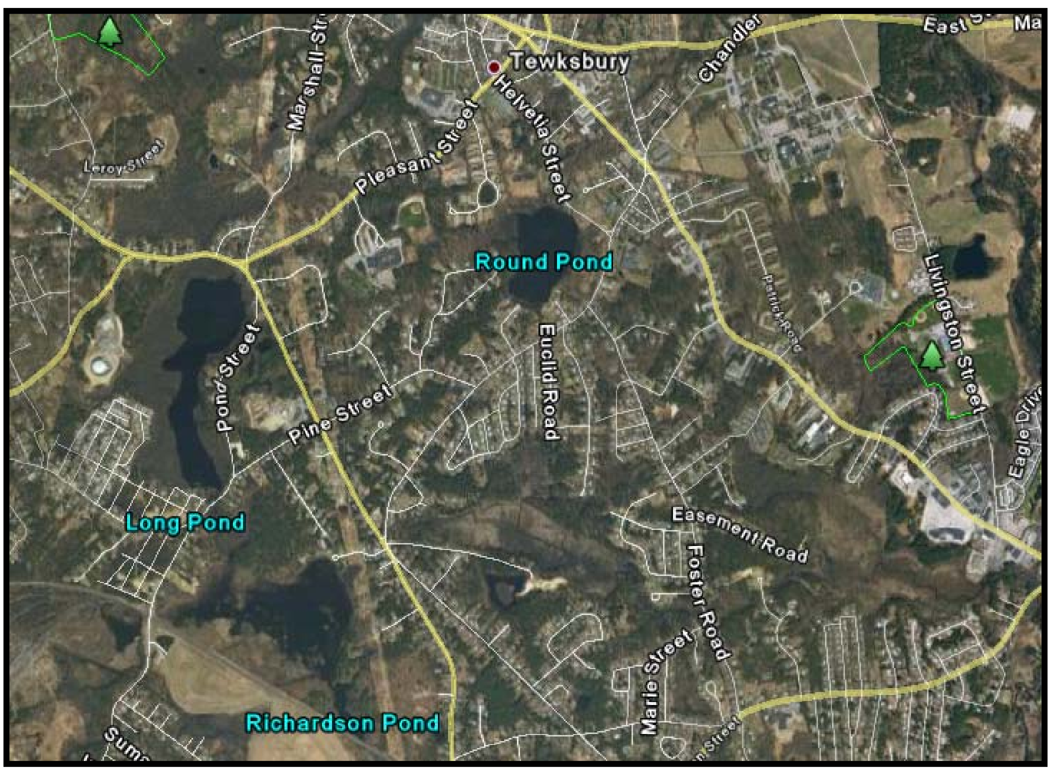
Table of Contents

A. HISTORICAL DATA

1. STUDY BACKGROUND

Long Pond in the Town of Tewksbury, MA is located in the southwestern portion of the Town. Long Pond is fed by a relatively small watershed and it drains to Richardson Pond in Billerica, MA and then to Content Brook and the Shawsheen River. Long Pond is classified as a "Great Pond" in Massachusetts having a surface area of 10 or more acres and as such it is subject to state Waterway Regulations, Chapter 91. Long Pond has had an extended history of poor water quality resulting in limited pond uses by Town residents. There have been several past studies of the Pond, including a study by Mistry Associates in the mid to late 1980's and a subsequent analysis and design report by SEA Consultants Inc. in 1989 to assess potential boat ramp construction and localized dredging options. Evaluations were primarily funded through a $150,000 grant from the Massachusetts Executive Office of Environmental Affairs (EOEA) for the purposes of controlling of algae and weeds, providing increased public access and conducting cleanup operations along the shoreline of Long Pond. Funding was also locally utilized to fund youth summer programs whereby teens would clean the shoreline of debris and vegetation to improve pond access and visibility. After funding was exhausted, Pond reclamation efforts took a down turn and little remediation work was conducted and the implementation of a boat ramp was, at least temporarily, abandoned. This current status report is being prepared with Community Preservation Act funding to establish an updated water quality baseline for the Pond and to provide insight to the Town as to potential remediation activities to enable increased use of Long Pond by Town residents, helping to preserve Long Pond as a community and recreational asset.



2. PREVIOUS POND STUDIES

A copy of the Mistry Associates Water Quality Report for Long Pond could not be obtained from the Town, so that this baseline data was unavailable for comparison purposes for this study. There was some limited water quality data available from a DEP/DWPC survey dated 6/20/89 which did show pond waters with low pH and defined oxygen depletion with depth. During that 1989 sampling, water depths average about 5 feet throughout the Pond and sediment was extremely fine. Macrophytes, attached algae and free floating algae were also present throughout the pond with encroaching shoreline vegetation. The only other related analysis data available for Long Pond was primarily associated with sediment samples collected from anticipated dredge areas near the proposed boat ramp/launch and swimming/beach areas. Those sediment samples were defined are mildly contaminated with oil and grease levels elevated in the proposed boat launch area which was proposed to be located close to Pond Street on the northeast edge of the pond. Sediment was a very fine textured material composed of silts and clays which was generally unsuitable for typical dewatering and disposal methods. The sediment samples quickly increased in organic content (over 55% volatile solids) and became finer (averaging about 90% passing a #200 sieve) as one moved away from the shoreline. Trace metals were relatively low in the sediment and no PCB's were detected. Overall, the material was classified as a Type C dredge and fill material limiting dewatering and disposal options. Excerpts of the previous sediment test data are included in Appendix A.

3. PREVIOUS WATERSHED STUDIES

There have been several Shawsheen River environmental assessments over the years but perhaps the most relevant was the "Shawsheen River Watershed Assessment Report 2002-2007" by EOEA. That study extended its analysis back into the river's sub-basins including the Heath/Content/Middle Shawsheen sub-basin which includes Long Pond. Appendix B contains relevant excerpts from that report including sub-basin maps and tables to be referenced later in this report. Although the scope of the Shawsheen River report focused on river flows and water quality issues, the report did define certain impacts of past urbanization on the watershed as a whole. Many of the induced stresses of urbanization on water bodies are evident within Long Pond's watershed. Specifically, water quality attributes have significantly degraded within the watershed as a result of urbanization. Bacterial contamination from septic systems, urban runoff, illicit connection to storm drains, waterfowl feces and agricultural pollution are all defined sources of contamination within the Long Pond watershed. Nutrient pollution from these same sources and residential lawn fertilizer are also clearly defined contributors to Long Pond's pollution problems. Urbanization has also resulted in the channelizing and piping of storm flows within the watershed expediting flows to the major streams and simultaneously reducing natural aquifer recharge and reducing baseflows within the area streams. By not allowing flows to to be detained and infiltrate into soils, natural filtration mechanisms are averted and the pollutional strength to stormwater flows increases. The reduction in base stream flow reduces macroinvertebrate populations within the streams limiting biodiversity and organism density. Lower baseflows also have impacts on summer mixing and flushing attributes of Long Pond, causing nutrients to be retained longer within the water body, promoting and enhancing both macrophyte and algae growth and further diminishing water body aesthetic attributes.

B. ENVIRONMENTAL STATUS ASSESSMENT

1. SCOPE OF WORK

The intended Scope of Work for this study was to assess past water quality data, assess the current conditions within the pond and formulate options for remediation efforts. The results of the investigations would be structure into an assessment report addressing four major tasks:

- i. Review and Analyze Past Studies and Recommendations
- ii. Watershed Based Nutrient and Water Quality Assessment
- iii. Nuisance Vegetation Assessment and Control
- iv. Formulate Potential Improvements, Identify Potential Funding Mechanisms for Remediation Efforts and Develop a Preliminary Management Plan

Field investigations would also be conducted to assess in-situ water quality and to make subjective estimations of macrophyte density within the pond. Watershed hydrology and hydraulics would also be evaluated in terms of aiding future remediation strategies.

2. FIELD SAMPLING AND TESTING EFFORTS

A field sampling and testing program was devised to allow a general assessment of water quality attributes and to provide a snap-shot of nutrient and bacterial conditions. The Scope of Work call for a single sampling which obviously limits any extensive analysis of seasonal and wet weather conditions which may exist. Authorization to proceed from the Town occurred in the late summer of 2007. Field efforts were immediately orchestrated to attempt to capture late summer vegetation proliferations and to evaluate resulting algae density and impacts on water clarity. Weather cooperated with the study intent, with warm weather extending through September 2007. On September 20, 2007 field sampling and testing efforts were conducted. Weather was clear, sunny and warm (rising to 80 degrees F) with mild winds gusting to only seven (7) mph. Seven (7) sampling locations were established within the pond and located using GPS location equipment. Sampling locations were spaced within the pond to help define tributary stream influences as well as establish ambient water quality gradients. The general flow within the pond runs from north to south with major inlets located in both the north and west quadrants of the pond. Sample location identification and location information is provided on the following two pages. In-situ monitoring was primarily conducted using a YSI Model 85 multi-parameter system monitor. In-situ monitoring included the following measurements: water depth (feet), secchi disk measurements (feet), temperature (degrees C), Dissolved Oxygen (% and mg/l), salinity (ppt), conductivity (uS) and specific conductance (uS). Since the water depth was generally only 4 to 5 feet throughout the pond, two in-situ water column measurements were taken at a 1 foot and 3 foot depth from the water surface. Visual observations were subjectively conducted of macrophyte density, free floating algae and bottom composition. At each sampling location, additional samples were collected for subsequent analytical evaluation. Sample were collected for Total Suspended Solids (mg/l), Turbidity (NTU), alkalinity (mg/l as $CaCO_3$), pH (SU), hardness (mg/l as $CaCO_3$), nitrate/nitrite nitrogen (mg/l), Total Kjeldahl nitrogen (mg/l), Total phosphorus (mg/l), fecal coliform bacteria (MF) (col/100ml), E. Coli (col/100ml), Enterococcus (col/100ml), and chlorophyll *a* (mg/m^3). QAQC included redundant blind sampling and laboratory confirmation of select field measures. Laboratory reports are included in Appendix C.

3. MONITORING RESULTS

Appendix C includes laboratory reports, field data summary sheets and also includes the data plots for each of the in-situ and laboratory sampling parameters. A brief summary of the findings and general analysis of the data is included below. Extend analysis relative to the pond tendency toward eutrophication and potential remediation measure is included later in the report.

Water Depth
Water depths were very shallow and uniform throughout the pond. Depth varied at the monitoring locations from 5.5 feet to 4.0 feet as follows: S1=5', S7=5.5', S2=4.5', S3=4.5', S4=4.5', S5=4.0', S6=4.5'. Additional depths were also taken between and adjacent to sample locations confirming the general uniformity of depth in open water areas. There were no deep pockets or valleys identified within the pond and no defined water column stratification.

Bottom Sediment Observations
The entire pond was underlain with 8 to 12 inches of extremely soft organic silt and sediment. The very soft bottom was loosely consolidated and could be easily penetrated. A cast 15 pound anchor was dropped at various locations and quickly became totally immersed with sediment. Anchor withdrawal easily re-suspended the sediment within the water column. Sediment color and odor became more indicative or advanced anaerobic states closer to the pond outlet. Substrate was considered "poor" for rooting of new macrophyte growth.

