Bare Hill Pond Watershed Management Committee
Town of Harvard
Harvard, MA 01451

July 12, 2010

Conservation Commission
Town of Harvard
Town Hall
Harvard, MA 01451

Re: Proposed Fall 2010 Drawdown and 2010 Report

Dear Commissioners:

On behalf of the Bare Hill Pond Watershed Management Committee, we are submitting our annual report under our 3 year 2008 Notice of Intent.

Introduction

Given the number of activities underway last year, this year and next year, and given the normal evolution of new members on both the Conservation Commission and at the Pond Committee, it might be useful to step back and provide more than a report on our drawdown related activities over the past year. First, for those who are new to the project, we are providing background on the State's regulatory context for the review of drawdown projects, including the additional protections we have built into the project that are not required by the standards as set forth in the Generic Environmental Impact Report on Eutrophication and Aquatic Plant Management in Massachusetts (the "GEIR"), and second, we will provide a summary of our drawdown related activities as we do every year at this time.

This letter is not intended to address matters related to the on-going Stormwater Treatment Project, however, we will identify where the drawdown activities relate to the successful operation of the Stormwater Treatment Project. As an aside, the Stormwater Treatment Project is substantially underway at this time under a separate Order of Conditions under the management and supervision of the DPW. It is a key part of our long term strategy under our Watershed Management Plan to control non-point source pollutants (particularly phosphorous and sediments) that endanger the pond and accelerate eutrophication and invasive species dominance.

Similarly, this letter is not intended to address or make recommendations regarding any future excavation activities at the Town Beach. That will require a new Notice of Intent that sets forth a clear proposal that addresses the operational concerns identified last year through the demonstration project. We are working with the DPW and Park and Recreation Commission to develop a sensible and workable proposal and do not expect it will be ready for discussion until September.

Since last year we have had additional changes in our membership. Bill Johnson has left the Committee in connection with his election to the Board of Selectmen. He continues to provide advice and support and has assumed liaison responsibility from the BOS for the Pond Committee. We are especially pleased to have Deborah Pierce and Mark Hardy join the Pond Committee in June, filling our 2 vacancies. They bring critical skill sets to our team being experienced scientists in biology and biochemistry. They plan to assume key roles in our environmental monitoring activities, and reflect a continuation of our goal of attracting members with expertise in this area. This has significantly enhanced the technical expertise Bob Blank offers on wetlands biology, and the knowledge our other members have acquired from study and attendance at sessions on Lake and Pond Management offered by the Congress of Lake and Pond Associations.

Drawdowns and Lake Management

In conversations with individual members of the Conservation Commission, several questions have come up that we spent considerable time discussing and seeking to address when our initial NOIs were filed in 2002, 2005, and 2008. Our current NOI is expires next year, but given the new membership on the Conservation Commission, we thought it would be helpful to provide some background on drawdowns and the GEIR adopted in 2004 by the Commonwealth that now govern their use. It is also worth noting that because we had initiated our work together prior to 2004, we began to collect data, and experience that suggested doing additional work which has been built in to our program, our Order of Conditions and our QAPP which governed our monitoring conducted for the DEP under our original 319 Program Grant. (Copies of the Introduction and Drawdown section from the GEIR as well as the QAPP are attached for your reference). You can find the entire GEIR for Lake and Pond Management at www.mass.gov/dcr/watersupply/lakepond/downloads/main_geir.pdf .

As an aside, the Massachusetts GEIR is a very helpful document to getting a grounding in the current state of the science in understanding the impact of a variety of lake and pond management techniques (both beneficial and harmful) on lakes, ponds and their surrounding wetlands. As discussed in the Introduction, it took a long time to revise and publish the GEIR and that it was sorely needed. In the absence of a GEIR, each Conservation Commission had to conduct its own analysis to determine whether a particular management practice could be permitted. The result was that the burden on applicants and Commissions was generally so high, it was impeding very important environmental protection projects (like ours) that were intended to control eutrophication and invasive species growth. The adoption of the GEIR made it possible for a Commission to rely on the GEIR to approve interventional activities without having to re-invent the wheel in each community. Our Order of Conditions took into account the issues in the GEIR and is designed to be compliant. We have also undertaken a series of monitoring activities (put in place in 2002 before the GEIR was adopted) that go well beyond what is required. We think these activities are worthwhile in that they provide us with confidence in our approach and add to the state of knowledge regarding the efficacy, risks and benefits of drawdowns. We presented our findings at the Annual Meeting of the Mass. Congress of Lakes and Pond Associations in January 2009.