Secchi Disk Measurements
Secchi disk readings were extremely low, never extending more than 2 feet below the water surface. The water column was very turbid and with suspended algae. Reading were as follows: S1=2.0', S7=2.0', S2= 1.9', S3=1.75', S4=1.9', S5=2.0', S6=1.6'. Poor light penetration also hindered new and existing macrophyte growth and enhanced sunlight heating of the pond.

Temperature
Due to the continued warm weather experienced during the month of September, water column turbidity and the relative shallowness of the pond, ambient temperatures generally averaged close to 20 deg C (68 deg F) one foot below the surface with a 1 to 2 degrees C drop in temperature at a depth of 3 feet. A slightly declining temperature gradient was discernable from inlet (north) (sample location S6) to outlet (south) (sample location S1) of about 2 degrees C. There was also a defined 5 degree C spike in the upper water column temperature at the Ponds mid-point (sample location S3) which is characterized by its most narrow open water section and fairly high densities of both macrophytes and suspended algae. Lower than normal secchi disk readings at this location and elevated chlorophyll *a* measurements lead to the conclusion that the temperature spike to induced by sunlight absorption of aquatic plant species.

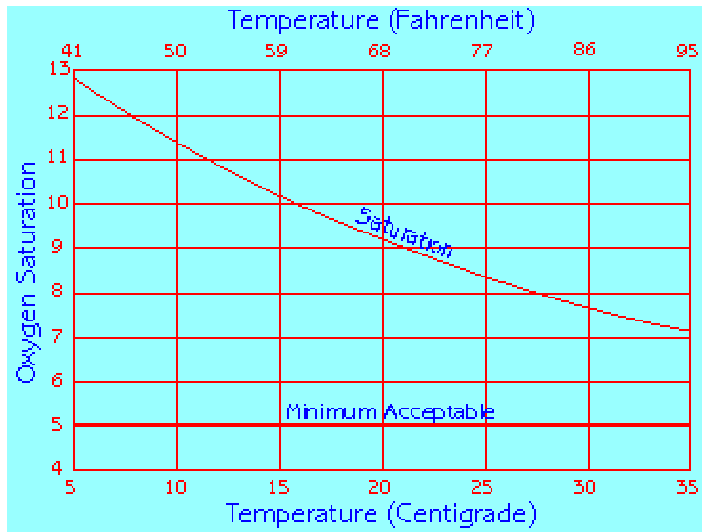
pH
Acid rain influences have been defined for decades in New England and the limited 1989 sampling data available for pH indicated values as low as 5.4 SU within the pond. During our field investigations pH values were measured via color indicating test strips and additional samples were sent to the laboratory for confirmatory testing. Measured levels were excellent

throughout the pond ranging from 6.5 to 7.5 with confirmatory lab testing ranging from 7.0 to 7.2, essentially neutral. This is not to say that pH fluctuations do not occur during wet weather periods. The field sampling had been preceded by relatively dry weather and available pond alkalinity may also have contributed to maintaining the more neutral readings observed.

Dissolved Oxygen

Dissolved oxygen was measured as both temperature corrected concentration in mg/l and % air saturation at both the 1 foot and 3 foot depths. Reading were taken at mid-day and as expected aquatic weeds and algae provided extensive photosynthesis to boost water column dissolved oxygen to near full saturation. Lower depths did see slight reductions dipping to about 70 % saturation, but generally all readings were in the 80% or higher level. A slight gradient in dissolved oxygen concentration was evident from inlet to outlet and paralleled that of temperature, but contrary to general trends as depicted in the following chart. A slightly higher oxygen concentration was evident at the warmer inlet end of the pond giving some indication of the possibility of oxygen uptake occurring by benthic deposits within the pond as water moved through the pond. Given the extensive amount of water column algae present and the extensive soft organic sediment at the bottom of the pond, it is anticipated that severe oxygen sags or depletion could be occurring during night-time respiration of plant species. Periodic anchoring within the pond resulted in significant release of gases from benthic anaerobic decomposition. Gas release volumes increased toward the outlet end of the pond, where detritus would normally accumulate, reinforcing the oxygen depletion premise.

Oxygen Saturation vs Temperature



Salinity

Freshwater bodies generally have low salinity values below 1ppt. Roadway de-icing materials and some fertilizers can sometimes increase the salinity of fresh water bodies. Seasonally, salinity levels can also varying as such salts may slowly be flushed from the system or otherwise bound and precipitated from solution. Salinity levels throughout Long Pond were low measuring at 0.2 ppt at all sampling locations.

Alkalinity

Alkalinity varies in water bodies depending of many numerous conditions including groundwater recharge, geology, pollutant influences and urban/agricultural pollution. Most New England surface water bodies range below 100 mg/l. Acid rain and ammonia pollution can cause a further reduction in available alkalinity. Within Long Pond, alkalinity measurements were very consistent at 28-29 mg/l at all sampling locations indicating minimal pH buffering capacity.

Conductivity and Specific Conductance (Temperature Corrected Conductivity)
These two parameters are measures of the ability of the water to conduct electrical current and they are directly related to the concentration of free ions in solution. Generally higher values can indicate urban or agricultural pollution in the form of nitrogen and phosphorous. Monitored values were generally higher at the inlet end of the pond and lower at the outlet end with a slight increase close to the homes on Pond Street near the narrow mid-point of the pond. Salinity can often raise the specific conductance, but in this case, where salinity values were uniformly low throughout the pond, septic system leachate or agricultural runoff may be more of an influence.

Hardness
Hardness is an indicator or mineral content and also an indicator of free ions in solution. New England surface waters are usually what is referred to as "soft" or having hardness values less than 60 mg/l. Examining the laboratory testing results reveals that all samples were essentially the same and ranged from 59 to 62 mg/l. Although not a significant eutrophic indicator, elevated hardness values can indicate pollution influences.

Turbidity
Turbidity is the laboratory equivalent of field secchi disk readings. As turbidity increases, the ability for light to penetrate the water column decreases resulting in lower secchi disk readings. Comparing the disk reading to turbidity values show a proportional response except that S5 secchi disks were slightly better than anticipated. Turbidity ranged from 6.4 to 9.2 NTU indicating a very murky and turbid water column. Generally this is associated with water color and suspended algae growth resulting from an excess level of nutrients in the water body.

Total Suspended Solids
Another parameter that helps to define the extent of algae associated with high turbidity and in contrast to color is Total Suspended Solids (TSS) which defines the amount of filterable material within the water sample. Examining the plot of TSS and turbidity reveals a very similar trend indicating that suspended algae is a major component of the overall turbidity of the sample. Direct observation of the samples also confirmed this trend. The only sample uncharacteristic of the trend was the TSS sample at location S1. S1 is located at the outlet end of the pond and free floating algae was observed to be more concentrated at this location and could have contributed to the slightly higher TSS concentration in this sample.

Nitrate/Nitrite Nitrogen
Samples were collected for Nitrate/Nitrite to enhance detection of partially reduced sources of urban pollution typically related to septic system leachate, agricultural pollution and benthic activity. Laboratory results indicated that levels were all below the 0.1 mg/l detection limit.

Total Kjeldahl Nitrogen (TKN)
TKN is a measure of organic nitrogen and ammonia in a water body. Generally a Total Nitrogen to Total Phosphorous ratio of 15:1 is considered an equilibrium nutrient balance for freshwater bodies. If the ratio is lower say 10:1, the system is nitrogen limited. TKN values are generally less than 3.0 mg/l in freshwater bodies with values above 1.0 mg/l clearly indicating nutrient pollution. Measured values for the pond averaged around 1.0 mg/l (ranging from less than 0.5 mg/l to 1.8 mg/l) showing somewhat inconclusive data relative to pollution influences.

Total Phosphorus (TP)

In most fresh water systems, phosphorus is typically the limiting nutrient which controls aquatic plant productivity. Some limnologists believe TP levels above 21 ug/l (0.021 mg/l) will promote eutrophic conditions. Water quality samples throughout the pond showed significant TP levels, ranging from 100 ug/l to 120 ug/l. As mentioned previously, a TN/TP ratio of 15:1 is generally considered to be nutrient equilibrium for fresh water bodies. Examining the sample sites individually yields ratios below this value in most cases indicating that there is excess phosphorus and that nitrogen is the limiting nutrient. The only exception is in the case of location S4 which had the highest TKN level at 1.8 mg/l. S4 is a somewhat isolated pocket of the pond which also has flow entering from a western tributary stream/channel which runs between a trailer park and commercial/industrial area. In the case of S4, both nutrients are very high in relation to what is typically considered to be promoting of eutrophication.

Chlorophyll a

Chlorophyll *a* is an excellent measure of water column algae/phytoplankton concentrations and an indicator of the water bodies eutrophic tendencies. Eutrophic water bodies often have chlorophyll *a* concentrations above 11 mg/m^3. Examining the test results, all sample sites were above this level with an average approximately 13.5 mg/m^3. The green/brown water tint evident during the sampling effort in all areas of the pond, helped to visually confirm the laboratory results of high concentration.

Fecal Coliform Bacteria (MF)

This is one of three bacterial monitoring parameters utilized during the study. Fecal coliform bacteria (using Membrane Filter (MF) method) are indicating organisms which are generally present at higher concentrations in the intestinal tracts of warm blooded animals. Although they can also be present in soils, high concentrations in water can be attributed to recent fecal contamination from septic systems, mammal feces and bird feces. Massachusetts water quality standards for recreational waters (including swimming and fishing) prior to January 1, 2007 required a geometric mean concentration for fecal coliform of less than 200 colonies/100 ml. Starting after January 1, 2007, Massachusetts began to use E. coli and enterococcus bacteria for water quality monitoring compliance. Although one sampling is not enough to ascertain if these health safety levels are satisfied, all sample test results were below 60 colonies/100 ml with an average of about 16 colonies/100ml. It should be noted that wet weather conditions and urban runoff often significantly increase fecal coliform level in receiving water systems. To properly assess public health concerns for Long Pond, more extensive testing would be required.

E. Coli

Escherichia coli (or E. coli) is a group of fecal coliform bacteria which are generally found in the intestinal tracts of warm blooded animals (humans, mammals and bird) and not generally in soils. By testing for E. coli one can better confirm the extent of bacterial contamination associated with fecal matter. Sample test results ranged from 2 to 23 colonies/100 ml with an average of 13 colonies/100ml. Massachusetts recently set the E. coli water quality standard at a geometric mean of 126 colonies/100ml for recreational activities. As noted above, one sampling is not enough to ascertain if these health safety levels are satisfied or if wet weather influences significantly impact the water body’s ability to meet these standards.

Enterococcus
The last bacterial indicator utilized in the study was enterococcus bacteria. Enterococcus are a subgroup of the fecal streptococci and are also found in the intestinal tracts of warm blooded animals (humans, mammals and bird) and not generally found in soils. Enterococcus bactertia have a higher survival rates in the environment and thus are better public health indicators than fecal coliform bacteria. Massachusetts has established a water quality standard of a geometric mean of 33 colonies/100 ml for recreational waters. Examining the sample test data, values ranged from 0 to 5 colonies/100ml indicating little contamination. As with the other bacterial indicators, one sampling is not enough to ascertain if these health safety levels are satisfied or if wet weather influences significantly impact the water body's ability to meet these standards.

Based the recent water quality testing, recreational uses do indeed appear feasible; however as outlined earlier, the recent testing is isolated to one specific window of time and seasonal and wet weather variations to water quality are likely different from what was monitored in September 2007. To ensure that the water quality is conducive to the recreational uses anticipated, additional bacteria and water quality testing is recommended three (3) times over the intented use period (June, July and August) and for at least two (2) post wet weather events. This will enable a better determination if water contact uses can be safely implemented to justify the expenditure for the various improvement measures.

4. ADDITIONAL EVIDENCE OF POLLUTION STRESSES

An examination of available aerial photography of the area helps to visually define nutrient loading to the pond through vegetation densities. To more clearly depict this condition, two aerial photos were color enhanced to reveal the changing vegetation density (defined by changing color) across the pond. The photos define varying macrophytes (aquatic weeds) densities depicted by shaded areas within the pond. The photos clearly define a density gradient of vegetation across the pond and the greatest source of nutrient contamination apparently emanating from the northern inlet of the pond.

INLET END OF LONG POND

MID-POINT OF LONG POND

There are several strategies for classifying lakes and ponds relative to their hydro-geologic state and the extent of eutrophication which may be present. Various studies have attempted to categorize such water bodies based upon analytical testing data, particularly using Total Phosphorus, chlorophyll *a* and secchi disk readings. One author, established the following table as a guide.

PHOSPHORUS AND CHLOROPHYLL CONCENTRATIONS AND SECCHI DISK DEPTHS CHARACTERISTIC OF THE TROPHIC CLASSIFICATION OF LAKES			
MEASURED PARAMETER	**Oligotrophic**	**Mesotrophic**	**Eutrophic**
Total Phosphorus (mg/m3) Average	**8**	**26.7**	**84.4**
Range	**3.0 - 17.7**	**10.9 - 95.6**	**16 – 386**
Chlorophyll *a* (mg/m3) Average	**1.7**	**4.7**	**14.3**
Range	**0.3 - 4.5**	**3 – 11**	**3 – 78**
Secchi Disk Depth (m) Average	**9.9**	**4.2**	**2.45**
Range	**5.4 - 28.3**	**1.5 – 8.1**	**0.8 – 7.0**
Wetzel, R.G. 1983. *Limnology*. Philadelphia, W.B. Saunders Co., 767 pp.			

Comparing this data to the analytical data derived during our 9/20/07 sampling, we find that all three parameters are clearly within the Eutrophic ranges (Average Values: Total Phosphorus =108 ug/l (108 mg/m^3), Chlorophyll *a* =13.5 mg/m^3 (13.5 ug/l) , and Secci disk = 1.88' (0.58 m).

A similar evaluation method involves calculating the Trophic State Index (TSI) for the water body. One index in common use was developed by Dr. Robert Carlson in 1977. The Carlson TSI was developed for northern temperate lakes and ponds. The index utilized the same three parameters, Secchi disk, Total Phosphorus and Chloraphyll *a* and uses defined logarithmic relationships to develop an indexing system for water bodies using each parameter. The relationship between the TSI indexes is defined on the following table based upon typical water body characteristics.

Relationship Between TSI Variables	Conditions
TSI(Chl) = TSI(TP) = TSI(SD)	Algae dominate light attenuation; TN/TP ~ 33:1
TSI(Chl) > TSI(SD)	Large particulates, such as *Aphanizomenon* flakes, dominate
TSI(TP) = TSI(SD) > TSI(CHL)	Non-algal particulates or color dominate light attenuation
TSI(SD) = TSI(CHL) > TSI(TP)	Phosphorus limits algal biomass (TN/TP >33:1)
TSI(TP) >TSI(CHL) = TSI(SD)	Algae dominate light attenuation but some factor such as nitrogen limitation, zooplankton grazing or toxics limit algal biomass.

Developing these Carlson TSI values for Long Pond results in the following estimations:

<u>Secchi Disk Calculations</u>
Average (Summer) Secchi disk = 1.88 feet = 0.58 meters
TSI = 60 - 14.41 (ln Secchi disk (meters))
TSI = 60 - (14.41) (-0.545)
TSI (SD)= 67.85

<u>Total Phosphorus Calculations</u>
Average (Summer) Surface Total Phosphorus = 108 ug/L
TSI = 14.42 (ln Total phosphorus (ug/L)) + 4.15
TSI = (14.42) (4.682) + 4.15
TSI (TP)= 71.67

<u>Chlorophyll *a* Calculations</u>
Average (Summer) Chlorophyll *a* = 13.5 g/L
TSI = (9.81) (ln Chlorophyll *a* (ug/L)) + 30.6
TSI = (9.81) (2.60) + 30.6
TSI (CHL)= 56.13

In this case, TSI (SD) is close to TSI (TP) but both are greater than TSI (CHL). Using the table on the previous page, it would appear that “Non-algal particulates or color dominate light attenuation” is occurring in the pond. Indeed, the water clarity is extremely limited, but the Secchi Disk and Total Phosphorus readings are also at the extreme end of the range for typical eutrophic attributes. To more precisely define eutrophic conditions we also examined the data against typical ranges for the parameter. In the case of Long Pond Total Phosphorus (TP) is the most extreme value in the Trophic State Index. The table on the following page depicts the “typical” range of parameter concentrations, the related TSI index and water body attributes normally associated with those values. According to this table, a TSI (TP) of roughly 72 would classify Long Pond as Hypereutrophic with light limiting productivity and dense algae and macrophytes. Hypereutrophic water bodies are in their last stages of hydro-geologic development.

During the field sampling and survey efforts, there were defined areas of macrophyte development, but dense macrophyte beds did not underlie all areas of the pond which was unusual for a water body with such shallow water column depths. Dense macrophyte populations were flourishing near the outlet end of the pond but beds were less dense as turbidity increased moving north along the pond. Water column turbidity appeared to be hindering macrophyte growth and the extremely soft, fine and thick sediment deposits within those portions of the pond also appeared to provide less suitable substrate for rooting species. Reviewing past aerial photos to field visual observations suggested that the lush macrophyte beds may have been subject to a "die off" in recent years. High anaerobic decomposition at the southern end of the pond may be attributed to the resulting detritus being transported to the outlet end of the pond after the "die off" occurred. This is not to say that macrophytes were eliminated in areas, which is not the case, only that the anticipated density was much lower than anticipated given historical aerial photos. Referring back to the following table, it is almost as if the pond was now entering the highest TSI level when macrophyte density reduction begins to occur.

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

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

When one examines the aerial extent of Long Pond, one quickly notices that the shoreline of the pond is comprised of extensive marginal wetland species and that these species appear to be expanding limiting the extent of open water within the pond. This is a typical eutrophic attribute whereby fringe areas become gorged with marginal wetland species which are nourished by high nutrient levels and as they grow, they trap more detritus and sediment eventually resulting in shallower fringe areas and a slow conversion of the pond to a swamp and then wet meadow. It is extremely difficult if not impossible to reverse this process without extensive dredging, watershed nutrient controls and flow manipulation/augmentation measures which are difficult to economically justify. In terms of Long Pond, watershed controls would likely be the most cost effective since the watershed is relatively small and there may be some potential for seasonal flow augmentation which could better flush the pond of both nutrient and soft sediment. Limited dredging may be feasible but more extensive analysis would be required to define cost/benefit aspects. Remediation measures will be addressed later in this report.

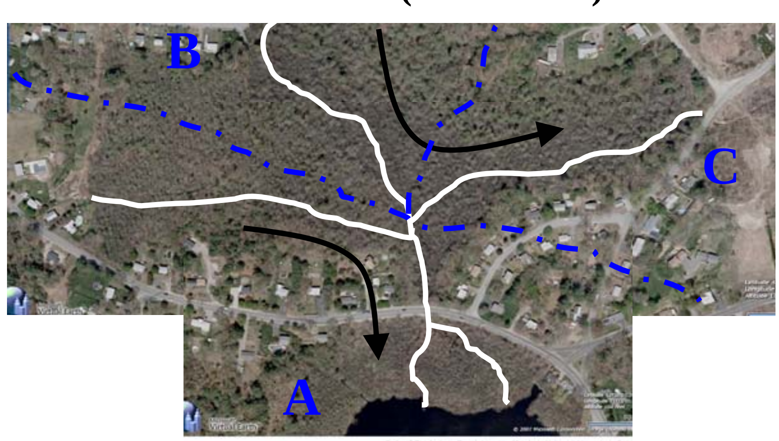
C. POTENTIAL REMEDIATION STRATEGIES

1. WATERSHED CHARACTERISTICS AND CONTROLS

Watershed controls have taken front stage in recent years with state and federal authorities promoting stormwater pollution control strategies and watershed based nutrient modeling. A vast array of pollution attenuation measures have emerged under what is commonly referred to as Best Management Practices (BMP's). Watershed control strategies and BMP's detain and treat urban pollution to reduce pollutant and nutrient loadings into our water bodies helping to preserve and often improve water quality. The Long Pond watershed has evolved over the last few centuries as urbanization occurred and development expanded. Natural water routes have been interrupted and baseflow within area streams has been significantly curtailed. As a result, the existing watershed adds significant nutrient loading to the pond while minimizing prolonged flushing attributes. Stormwater flows quickly wash urban areas clean flushing nutrients and pollution into the pond, concentrating in sediments and nourishing aquatic plants and algae.