It is also worth noting that since 2002, we have proceeded incrementally. We started with an 18" drawdown in 2002, then several years of 3.5 foot gravity drawdowns. We learned about the flow of the Pond downstream, the refilling of the Pond, and the impact the drawdowns had on the downstream wetlands. As a result of the designation of the Pond as endangered by invasive species and phosphorous by the DEP, we qualified for a 319 EPA Program grant that allowed us to build the pump house and incrementally increase depths, initially to 5 feet, then to 5.5 feet, and then to 6 feet. We continued to monitor fish, turtles, amphibians, the down stream wetlands, the in-lake invasive species and the water quality.(See the QAPP). We also initiated on our own, shellfish or mussel monitoring at 5 feet to ensure they were continuing to thrive. Mussel photos are attached from last year showing the prevalence of mussels at the monitoring site and we continue to observe juvenile mussels as well. Our downstream wetland monitoring was designed in a collaboration between Michele Girard and Rich Orson. Rich Orson wrote a protocol which is on file with the Commission and a copy is on the Pond Committee page of www.harvard.ma.us . What we have seen since 2002 is what is reflected in the GEIR, that downstream wetlands are generally not harmed by fall and winter drawdowns (largely because the plants are dormant and because the plants tolerate changes in water levels). What Michele has observed in her reports is that the wetlands species, if anything, are now more diverse and thriving; although the dead trees that were in the wetland became less stable and many have fallen. These monitoring activities go well beyond those required following the adoption of the GEIR, which established a template of best practices for drawdowns and determined their safe and effective use when used on target species. Interestingly, when you read the GEIR, one sees reflected in our data the predicted impacts in the GEIR.

Our long term plan is to run the pump for two years in a row, to take a year off from pumping (using the funds saved on electricity that year to do the professional water quality and in lake monitoring). The rationale for a year off is that there is some data in the GEIR and in the ENSR 2002 Report we submitted with our first NOI, that continuous drawdowns once a lake reaches equilibrium in non-invasive diversity, will avoid introduction of invasive seed bearing plants. We have not seen new invasive species yet, and the GEIR indicates some lakes may not see it. We have also not yet achieved a control equilibrium. Still we support following this approach as we are seeing incremental improvement. Our last year off was in 2008. We had a discussion in 2008 about the best course of action in the year off. Should we do nothing or do a gravity drawdown. We recommended doing a gravity drawdown, not for invasive control purposes but rather to reduce the variation between on and off years so that the amphibians, reptiles and shellfish did not get re-established at the higher levels during the off year. After the year off, our invasive growth was substantially worse the following summer, and we had to catch up again last year and this year. We did based on our surveys appear to avoid a loss of mussels in the 0-3.5 foot zone by using a gravity drawdown in the off year.

We have also seen varying impacts of the drawdown in different parts of the Pond. Areas in the drawdown zone have seen dramatic reductions in milfoil where milfoil was previously the dominant species. This is most notable in the 0-4 foot zone between the dam and the beach, going out along the Warren avenue shore from the beach, between Minister's Island and Clapp's Brook where there was very heavy milfoil growth prior to 2007. What we have also seen is that native plant shoreline diversity in many areas is increasing. Several abutters have complained that phragmites have now populated their shoreline at the South end of the Pond. This beneficial restoration of species is noted in the GEIR and a good example is attached in photos of the Clapps Brooks area where you can see significant growth of grasses (as well as the near elimination of invasive waterchestnut due to repetitive harvesting prior to annual seeding). Although not a drawdown target species, the harvesting (mechanical and by hand) of waterchestnut and its eradication may be in sight. It is worth noting as well that this significant restoration of native species is in the drawdown zone which is frozen and not covered with water in the winter.