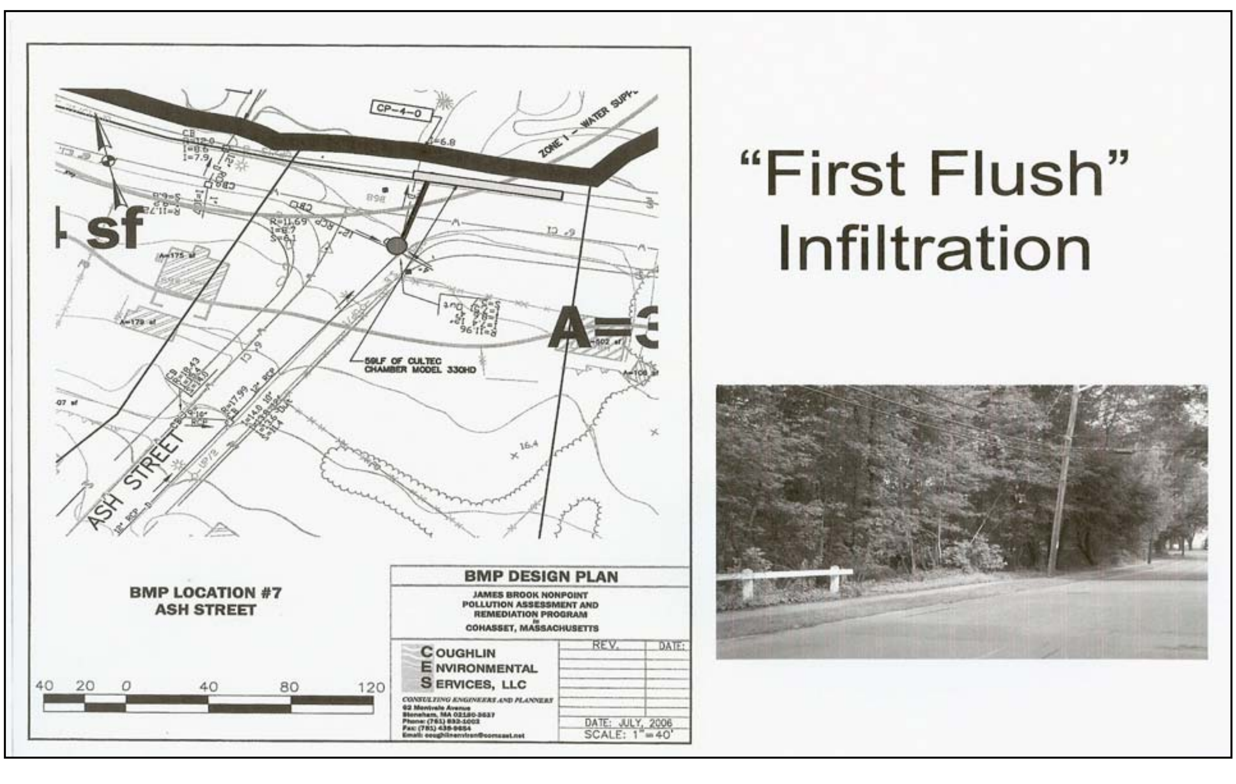
To better assess potential watershed controls that can be conducted, the first step is to define the limits of the watershed and its current land uses. Appendix D provides sub-watershed delineation runs for the watershed utilizing USGS StreamStats computational software. The following Land Use Plan on the next page has been overlaid with the sub-watershed delineations to provide a graphic overview of the tributary areas. Sub-watershed area "A" is the currently defined watershed for Long Pond. The watershed is approximately 0.96 square miles, has an average slope of 1.43%, has a stratified drift per stream length ratio of 0.85 and has a 7Q10 (7-day, 10 year low flow) baseflow of 0.0866 cfs through the watershed. Based upon watershed wide assessment of historical flows, these baseflows are believed to be more than 12% lower than those experienced about fifty year ago as a direct result of urbanization. As development density increases, these baseflows could further decrease and further jeopardize bio-diversity within area streams. Sub-watershed areas "B" and "C" depict two proximate sub-basins. Area "B" flows through a wetland area to the north of Long Pond and then flows into area "C" the upper watershed of Marshall Brook. Examining the extent of the wetland to the north of Long Pond, several channels tread through the wetland and channel shapes suggest that at one time, or perhaps during intense storm events, portions of area "B" may flow to Long Pond. The aerial view of this northern wetland at the right shows the current flow paths defined by black arrows, and watershed boundary (blue dashed line). The wetland channel configuration (shown in white) suggests that flows once continued to Long Pond adding additional flushing waters. The wetland channels are very overgrown and sediment deposition could have caused flow to be re-directed toward Marshall Brook over time.

LONG POND (North Inlet)



Nutrient contamination in a water body generally comes in the forms of phosphorus and nitrogen. Phosphorus is primarily added to the watershed from septic systems, lawn fertilizers and various agricultural uses. It can be stored in aquatic sediment and re-released at later dates if disturbed, through biological mechanisms or simply based upon sediment/water column concentration gradients . It is also present in plant materials and detritus deposited in the watershed. When introduced into subsurface soils such as through septic systems, it typically can be bound to the soils generally within 400 feet of the source providing that the nature, texture and exchange potential (cation exchange) of the soils provide suitable contact and adsorption with soil particles. Nitrogen can move more freely in groundwater systems, so it is important to try to reduce nitrogen loadings at the source or to establish vegetated treated systems to help remove the nitrogen before it enters tributary streams.

Further examining the Land Use Plan in areas "A" and "B" indicate a predominance of primarily single family residential uses with more limited industrial and agricultural land uses. Watershed controls for residential properties to reduce nutrient loadings include sewer expansion, local lawn fertilizer application restrictions, implementation of rain garden and other BMP's to promote stormwater detention and infiltration, drainage system modifications to attenuate runoff flow, drainage collection system modifications to collect, trap and treat urban runoff and road-side runoff vegetation practices to promote attenuation of pollutants.



Septic system can add significant nitrogen loadings to a groundwater system often at concentrations as high as 45 mg/l. The Town has undertaken an extensive sewer expansion campaign over the last eight years to bring this environmentally sound utility service to its residents. Mainline sewer is currently being completed in the northern reaches of the tributary watershed, but homes most proximate to the pond should also be required to connect. It is often the homes within 400 feet of a watershed or its tributaries that influence water quality the most, because the travel time of the nutrients is significantly reduced. In the immediate proximity of Long Pond there are numerous residential properties. A large trailer home park, primarily in Billerica has now been sewered, but there are several homes along Pond Street which still need to be connected to sewer, many within 400 feet of the waters edge. Activation of service connections for homes on the newly expanded sewer system should also be promoted and expedited as feasible.

Lawn fertilizers are more difficult to regulate within a watershed. Some communities now require commercial application companies to register within their towns and submit a list of application addresses and annual loading information in addition to the existing state reporting requirements. Although such data generally does not include “owner applied” fertilizer applications it can provide a community with baseline data to qualify the extent of problem which may exist. By collecting this data, communities plan to begin to designate “low application” zones based upon watershed characteristics and sensitive water resource receptors.

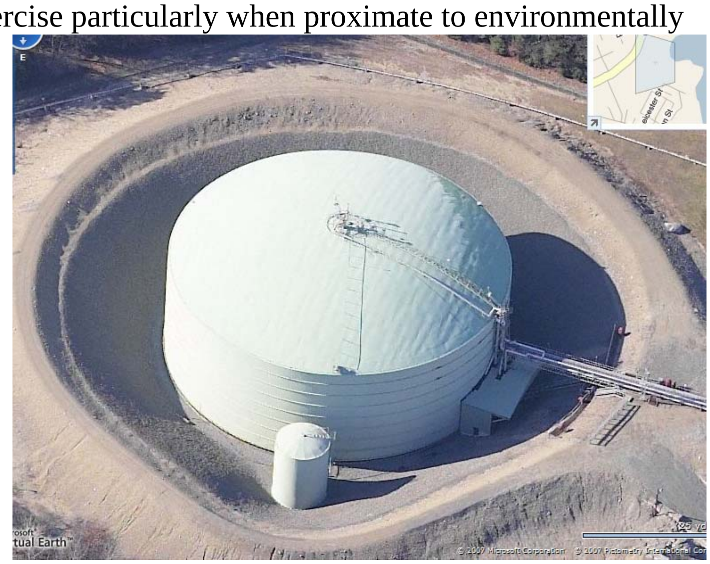
Agricultural influences on first examination appear light; however, a more detailed examination of the watershed do reveal some more direct influences which can be better managed. Sub-watershed “B” had two potential significant pollution contributors, one an active farm with livestock and the other a vehicle and material storage area north of Long Pond.

Potential for direct manure contamination of runoff and wetland

As evident from the photo at the right, livestock grazing occurs adjacent to the wetland area. During wet weather, surface runoff washes livestock fecal matter into the wetland north of Long Pond. The adjacent open water wetland area proximate to the farm also appears to be under stress with extensive macrophytes and wetland vegetation evident in the blow-up of the open water section. As previously discussed, normal flow from this area now appears to flow to Marshall Brook, but would still have to enter the "shared" wetland just north of Long Pond. Surface runoff collection and settling prior to allowing flow to enter the wetland, can provide significant reduction of such fecal /nutrient pollution.

The other site north of the pond which also has a potential for watershed contamination is the vehicle and material storage area previously referenced. Further examination of the area via aerial photo does show that stockpile areas are somewhat removed from wetland buffers and the area may not pose a significant threat at this time, but the site should be monitored to ensure that site practices reduce stormwater runoff pollution and that site activities do not pose any other environmental threat to either surface or groundwater systems as may be related to hazardous materials, fluids and toxics. It was recently discovered that this site may have previously been the subject of a MADEP Wetland Enforcement Order.

Industrial sites can also exercise BMP's and enhanced pollution prevention. Vegetation practices to be implemented to clean runoff from paved and impervious surfaces. Various infiltration methodologies can also be installed to detain and clean flows before they enter area streams. Enhanced chemical and toxic containment methods should also be exercise particularly when proximate to environmentally sensitive areas. The industrial property (LPG Storage) due west of Long Pond (shown at right) has earthen containment facilities around its storage tank, so it is less susceptible to spills and leaks; however, vehicular traffic associated with such facilities can also result in pollutional stresses and oil/grease containment methods should be enhanced on such sites when feasible. We should note that several Long Pond sediment samples tested during the 1989 study showed oil and grease contamination.



2. AQUATIC WEED CONTROL

There are several chemical and physical methods for the control of aquatic weeds, both attached and free floating. During our field investigations, free floating weeds were not a significant problem through most of the pond except for the outlet or southern end. Historical aerial photos do show dense macrophyte beds especially at the northern end of the pond, but as mentioned earlier, water column turbidity appears to have hindered their growth to some degree as visually evident during the field sampling program. Macrophyte density could also be seasonally variable as water column algae and turbidity increases through the summer growing months. Follow up surveys may be appropriate to ascertain such seasonal variations.

Physical weed control practices for shallow ponds typically involve vegetation harvesting using a floating harvester such as that depicted at the side. This type of control method, if permitted, must generally be instituted every few years depending of weed growth rates and in the case of Long Pond, annual harvesting may be appropriate. Such procedures are both expensive and disruptive to pond ecology, but it does provide a mechanism to increase recreational uses, remove nutrient laden vegetation and reduce detritus deposition within the pond. Access for the harvester and vegetation removal equipment would be required beyond what is currently available. Vegetation can be composted, but organic decay and odor issues may be a concern if composting operations are not adapted for the material. Strategies for harvesting can also be varied for each water body and for specific intended uses. An option to the 1989 strategies when extensive dredging was proposed is to exercise harvesting practices in those areas instead of dredging. This option will not deepen the water body beyond its existing 4 to 4.5 feet, but it may open up the water body to increased recreational uses. Another harvesting strategy is to remove vegetation along a central axis within the pond. For example, a 50 foot wide swath could be harvested from the northern inlet all the way to the southern outlet. Since aquatic weeds impede flow through the pond and promote detritus to settle in the pond due to decrease velocities, a clear channel through the pond's center can promote flushing of seasonal nutrient loadings, soft sediment and detritus. An open water section void of large macrophytes will allow slightly increased velocities through the pond and helping to reduce the current "plug flow" characteristics. The benefits of such a program would need to be verified by a re-inspection of the macrophyte densities at various seasonal intervals. A higher velocity zone may also benefit the removal and/or concentration of soft sediment within the pond helping to prolong its useful life. A related strategy would include implementing dredging along a central axis in a similar fashion, which will be discussed later in this document. Axis dredging would create a deeper channel through the pond enhancing abutting sediment transport toward a central area verse across the pond's length.

Besides physical weed control strategies, chemical controls are also available with proper permitting. Chemicals include a variety of aquatic herbicides which are regulated state to state and would require permitting for use prior to application. As discussed earlier, periodic seasonal inspections would need to be conducted to assess what specific aquatic species would need to be addressed and at what points in the season to enhance recreational uses. Since Long Pond immediately discharges into another water body, Richardson's Pond, in Billerica, MA, multi-town and state permitting requirements would be needed and control strategies would need to be assesses by both communities. The chemicals have specific uses, applications methods and use restrictions and as such, uses need to be specifically tailored to the pond's seasonal needs. As a general guide for typical products, application doses and use restrictions, tables detailing such are provided on the following pages. (Source: Nuisance Aquatic Vegetation Management (A Guidebook) State of Connecticut, March 2005)

Given the limited survey performed on 9/20/07 during the water quality sampling program, macrophyte and water column algae would be the primary items for control it some emergent vegetation controls being also utilized at future public access points. In addition, limited free floating plant controls could also be exercised at the pond outlet. Our recommended chemical control strategy to address these issues would likely entail Copper sulfate application for water column algae and diquat (Weedtrine D or REWARD) in various application concentration to control the various rooted and free floating vegetation. As an alternate to the diquat, flouridone (SONAR or AVAST) could also be utilized in both pellet and liquid form depending upon the rooted or free floating weed control uses respectively, but would need more restrictive controls after application and proximate water uses downstream would also need to be identified. Irrigation uses and water supply wells would be of particular concern when using flouidone control products. Selection between diquat and flouridone will depend upon seasonal weed variations and regulatory authority preferences.

<u>DOSAGE TABLES</u>

The following tables are subject to change. Pesticide products and labels may change and new products and labels are frequently introduced. Before using any pesticide product, the specific product label should be consulted to determine the exact dosage rates. Labels contain the legal requirements for pesticide product use.

Listed below are the dosages recommended by the manufacturers of algicides and herbicides used for effective control of the aquatic plants described in this brochure.

Unicellular Algae	
CHEMICAL	DOSAGE
Copper Sulfate	0.7 - 2.8 lbs. per acre foot
Liquid Copper TEA	0.6 gal. per acre foot
Light blocking dye	0.25 gal. per acre foot
Dimethylcocoamine salt of endothall (Hydrothol)	0.6 - 2.2 pints per acre foot

Filamentous Algae	
CHEMICAL	DOSAGE
Cutrine Granular (for bottom growth)	60 lbs. per surface acre
Liquid Copper TEA	0.6 gal. per acre foot
Copper Sulfate	0.7 - 2.8 lbs. per acre foot
Diquat	1 - 2 gal. per surface acre
Light blocking dye	0.25 gal. per acre foot
Dimethylcocoamine salt of endothall (Hydrothol)	0.6 - 2.2 pints per acre foot

COPPER SULFATE DOSE TABLE: (Maximum Rates)		
Trout or Triploid Grass Carp Present	0.25 ppm	0.7 lbs. per acre foot
Warm water fish (Bass, sunfish, perch) present	0.5 ppm	1.4 lbs. per acre foot
No fish present	1.0 ppm	2.8 lbs. per acre foot

Stoneworts *(Chara, Nitella)*	
CHEMICAL	DOSAGE
Liquid Copper TEA	1.2 gal per acre foot
Granular Cutrine	60 lbs. per surface acre

Duckweed and Watermeal	
CHEMICAL	DOSAGE
Diquat	1 gal. per surface acre (diluted in 50-150 gal. of water) sprayed directly on plants
Weedtrine D diquat	5 gal. per surface acre
Fluridone Liquid	0.16 - .025 qts. per acre foot (dilute and spray directly on plants)

Water Milfoil	
CHEMICAL	DOSAGE
Granular 2, 4-D	100 lbs. per surface acre
Weedtrine D diquat	5 - 10 gal. per surface acre
Diquat	1 - 2 gal. per surface acre
*Fluridone Liquid	0.03 - 0.24 qts. per acre foot
*Fluridone Pellet	0.9 - 5 lbs. per acre foot
Liquid Potassium Endothall	1.25 - 2.0 gal. per acre foot
Granular Potassium Endothall	54 - 81 lbs. per acre foot

* Variable leaf milfoil is not controlled by fluridone

Coontail	
CHEMICAL	DOSAGE
Granular 2, 4-D	200 lbs. per surface acre
Fluridone Liquid	0.03 - 0.24 qts. per acre foot
Fluridone Pellet	0.9 - 5 lbs. per acre foot
Diquat	1 gal. per surface acre
Weedtrine D diquat	5 - 10 gal. per surface acre
Liquid Potassium Endothall	0.7 - 1.25 gal. per acre foot
Granular Potassium Endothall	27 - 54 lbs. per acre foot

American Elodea	
CHEMICAL	DOSAGE
Diquat	2 gal. per surface acre
Weedtrine D diquat	10 gal. per surface acre
Fluridone Liquid	0.03 - 0.24 qts. per acre foot
Fluridone Pellet	0.9 - 5 lbs. per acre foot

Curlyleaf Pondweed	
CHEMICAL	DOSAGE
Granular Potassium Endothall	13 - 40 lbs. per acre foot
Liquid Potassium Endothall	0.3 - 1.0 gal. per acre foot
Diquat	2 gal. per surface acre
Weedtrine D diquat	10 gal. per surface acre
Fluridone Liquid	0.03 - 0.24 qts. per acre foot
Fluridone Pellet	0.9 - 5 lbs. per acre foot

Floating Leaf Pondweeds *(Potamogeton spp.)*	
CHEMICAL	DOSAGE
Granular Potassium Endothall	27 - 54 lbs. per acre foot
Liquid Potassium Endothall	0.7 - 1.25 gal. per acre foot
Diquat	2 gal. per surface acre
Weedtrine D diquat	10 gal. per surface acre
Fluridone Liquid	0.03 - 0.24 qts. per acre foot
Fluridone Pellet	0.9 - 5 lbs. per acre foot

Fanwort	
CHEMICAL	DOSAGE
Fluridone	0.03 - 0.25 qts. per acre foot

Naiad	
CHEMICAL	DOSAGE
Granular Potassium Endothall	13 - 40 lbs. per acre foot
Liquid Potassium Endothall	0.3 - 1.0 gal. per acre foot
Diquat	1 gal. per acre foot
Weedtrine D diquat	5 gal. per surface acre
Light blocking dye	0.25 gal. per acre foot
Fluridone Liquid	0.03 - 0.24 qts. per acre foot
Fluridone Pellet	0.9 - 5 lbs. per acre foot

Spatterdock, Water Lily and Watershield	
CHEMICAL	DOSAGE
Glyphosate	6 pints per acre
Granular 2, 4-D	200 lbs. per surface acre
Fluridone Liquid	0.03 - 0.24 qts. per acre foot

Bladderwort	
CHEMICAL	DOSAGE
Weedtrine D Diquat	5 - 10 gal. per surface acre
Fluridone Liquid	0.03 - 0.24 qts. per acre foot
Fluridone Pellet	0.9 - 5 lbs. per acre foot
Diquat	1 - 2 gals. per surface acre

Cattails	
CHEMICAL	DOSAGE
Glyphosate	4.5 - 7.5 pints per acre
Diquat	1 gal. per acre in 100 gals. water
Fluridone Liquid	0.03 - 0.24 qts. per surface acre

Phragmites	
CHEMICAL	DOSAGE
Glyphosate	6 pints per acre
Fluridone Liquid	0.03 - 0.24 qts. per surface acre

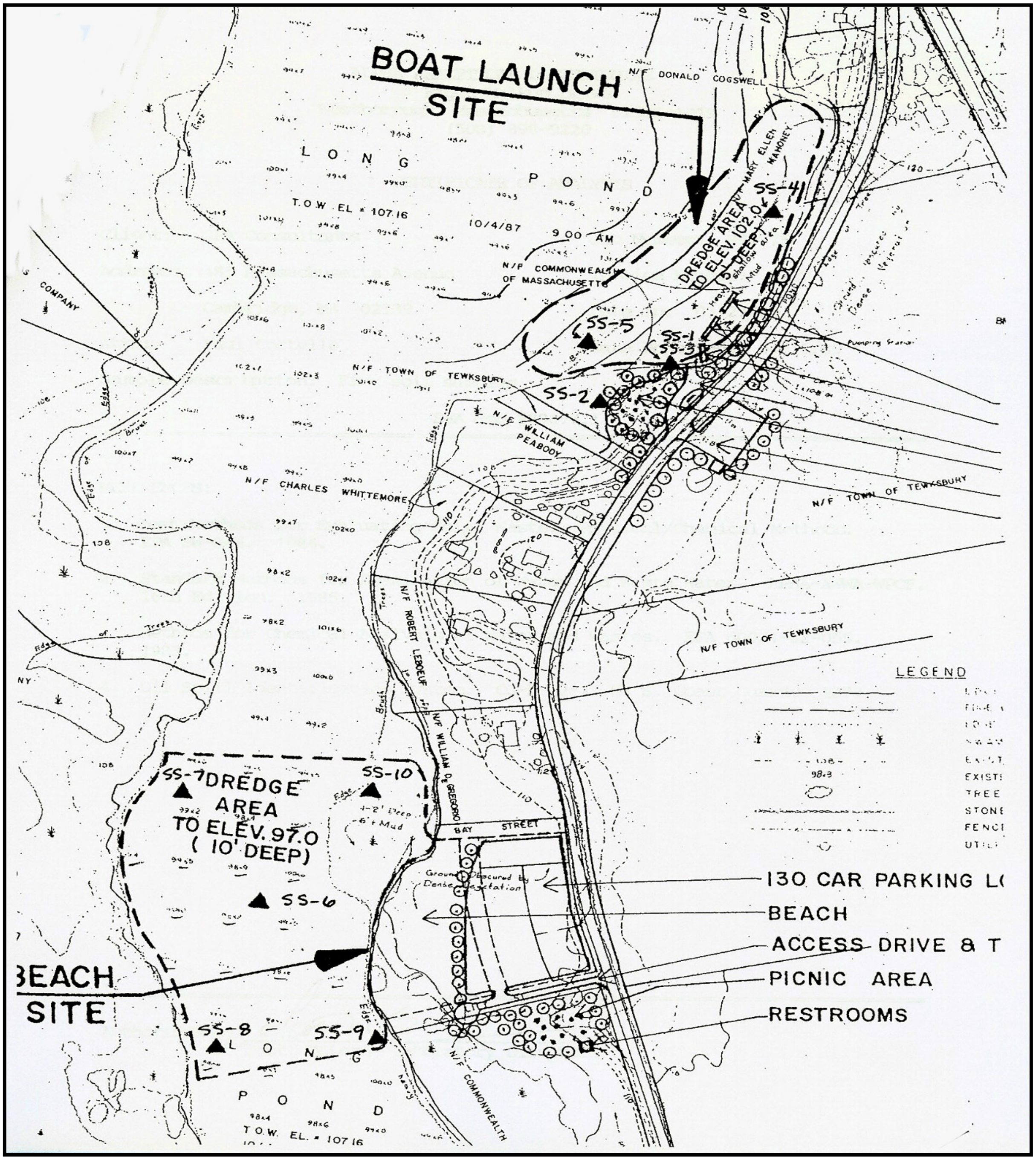
Active Ingredient	Trade Names	Watershed Use
Copper Sulfate		possible w/copper concentrations up to 1.3 ppm
Copper TEA	Cutrine, K-TEA	possible w/copper concentrations up to 1.3 ppm
Dimethylcocamine salt of endothall	Hydrothol 191	NO
2, 4-D Ester	Aquakleen, Navigate	NO
Diquat	Reward, Weedtrine D	NO
Potassium Endothall	Aquathol K	NO
	Aquashade	NO
Glyphosate	Rodeo	possible w/conditions
Fluridone	Sonar, Avast	possible w/conditions