Finally, we continue to see substantial invasive species growth in deeper zones (above 5 feet) or in zones where there is continuous water flow that interferes with the drawdown mechanism of action (freezing and drying). A good example is near Thurston's Beach this year. Milfoil is very heavy in that area, but not 200 yards in either direction. This suggests that the stream flow may be preventing the drawdown from having an effect in that area. It is also possible that the stream that enters the Pond in that location may also be delivering phosphorous. We are planning stormwater intervention for next year under our grant (it looks like we may have sufficient funds to do more than was originally planned) and this might be a good location. Similarly, the Town Beach has not dried out during a drawdown and that could explain the continued high growth in that area.

In summary, our drawdown activities have been implemented in accordance with the GEIR, and we have also adopted practices that exceed the best practices provided for in the GEIR. The GEIR, for example, merely states that drawdowns occur in the fall and winter and allow for drawing down until December, without regard to the timing of the first freeze. Our OOC provides that we stop at the first freeze. The GEIR, because it finds drawdowns to be acceptable interventions when used to control "controllable invasive species" does not mandate any monitoring of amphibians, reptiles, mammals, fish, downstream wetlands, etc. We use volunteers to do this. The introduction to the GEIR makes a key point stating in effect that if we make protection of our lakes and ponds too hard, that we will discourage important interventions that can protect against eutrophication and invasive species. This does not mean we should be reckless, but rather that we should proceed, as we have sensibly, with environmental concern and a level of checks and balances that to not make perfection the enemy of the good. Prior to the adoption of the GEIR, and prior to the adoption of our first Order of Conditions, little was done to protect Bare Hill Pond, or many other lakes and ponds in the Commonwealth. Now that there is an approved set of approaches, we have the ability to proceed incrementally, and care for one of our most precious Town resources.

Annual Update

As you may recall, in 2008-9 we took a year off from a deep pumped draw down in accordance with the recommendations of the GEIR and our 2002 ENSR Report on conducting drawdowns. The theory is that continuous deep draw downs could result in the establishment of a population of drawdown resistant species and that taking a year off periodically or documenting an ineffective drawdown year (due to a lack of a freeze or excessive rainfall) would maintain competition between drawdown responsive species and resistant species. Although we continued to see an increase in the diversity of the plant life in the pond, the gravity drawdown in 2008-9 had little or no effect outside the 3.5 foot drawdown zone. As a result invasive species of milfoil and fanwort have increased in the 3.5- 6 foot zones and we had significant catching up to do in 2009-10.

We achieved a 6 foot drawdown in 2009-10 and had an excellent freeze. From visual observation in early July, it appears to have reduced the milfoil and fanwort that had proliferated in the 3.5-5 foot zone in the off-year. As noted above, we have observed some areas above 5 feet that have very significant milfoil growth because they are not yet impacted by the drawdown either due to stream inflows or depth, but they are local in nature and the Pond as a whole is diversifying its native, bottom growing species. This is evident in the area between the beach and the dam. In the Clapps Brook Area as well, the shoreline phragmites have become a dominant species again along the shore with native grasses and water lilies.

Our proposal will be to proceed this fall with a gravity drawdown of up to 6.5 feet depending on the timing of the first freeze. Our Order of Conditions, consistent with the GEIR permits the drawing down to continue to November 30, however, our experience is that cold weather on average sets in about November 25. We have generally achieved the drawdown level by November 20 unless there is unusual precipitation in November. We also propose stopping at 5 feet as we have in the past to do a mussel survey to ensure there is a thriving mussel population below the proposed drawdown zone. It is possible to see the relevant mussel habitat when we stop at 5 feet.