Recommended Amount of Time to Allow After Treatment of Herbicides and Algicides in Ponds or Lakes				
CHEMICAL	DRINKING	IRRIGATION	SWIMMING	FISHING
Copper Sulfate	*	*	*	*
Copper TEA	*	*	*	*
Dimethylcocamine salt of endothall	7 days	7 days	24 hours	3 days
Diquat	3 days	3 days turf & ornamentals 5 days food crops	*	*
Granular 2, 4-D	refer to label	refer to label	*	*
Granular potassium endothall	7 days	7 days	*	3 days
Liquid potassium endothall	14 days	14 days	*	3 days
Glyphosate	do not use within 1/2 mile of water intake	*	*	*
Fluridone	do not use within 1/4 mile of water intake	30 days	*	*
Light Blocking Dye	do not use	*	*	*
* This information is taken from the pesticide product labels. If no specific time is noted, then the lake or pond can legally be used for the specific purpose as soon as the chemicals have dispersed. Caution, however, may indicate waiting at least one day before using the lake or pond.				

(State and federal regulatory controls for the use of these products has historically changed over time and consultation with state regulatory authorities is highly recommended at the early stages of formulating a chemical control plan after the specific aquatic vegetation and its density has been documented over the recreational use season.)

3. DREDGING AND FLOW AUGMENTATION

The original 1989 evaluations detailed two areas for improving public access and simultaneously identified areas proposed for dredging to enhance anticipated uses. A copy of the proposed dredging areas is shown below. In this 1989 survey, depth transects across the pond indicated that the average depth was closer to 8' as compared to the 4-5 foot depth recently found. Bathymetric mapping was not included in the scope of work for this latest monitoring effort so exact differences cannot be ascertained. It is possible that the water surface elevation was slightly lower when the September 2007 survey was conducted, but such variations are likely in



the order of 6” or less. In conclusion, it appears that significant sediment accumulation has occurred over the last twenty years and this could also be restricting rooted plant species. Based upon the accelerated accumulation of such sediments within the pond, dredging activities which were originally proposed may no longer be as viable as anticipated. The original dredging program proposed about 2 feet of dredging in the proposed beach area to extend the water column depth to 10 feet. Generally 10 feet is an ideal swimming depth and also the depth at which bottom vegetation is typically controlled due to the limits of light penetration through such a water column depth and the limitations of native rooted nuisance species. To obtain that desired depth now would require more extensive removal of sediment from 2 feet to 5 feet and result in 250% more dredge material for disposal.   Dredging such a “pocket” within the pond would also make this area a “sink hole” pond sediment due to the bottom gradients created by the dredging appreciably shortening the useful life of the dredging efforts. The proposed dredging at the boat launch area (proposed to 5 foot water depth) appears more consistent with the current pond bathymetry and more likely to be preserved over a longer useful life. In review of the original proposed dredging program, we would recommend that the boat launch dredging still be conducted, but that the beach site currently be put on hold until seasonal water quality aspects can be better defined to ensure that swimming uses can be achieved over the summer period without significant restriction.

As an alternate dredging strategy, instead of a deep localized dredging at the proposed beach, dredging of a central axis through the pond from northern inlet to southern outlet may be more beneficial for this water body. As discussed earlier, a weed harvesting program through the central axis would tend to channelize flows through the pond helping to flush nutrients and detritus from the pond. Expanding on this premise, dredging a channel to an 8 foot depth along the ponds central access with concentrate velocities through the pond and also provide a lateral draw of soft sediment from shoreline areas helping to improve bottom texture and consistency. Nutrients and detritus entering the pond from the inlet would be less likely to accumulate throughout the pond and tend to flow along the deepened channel flushing from the pond. The following page depicts the proposed channel routing through the pond. Detailed bathymetry via survey would be required to allow for quantification of material and cost estimation of this effort. Additional sediment samples would also be required to clarify dewatering and disposal methodologies. Since the pond is under the jurisdiction of Chapter 91, state permitting and approval would be required for all remediation efforts.

As a further option for both the channel harvesting and channel dredging activities, seasonal flushing is also an option for the pond. Generally, flushing can be accomplished by periodic lowering of the water level via an outlet control structure, preferably with a lower outlet withdrawal pipe. In terms of Long Pond, outlet control is limited and the overall shallow depth of the pond eliminates the possibility of any lower stratification flushing activity.

POND OUTLET

Flushing is also limited by the fact that the outlet is restricted both upstream and downstream by extensive surface vegetation encroachment. (See views below.) The hydraulic grade out of the pond and into Richardson's Pond is also minimal, so that dredging of the channels in both directions would also be required to allow suitable flow through the outlet. The only other option is to allow a higher regular pond water height and then draw it down, but the proximity of abutting properties especially near the pond outlet would make this option less attractive due to potential flooding impacts and private property concerns.

Since level fluctuations are limited, another strategy would be to seasonally divert more flow to the pond to flush it. As noted earlier, the wetland area near the northern inlet bisects flow allow some to go to Long Pond and some to go toward Marshall Brook. By seasonally diverting fall and early spring flows from Marshall Brook and toward the pond, significantly more flushing waters would be sent into the pond during non-breeding periods to allow for increased nutrient flushing. Central axis dredging plan on the previous page also depicts an extended dredge area in that northern wetland. By opening up the channel in the wetland and install a flow diversion structure before Marshall Brook, seasonal flushing could be instituted. This option could have other environmental consequences and some baseflow would need to be maintained within Marshall Brook, but the diversion does appear feasible from a preliminary review. Appendix D contains StreamStats output for the various watersheds and such a season flow diversion would double the tributary drainage area flowing to the pond aiding in increased flushing. Some gauging and seasonal water quality evaluations would be required to fully assess this option.

C. CONCLUSIONS AND RECOMMENDATIONS

1. ANTICIPATED USES

As outlined in the previous text, observed water quality aspects do not prohibit recreational uses but aesthetic attributes are relatively poor with high turbidity, suspended solids, water color and floating and rooted aquatic vegetation. The pond is almost in a hypereutrophic state well on its way to becoming a wetland and wet meadow. The shallow depths and accelerated rates of sediment deposition make future uses and expenditure questionable, but even in such hypereutrophic states some recreational uses can always be identified.

Ponds in this state typically have good fishing attributes due to the over-abundance of food and cover, but they can also be susceptible to fish kills if nighttime respiration depletes water column dissolved oxygen and warm water temperatures combine to worsen the conditions. Due to the presence of significant organic sediment which can also deplete water column dissolved oxygen (more likely to occur at the outlet end of the pond where anaerobic conditions were evident in the sediment) and turbidity which can increase the absorption of solar radiation, the possibility of a fish kill could be easily manifested. The only factor helping to maintain nighttime oxygen is related to the shallow depth of the pond. The surface/air interface can readily re-oxygenate the water column within the upper two feet. Since the upper two feet also represents half of the water column dissolved oxygen may be suitably maintained for fish species remaining within the pond. During field observations, limited fish activity (surface breaches) were noted and no shoreline fish activity was observed. There was a healthy population of waterfowl however including a family of swans and several blue herring. For these larger fish predators to nest in and around the pond fish populations is an indication of a healthy fish population. No information of previous fish kills was available, so it is still believed that fish populations still exist, although possibly not as diverse as they once were due to the shallowing depth and warmer temperatures observed. Mercury contamination of fish stocks is likely, so a catch and release program is advisable to better ensure public health. Since most of the shoreline is either private or inaccessible due to emergent vegetation, practical use of the pond for fishing can only be functionally achieved via boat access.

Boating for fishing or simply recreation is also a potential activity for the pond, however water turbidity, soft bottom sediment and lack of access to shoreline areas could limit public utilization of this activity beyond canoe and kayak activity or shallow fishing boat. The boat launch area proposed in 1989 is a suitable access point; however, it was laid out in such a manner that pedestrians would need to cross the street to access the very small parking area. This could limit boating uses. The area designated as the proposed beach, may actually be a more suitable location for the town initial reclamation efforts. If the beach area was utilized for the boat launching, would eliminate street crossings, provide suitable parking and also afford an area for shoreline fishing and picnicking. The above noted water quality aspects (turbidity, soft sediment, aquatic vegetation and color) currently limit the practical use of the pond for swimming at this time. Many communities have moved away from providing public swimming areas due to safety monitoring costs as well as the costs of regulating and restricting it use solely for town residents. If pond flushing is achieved to control these aspects, swimming uses may become more acceptable to residents and the boat launch could later be relocated.

2. RECOMMENDATIONS

This study is primarily based upon a single sampling event and as such is limited as to providing ample justification for any extensive capital improvement plan. Our recommendations are primarily focused on filling the voids in the current information database whereby more reliable results can be anticipated. There are obviously several measures that can be implemented now regardless of subsequent sampling and testing simply based upon good environmental policy. For this reason, we have structured our recommendations into three major categories: Environmental Policy, Supplemental Evaluations and Future Remediation Efforts.

Environmental Policy

1. Move to connect all homes within 400 feet of Long Pond or its tributary waters into the municipal sewer system.
2. Clean all culverts in and out of Long Pond to enhance flushing. Dredge associated channels and remove vegetation to promote unrestricted flow.
3. Implement Best Management Practices (BMP's) for stormwater systems including vegetative detention areas. Conduct a study of potential BMP sites within the existing watershed for Long Pond to attenuate nutrient and urban pollution and reduce the loading on the pond.
4. Have Conservation Commission agent investigate areas proximate to wetland and streams to identify any wetland violations and to advise land owners of BMP practices to reduce pollution leaving their sites.
5. Begin discussions with Billerica regarding long term watershed strategies to improve conditions within Long Pond and Richardson Pond.
6. Research private property limits and town pond limits to ascertain potential hindrances to future shoreline maintenance activities which could be implemented.
7. Investigate state and federal funding mechanisms for various pond and watershed reclamation efforts including ACOE, EOEA and MADEP.

Supplemental Evaluations

1. Provide periodic monitoring of pond inlet and outlet flows and flows in Marshall Brook to assess the potential for seasonal diversions and alternate flushing strategies.
2. Conduct a minimum of three more water quality samplings to better define variations in pond water quality during the recreational use period (June, July and August).
3. Conduct a minimum of two wet weather samplings of the pond and tributary streams to verify the presence of any bacterial contamination that may be existing.
4. Conduct a bathymetric verification survey to compare to the 1989 data and allow calculation of sediment deposition rates.
5. Collect additional sediment samples for analysis to update out-dated test results and to allow a determination as to potential dewatering and disposal methods.
6. Develop conceptual design plans for an enhanced boat launch/picnic area at the original beach site.
7. Survey and inspect the existing outlet structure to evaluate potential enhancement to allow increased control over water levels and flushing mechanisms.
8. Conduct a vegetation survey (July 2008) to verify coverage, density and need for chemical control strategies. Assess appropriate chemical control based upon survey.
9.

Future Measures Related to Remediation Efforts

1. Coordinate with state and federal regulators for approval of any remediation strategy prior to implementation.
2. Make grant/funding applications as may be appropriate for anticipated remediation efforts. Investigate "line item" funding with state and federal authorities.
3. Establish local regulations to require commercial fertilizer applicator working within the town limits to provide annual documentation relative to pounds of nitrogen and phosphorus being applied.
4. Based upon the previously proposed July 2008 vegetation survey, evaluate the need to aquatic weed harvesting within the pond and the benefits of harvesting within a central axis through the pond.
5. Based upon the previously proposed July 2008 vegetation survey and chemical control evaluations conduct permitting and implement of chemical control strategies as may be appropriate.
6. Based upon flow monitoring data collected on tributary streams and Marshall Brook, evaluate flow diversion potential benefits and anticipated environmental impacts.
7. Re-assess more extensive dredging options based upon a review of previous supplemental investigations.
8. Prepare plans and specifications for new Boat launch/picnic area.
9. Prepare plans and specifications for culvert, channel and BMP improvements.
10. Develop a long term Management Plan for the Pond with perpetual funding strategies via tax base (or Community Preservation), Stormwater Permitting fees and/or use fees. Plan shall be based upon a holistic approach to the water body in accordance with state policy. (See Appendix E.)

3. IMPLEMENTATION

An Interim Report was electronically distributed to Town "reviewing" entities for review and comment. Specifically the Community Preservation Committee, the Director of Planning and the Town Manager provided the core of the review. Based upon that review, specific recommendation items were short listed for implementation. Specifically the following recommendations were selected for further evaluation: ***Environmental Policy*** Item #**4**, ***Supplemental Evaluations*** Items #**1**, **2**, **3**, **4**, **5**, **7** and #**8** and ***Future Measures Related to Remediation Efforts*** Items #**4** and #**5**. To facilitate subsequent implementation, those recommendations were expanded in detail and cost estimates were generated along with implementation strategies and a recommended schedule. The following text details each of these implementation items and their associated budgetary cost. Where appropriate, funding mechanisms for the task items are also identified.

Environmental Policy

4. Have Conservation Commission agent investigate areas proximate to wetland and streams to identify any wetland violations and to advise land owners of BMP practices to reduce pollution leaving their sites.

In subsequent discussions with the Conservation Commission agent, such activities are within the scope of his existing job descriptions and would not entail additional compensation relative to field investigation efforts. The agent believed that one of the potential sources of pollution identified within this study may indeed already be subject to a MADEP Enforcement Order and as such a defined wetland violation may be on-going. The agent has not fully explored the tributary watershed and it may take some time to access all areas. If given the directive by the Town to explore the Long Pond watershed for wetland violations and improper management practices it is estimated that two to three months would be required to complete the inspection given existing work load and regular tasks. An inspection of the watershed would be conducted during a period spanning May, June and July to best identify seasonal hydraulics of the watershed, identify areas susceptible to erosion and runoff and identify seasonal nutrient sources.

The agent would attempt to contact owners prior to entering properties to obtain consent for the inspection. In some instances, such consent may not be obtained and the agent may need to view the subject property via abutting lots or through other means (review aerial photography, etc). Whenever possible, a cooperative but professional relationship should be maintained to help expedite the compliance efforts of the owner. A small handout may be appropriate from the Town, detailing detrimental activities and describing environmentally sound practices. Such handouts could address Wetland Regulation jurisdiction, sewer environmental benefits, environmentally sound lawn fertilizer practices, single lot runoff control measures and urban runoff control measures. Such handouts could be developed for about $1,000.00 and simply copied and distributed as needed by the agent depending upon the site priorities. Minor wetland violations would be addressed via a Violation Notice which would advise the owner that a formal filing with the Conservation Commission would be required. In some instances where violations were more significant, a Cease and Desist Notice and an Enforcement Order may be warranted. When dealing with the owners, the agent could recommend the necessary improvement measures to safeguard the water resource, or in some instances, engineering expertise may be warranted to formulate a suitable remediation strategy or to select and design suitable BMP. The agent shall review both private and public lands to also aid in additional BMP placement to enhance pollution attenuation within the watershed.

After the watershed inspection efforts, it is anticipated that professional engineering support may be appropriate to assess the survey/inspection findings and develop a BMP implementation strategy. State Section 319 Grants have been utilized to implement BMP's in other communities, and by using professional engineering support to identify potential BMP site and aid the Town with a 319 Grant submission, funding for BMP construction may be more readily obtained. In this regard, professional engineering support for BMP location identification, conceptual design and grant application support is anticipated to total about $6,000.00 for the Long Pond watershed. Section 319 grants generally have a spring submission deadline, so based upon the inspection efforts of the Conservation Commission agent, a spring 2009 grant application could be anticipated. Section 604b grant funding deadlines have past for FFY2008, but an FFY2009 filing may also be suitable for sub-watershed planning efforts.

Supplemental Evaluations

1. ***Provide periodic monitoring of pond inlet and outlet flows and flows in Marshall Brook to assess the potential for seasonal diversions and alternate flushing strategies.***

This task will involve some minor clearing of vegetation and debris by the Department of Public Works in the inlet and outlet areas for the construction of a suitable gaging station to provide for either periodic flow quantification. The gaging station will likely involve a stop log type post and board dam within the channel to establish a board crested weir to facilitate flow measurement. Materials and labor for the establishment of the gaging stations is envisioned to be $1,000.00 per installation with a minimum of three locations (main channel in and out of Long Pond and Marshall Brook at Marshall Street) for a total of $3,000.00. Weekly flow measurement utilizing a channel flow monitor would be conducted for approximately 40 weeks of the year (assuming no monitoring during winter weeks) at a rate of $50 per location per monitoring for a total of $6,000.00. Conservation Commisson permitting and engineering analysis of the resulting data have an anticipated budget of $2,500.00. The total budget cost for this task is estimated to be $11,500.00. Bi-weekly monitoring could reduced this task items budgetary cost to $8,500.00, but the resulting data set would be half as large and may be susceptible to improperly defining wet weather impacts on stream flows.

Supplemental Evaluations

2. ***Conduct a minimum of three more water quality samplings to better define variations in pond water quality during the recreational use period (June, July and August).***

Based upon the most recent sampling event, the analytical work can be refined to reduce the cost of each sampling set while still maintaining study integrity. Based upon June, July and August samplings, a cost of $5,000.00 per event can be anticipated for a total task budget cost of $15,000.00 for the three events, including a letter report of the findings. The three samplings will enable the seasonal variations in water quality to be defined and help to categorize the best control mechanisms for pond remediation efforts.

Supplemental Evaluations

3. ***Conduct a minimum of two wet weather samplings of the pond and tributary streams to verify the presence of any bacterial contamination that may be existing.***

Wet Weather monitoring will be a key element to assess the general suitability of Long Pond for long-term water contact recreational uses. It is envisioned that a minimum of seven sampling locations will be sampled during two separate wet weather events. The events would be conducted in May through June and generally follow the following criteria: (1) minimum 5 days of preceding dry weather, (2) minimum anticipated rainfall of one-half inch over a six hour duration, (3) runoff travel time delays incorporated into sampling sequence of tributary streams and pond samplings to occur the following day after the storm. The analytical testing will include bacteria monitoring (E. Coli and enterrococcus) as well as TKN and Total Phosphorus. The nutrients are also proposed to determine the influences of urban runoff to the pond. Budgetary costs are estimated to be $3,500.00 per event for a total of $7,000.00 for the wet weather impact evaluation including a letter report.

Supplemental Evaluations

4. ***Conduct a bathymetric verification survey to compare to the 1989 data and allow calculation of sediment deposition rates.***

Some pond bathymetry is available from the 1989 survey which indicates water depths of almost 8 feet in many areas. This task will allow for a new survey of the pond and is anticipated to be conducted by boat using a rod and GPS location device. Since limited datum information was available with the 1989 survey, a level survey will be conducted to establish a datum reference from approximate roadway grades and referenced water surface elevations. Survey shots shall be made in an approximate grid pattern across the pond at approximate 100 foot grid intervals.

Separate shots along the proposed axis channel within the pond will also be conducted to aid in any subsequent estimations of dredging quantities. A plan shall be prepared showing bathymetric data and an evaluation will be made as to the rate of sediment deposition within the pond based upon the use of the 1989 data. It is anticipated that the survey can be completed within one weeks time at a cost of $5,000.00 with an additional $1,500.00 for data reduction and plan preparation, for a total budget cost of $6,500.00.

Supplemental Evaluations

5. ***Collect additional sediment samples for analysis to update out-dated test results and to allow a determination as to potential dewatering and disposal methods.***

Based upon the assumption that significant sediment deposition has occurred since the 1989 sediment sampling, it is anticipated that new analyses will be required for the original dredge areas to obtain the necessary permits for dredge activity. The original sediment study included nine sampling stations (5 in the proposed beach area and 4 in the proposed boat launch area). As confirmatory testing, we would recommend only 3 samples in each location, assuming underlying material composition has not changed. In addition to these six samples, an additional six samples are also recommended along the proposed axis channel within the pond for a total of twelve sampling locations. Analytical testing costs are anticipated to run between $1,000.00 to $1,300.00 per location, for the grain size evaluations and disposal related classification parameters. Field sample collection is anticipated to be about $350 per sample. For a sediment sampling program involving twelve sample locations, a budget cost of $19,800.00 is anticipated.