Last year, we worked with the Rowing Association and have continued to meet with their leadership to develop a plan that to the extent practical accommodates the fall rowing season, but respects the environmental constraints. Each year we learn more about the pumping capacity, and last year the DPW was able to stem the majority of the backflow of the dam, by closing the gate valve. Additional repairs are planned for the dam as a whole but they are probably another year off. DPW also devised new set of screening at the Rt 110 Culvert to reduce the flooding in the wetland and it was quite effective in reducing backflow pressure as well and should make it possible to use gravity to a greater extent.

The Rowing Association raised 2 concerns. One concern was the level of the Pond due to rocks. Fortunately, with their leadership, a significant number of the rocks on their rowing paths were broken last winter and the one major rock that becomes an issue later in the drawndown was marked. Essentially, this means that they have relative freedom to row until the Pond is 3-4 feet down. More will be learned this year. The other concern which is not as practical to address fully is the reduction in the length of the rowing course below 3 feet of drawdown. The excavation at the boat ramp helped to some extent alleviate this issue by extending the course eastward. What we learned from the Rowing Association was that they were not concerned about when we start the draw down, but requested we hold the drawdown to 3 feet until Friday, October 29. We propose holding it to 3 feet through Friday, October 22, and then holding it above 3.5 feet through Friday, October 29. The Rowing Association considered the proposal and indicated this would be workable.

We developed this approach by working backwards from November 25, recognizing that this may put at risk to some degree whether we reach the 6.5 foot goal. Based on pumping and draw down data, we believe we can go from 3.5 feet to 6.5 feet if we can turn the pump on at high speed (1.5" per day) on Friday October 29. This is necessary to have a reasonable probability based on prior year's data of reaching 6.5 feet before the first freeze. Based on this we have developed the following plan for this Fall.

1. Initiate the gravity drawdown the week of September 20, and start the pump only when needed to achieve a level of 3 feet by October 22. We anticipate this will require some pumping beginning on or about October 15. Hold the level at 3 feet until October 22 and re-start pumping on Saturday, October 23rd at less than full rate and drop to 3.5 feet by October 29. Then turn the pump on until the 5.0 foot level is achieved for a mussel population review, and then if acceptable, resume pumping to 6.5 feet prior to the first freeze or November 30, at all times at a rate not to exceed 2" per day per the Order of Conditions.

2. Initiate the Refill on or before February 1, 2011. Our objective is to bring the Pond to the level of the gravity drawdown on or before the date we have historically initiated the gravity drawdown refill. The prior to deep draw downs both had more than sufficient time to refill when started at this time. The water table is unusually high this year due to the level of rain so that should also mitigate any refill concerns.

This increases incrementally the deep pumped drawdown by ½ foot. This level should expose the area of the Town Beach that remained wet last winter. It will allow it to act on the invasive growth in the swimming area at the beach and also make it possible, should a second NOI be approved this fall, to excavate the peat at in the swimming area at the beach.

Our observation of the invasive species growth patterns suggest that it would benefit the continued decline of invasive species and restoration of native species by proceeding to 6.5 feet. At the same time, we do not wish to go beyond 5 feet without assuring ourselves that the mussel population continues to thrive. Publications concerning water height change suggest that mussels that are not trapped by rock formations will move with the water as it recedes, but we would like to continue each year to satisfy ourselves that this is in fact occurring.

Independent of the drawdown, harvesting and handpulling (coupled with a surface fence have even further reduced the level of waterchestnuts in Clapps Brook. This year, Rick Dickson had to harvest under 5 loads (he estimates 4 as of the date of this report) compared to approximately 15 loads last year and 60 loads 2 years ago. The area was essentially clear in early July with only a few plants still emerging. Pictures are attached. We are optimistic we will observe a similar reduction next year and that we may succeed in removing them from the Pond altogether in the next 2 years with significantly less effort being required.

Coupled with the drawdown, significant re-emergence of grasses and reed type plants along the shoreline continues to occur. In other respects, this year's monitoring results are consistent with our observations over the past and continue to support the efficacy of utilizing drawdowns.