Supplemental Evaluations

7. ***Survey and inspect the existing outlet structure to evaluate potential enhancement to allow increased control over water levels and flushing mechanisms.***

Work under this item shall include level survey of controlling structures (inlet, outlet and abutting channels) to allow for the development of a hydraulic profile through the system. The inlet and outlet structures will be measured and detailed to develop a suitable rating curve for flow/height relationships. Based upon field survey data, an engineering assessment will be made for potential improved passive and mechanical control measures. The intent of such control measures will be to allow increase flushing and sediment transport through the pond during high flow periods. This would generally be accomplished by water depth reductions during such periods to further decrease detention within the pond. Alternate strategies may be to lower depths to flush seasonally nutrient laden waters or to lower depths to enhance harvesting or aquatic weed control measures. A budget cost for this task is $3,500.00 including a letter report. Note: Additional of Richardson Pond in Billerica, MA may be required to identify additional downstream hydraulic restrictions. Cost for such additional survey are not include above.

Supplemental Evaluations

8. ***Conduct a vegetation survey (July 2008) to verify coverage, density and need for chemical control strategies. Assess appropriate chemical control based upon survey.***

A vegetation survey is anticipated to take from 3 to 5 days to complete based upon assumed vegetation density and water turbidity. A baseline survey was completed in 1989, but aerial photography indicates an increased density of macrophytes at the northern (inlet) end of the pond. The survey will be conducted via boat with both density and specie identification provided and mapped. The survey data will be utilized to establish both the preferred chemical control measure as well as the anticipate application method and rate. Also involved with the chemical selection process will be an evaluation of application location, water depth, sensitive receptors, bottom texture, flushing attributes and fringe vegetation. The budget cost for this vegetation survey and mapping task is $4,800.00 and is anticipated to be conducted no later than the second week of July, before excessive turbidity from water column algae further hinders visual observation efforts.

Future Measures Related to Remediation Efforts

4. ***Based upon the previously proposed July 2008 vegetation survey, evaluate the need to aquatic weed harvesting within the pond and the benefits of harvesting within a central axis through the pond.***

Aquatic weed control via harvesting may be advisable and could also be used to enhance other chemical weed control mechanisms as well as enhance pond flushing attributes. As discussed in the report text, the harvesting of vegetation along a central axis may help to increase flow through velocities within the pond and enhance soft sediment removal. Aquatic weed harvesting to create a weed-free zone near the proposed beach or boat launch area may enhance recreational shoreline fishing and harvesting near the pond outlet may help to reduce the potential for night-time dissolved oxygen depletion believed to occur in this area. This task will involve a detail evaluation of the vegetation survey results and the development of a detailed strategy and costs for mechanical harvesting control measures. The evaluation will also define the limits of proposed harvesting areas, estimate areas of harvesting, approximate weed volumes and weights, estimate trucking and disposal costs and identify suitable access areas for the harvesting equipment. An abbreviated specification will also be compiled to be used in conjunction with the report suitable for use by the Town to solicit quotes for the harvesting work. A cost estimate will be developed for the harvesting and weed disposal and the useful life of the control measures will be projected. The cost for this evaluation is estimated at $3,800.00. (*Based upon a preliminary assessment, a twenty (20) acre area could be harvested to enhance recreational uses in Long Pond. Generally harvesting equipment can harvest about 2 acres per day at a cost of about $3,000 per day assuming the weeds are loaded and trucked away by the DPW for composting. Aquatic weeds are amenable to composting, but may create odor issues if not promptly blended with active compost. Based upon the criteria detailed above, a harvesting cost of $30,000.00 could be anticipated. It is estimated that harvesting is generally needed every four years unless supplemental control measures are also utilized. Permitting would also be required prior to harvesting activities. An additional budget cost of $3,600.00 can be assigned for local and state permitting activities.*)

Future Measures Related to Remediation Efforts

5. ***Based upon the previously proposed July 2008 vegetation survey and chemical control evaluations conduct permitting and implement of chemical control strategies as may be appropriate.***

This task will involve a detail evaluation of the vegetation survey results and the development of a detailed strategy and costs for chemical weed control measures for Long Pond. As outlined in the report text, several chemical control measures are available for weed control, but in order to optimize performance, adapt to site specific characteristics and protect sensitive receptors, proper evaluation of weed density and type is essential to formulate a sound control strategy. Diquat and flouridone are the most common chemical control measures. Diquat is applied to the water surface in liquid form at a rate of 1 to 2 gallons per acre and generally results in a cost of $500 to

$800 per acre in this dose range. Flouridone is available in granular or palletized form and in this form it can enhance treatment of rooted weeds. Flouridone application costs are estimated to be about $1,200 per acre. *(Based upon assumed densities of vegetation, 30 acres are anticipated to be treated with diquat and 15 acres with flouridone. A budgetary cost of $42,000.00 can be assumed at this time for chemical application.)* To better define actual application areas and resulting costs, an evaluation of the proposed vegetation survey must first be conducted. Based upon the results of this evaluation, a refined control plan can be developed and permitting can be commenced based upon the survey and analysis. The analysis and development of the chemical control strategy is estimated at $1,000.00. Local and state permitting are estimated to be about $3,600.00 and supervision of chemical applications are anticipated to be an additional $1,500.00 for a total task cost of $6,100.00. (Note: Permitting costs for Item 5 also cover permitting cost for Item 4.)

LONG POND REMEDIATION IMPLEMENTATION COSTS

TASK ITEM			Sub-Task Cost	Task Cost
Environmental Policy				
4	***Have Conservation Commission agent investigate areas proximate to wetland and streams to identify any wetland violations and to advise land owners of BMP practices to reduce pollution leaving their sites.*** ***Implementation: Immediate***			
		Resident/Owner Handout	$1,000.00	
		BMP Engineering Design	$6,000.00	
		Total Cost		$7,000.00
Supplemental Evaluations				
1	***Provide periodic monitoring of pond inlet and outlet flows and flows in Marshall Brook to assess the potential for seasonal diversions and alternate flushing strategies.*** ***Implementation: Immediate***			
		Gaging Stations	$3,000.00	
		Monitoring	$6,000.00	
		Permitting	$2,500.00	
		Total Cost		$11,500.00
2	***Conduct a minimum of three more water quality samplings to better define variations in pond water quality during the recreational use period (June, July and August).*** ***Implementation: June 2008***			
		Sampling and Testing	$15,000.00	$15,000.00

Supplemental Evaluations

3	***Conduct a minimum of two wet weather samplings of the pond and tributary streams to verify the presence of any bacterial contamination that may be existing.*** ***Implementation: May 2008***			
		Sampling and Testing	$7,000.00	$7,000.00
4	***Conduct a bathymetric verification survey to compare to the 1989 data and allow calculation of sediment deposition rates.*** ***Implementation: May 2008***			
		Survey and Plan Development	$6,500.00	$6,500.00
5	***Collect additional sediment samples for analysis to update out-dated test results and to allow a determination as to potential dewatering and disposal methods.*** ***Implementation: July 2008***			
		Sampling and Testing	$19,800.00	$19,800.00
7	***Survey and inspect the existing outlet structure to evaluate potential enhancement to allow increased control over water levels and flushing mechanisms.*** ***Implementation: April 2008***			
		Survey and Evaluation	$3,500.00	$3,500.00
8	***Conduct a vegetation survey (July 2008) to verify coverage, density and need for chemical control strategies. Assess appropriate chemical control based upon survey.*** ***Implementation: July 2008***			
		Survey	$4,800.00	$4,800.00

Future Measures Related to Remediation Efforts

4	***Based upon the previously proposed July 2008 vegetation survey, evaluate the need to aquatic weed harvesting within the pond and the benefits of harvesting within a central axis through the pond.*** ***Implementation: August 2008***			
		Evaluation	$3,800.00	$3,800.00
5	***Based upon the previously proposed July 2008 vegetation survey and chemical control evaluations conduct permitting and implement of chemical control strategies as may be appropriate.*** ***Implementation: August 2008***			
		Evaluation	$1,000.00	
		Permitting	$3,600.00	
		Application Supervision	$1,500.00	
		Total Cost		$6,100.00
		Total Task Costs		**$85,000.00**

Based upon the Town's review of this Stage 1 Environmental Status Assessment report, select recommendations were chosen for implementation as a future Stage 2, involving elements of analysis, design and permitting. As referenced in the previous table, all chose recommendations are estimated to cost about $85,000.00. Some fine tuning of cost may be necessary as work progresses, and some task items may later not be pursued based upon Town goals for Long Pond or restricted funding. There are specific competitive state and federal grant programs to aid communities with lake and pond restoration. Both the Department of Conservation and Recreation (DCR) and the U.S. Environmental Protection Agency (EPA) have funded lake and pond restoration in the past and Long Pond also holds the distinction of being one of Massachusetts Great Ponds which may promote funding efforts. Other grant programs, such as Section 319 and 604b, can also help with watershed protection and non-point pollution abatement. 604b can provide watershed planning monies for assessment studies and remediation planning. Section 319 can provide design, permitting and construction funding for BMP's or Low Impact Development (LID) techniques. Such funding can often take over a year to acquire and grant competition can be aggressive, but long term structuring of Town resources to take advantage of such grants is essential to build upon previous assessment efforts. I terms of Long Pond, several of the Stage 2 measures detailed in this section may be opportune to implement immediately, but a few of the more expensive measures may be more readily implemented if grant funding were to be pursued. For instance, the collection of sediment samples for testing and disposal analysis may not be opportune to implement immediately due to the cost of that task and based upon the fact that dredging benefits may not be long term or allow the recreational uses anticipated.

As a general recommendation, we propose that ***Environmental Policy*** Item #4 and ***Supplemental Evaluations*** Items #2 through #4 and #7 and #8 be performed this year if funds are available to properly define the characteristics of environmental stresses on Long Pond. These items total approximately $43,800.00. Upon completion of these tasks, the Town will have much greater understanding of the stresses on Long Pond and the feasibility of the Town obtaining its recreational use goals. After these studies are complete, the Town will also have sufficient data to better support grant and remediation funding applications. 604b funding can be pursued for other sub-basin non-point pollution abatement planning. 319 funds can be pursued for Long Pond watershed BMP's. DCR and/or EPA funding can be pursued for weed harvesting, chemical weed control and potentially dredging operations. There may be a potential that the Town could get direct DCR support (generally technical) for certain aspects of its remediation efforts including support at the intermunicipal level in regards to Long Pond outfall limitation attributed to Richardson's Pond in Billerica. In order to enhance the Town's ability to combat non-point pollution and improve its town water resources as well as the Shawsheen River, comprehensive long term efforts must be exercised sub-basin by sub-basin. Stormwater Regulations have compelled communities such as Tewksbury to evaluate its stormwater systems and identify watershed pollution sources. By expanding the Town's efforts in these areas, it will beter preserve and protect is open spaces, improve access and use to these valuable water resources and safeguard these resources for future generations.

APPENDIX A

1989 Sediment Testing

APPENDIX B

Excerpts from
Shawsheen River Watershed Assessment Report
2002-2007

APPENDIX C

Analytical Testing Results
(Sampling Date 9/20/07)

APPENDIX D

Watershed Hydrology