We have also continued our volunteer wildlife monitoring efforts. I have conducted turtle counts this year and the results, like last year were not meaningful or comparable to prior years. As noted last year, I generally see only several turtles in an hour rather than 40-50 in the Clapps Brook shoreline area. After 2 years, I am now convinced that the poor count is the result of the method adopted for the count a few years ago and it will need to change. The method was to count turtles along the shoreline (mostly sunning on logs and rocks) in a one hour period. With the re-emergence of the significant growth of shoreline grasses and cat tails and the restoration of the lily pads in those areas, sunning locations are no longer visible from a canoe or kayak. I am confident that the turtles are not lost because both this year and last year, Rick Dickson says he was regularly removing (without harm) turtles from the conveyor on the harvestor. He says he typically removes 4 to 5 turtles per harvester load. This suggests that we are not seeing a change in population. Last year I recommended we switch to this protocol for year to year comparisons. With our new members, we will examine this and make a recommendation before next year. The harvester method will become obsolete as it may not be needed much longer for waterchestnut harvesting. I have seen a greater number of water snakes (a rather large one is always on the dam on sunny days when I check the water level this year and last). I have also seen several juvenile black rat snakes this year which are listed as endangered. (They are not friendly.)

We also continued to take secci disk readings to evaluate turbidity. The results continue to show improvement. A few years ago we often had readings closer to 5 - 5.5 feet. Now it is generally 5.5 feet on windy days or days with high boating activity and as high as 6.5 feet early in the morning when there is light wind and traffic on the pond. On several mornings there was 6.5 feet which is more than in prior years

Beaver activity was significant in the downstream wetlands this Spring evidenced by the clogging of the grate regularly near route 110 as well as on the Pond itself with evidence of tree cutting. Fox activity continues to be active in the early morning hours.

Frog counts continued this year under the leadership of Jeff Ritter. A copy of his report is attached and he notes a surge in the pickerel frog population this year.

The Park and Recreation Commission gave 3 fishing derbies permits this year and there results were all positive. The fishing clubs report that the fishing in Bare Hill Pond is excellent although while the numbers were consistent, some of the sizes of the bass were down this year.

The 100’ photos are attached. I was unable to access several sites due to low water, and an early snow made it impossible to take pictures from land. I have normally taken these photos the week after the drawdown completes. My general observations are that the shorelines continue to have less silt and more exposed rocks and that the 100” photos have not revealed any significant changes.

Finally, per the QAPP (copy attached) we have taken water quality samples of the incoming streams as well as the Pond at designated locations. The report of the stream samples is attached. The lab report for the in lake samples will be available on or before August 5. The samples in the streams taken on both a rain event and a dry day confirm what is expected. As noted in the report the lake has excellent water quality (aside from the phosphorous which is outstanding), and you will note that the highest levels of phosphorous are the parking lot runoff behind the high school and the stream running under Pond road, as would be expected. The new stormwater treatment project will treat these inputs.

We appreciate the time the Commission has take, and the effort made to understand, and help manage the project. We look forward to the meeting on August 5.

Sincerely,

Bruce A. Leicher
Chair, Bare Hill Pond Watershed Management Committee

Cc: Conservation Commission Members
Pond Committee Members
Selectmen

Attachments:

1. Drawdown and Refill Measurements
2. Frog Count Report
3. Water Quality Report
4. Shoreline Photos
5. Clapps Brook Photos – Waterchestnut Clearance and Shoreline Native Plant Restoration
6. Clapps Brook Drawdown Photos
7. Mussel Photos
8. QAPP
9. Introduction and Drawdown Section of GEIR

Attachment 1

2009-2010 Drawdown and Refill Data

The drawdown and the refill were measured weekly from the top surface of the dam to the surface of the water to measure the rate of decline or rise in water level. The following table shows the data collected:

Date	Distance from top surface of dam
9/21	22" (low starting point – normal is 20-22") Initiate
9/26	29" Initiate Drawdown
10/3	36" High Flow
10/9	45" Moderate Flow
10/10	45" Turn On Pump
10/17	57"
10/24	68"
10/31	78"
11/6	92"
11/8	94"
11/11	92" (2.5" rain on 11/14)
11/15	88"
11/19	88"
11/23	92" and hold at 92"
1/1- 1/26	Rose to 85" due to snow - - Solid Freeze
1/31	85" Initiate Refill
2/6	78" Solid Freeze
2/15	75" Solid Freeze
2/21	70"
2/27	48" Rain and some significant melt
3/6	35" melting
3/13	29" more melting
3/19	9" flooding rain
3/20-22	4" flooding rain
3/30	10"
4/4	19" High normal for Spring

Amphibian Monitoring on Bare Hill Pond, Harvard, 2010 **Attachment 2**

Numerous wood frogs were reported in Harvard's vernal pools in early to mid-April, due perhaps to the unexpectedly warm spring weather at the beginning of April. Our survey work does not typically include monitoring vernal pools, due the fact that the water levels and migratory timetables vary greatly from year to year. But this year the number of wood frogs noted by residents near pools seemed higher than usual, even though this evidence is anecdotal.

Two formal amphibian monitoring surveys were conducted in the spring of 2010. On Sunday, April 4, survey groups were at five sites on Bare Hill Pond. Air temperatures were warm at near 60 degrees, and wind was light, with clear skies. Peepers were chorusing at every survey location, not an unusual finding for early in the season. But pickerel frogs were also noted in abundance in the Sprague Swamp, which was unusual. In past years, pickerel frogs have been only sporadically heard, and never in abundance.

On Sunday, April 25, during the second count, temperatures were in the mid-60s with clear skies. The weather in the weeks prior to this count had been abnormally warm for mid-April (meteorologists noted that Spring 2010 was the second warmest spring in the past 100 years in New England). Peepers were still quite abundant, but for the first time in many years chorusing pickerel frogs were heard at two locations, Sprague Swamp and Clapps Brook. Also, a few leopard frogs were reported, noted by their distinct intermittent calls.

It is difficult to explain the sudden abundance of pickerel frogs. In recent years, amphibian counts have found only a limited number of pickerel frogs in the pond littoral habitat. But this year's data suggests that the local environment is providing good habitat for amphibians. Perhaps recent changes in the dynamics of the pond (deeper drawdowns, reduced invasive aquatic plant life, or other factors such as improved weather conditions) created a more favorable environment for traditional amphibian species. In any event, we can report that the pond now harbors species in greater numbers than in prior years.

In an important observation from *last summer*, residents on the pond noticed the presence of two great blue heron beginning in June and lasting well into November. This could be interpreted as a sign of improved pond habitat, since heron consume large quantities of small fish and amphibians. They feed somewhat indiscriminately on everything in the marshes and in shallow waters. The fact that heron find Bare Hill Pond inviting suggests that there is, at present, an abundance of food, including frogs, salamanders, fish, etc. to feed their appetite. It remains to be seen whether the heron return this summer.

In summary, the pond amphibian habitat shows marked improvement over prior years. We await other observations this summer regarding fish populations, the increased presence of mammals such as beaver and muskrat, and the observed presence of heron as further indicators of an improving watershed.

Respectfully,
Jeffrey Ritter
Member, BHPWMC

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Aquatic Restoration Consulting, LLC
18 Sunset Drive
Ashburnham, MA 01430
Phone: 508-397-0033

Bare Hill Pond Watershed Management Commission
Tom Gormley
Town of Harvard
99 Ann Lee Road
Harvard, MA 01451

Mr Gormley,
As requested, below is a summary of the watershed and in-lake data collected to date. Please let me know if you have any questions regarding these data or if I can assist in any other way.

Watershed Sampling

Dry weather sampling of the tributary beneath Pond Road (BHP-T1) was conducted on June 9, 2010. All other planned sampling locations were dry (no surface flow). In-situ measurements of temperature, dissolved oxygen (DO), pH and specific conduct ivy were recorded. A surface grab sample was collected and sent to Berkshire Enviro Labs for total phosphorus (TP), dissolved phosphorus (DP) and total suspended solids (TSS) analysis. Results of the in-situ sampling are provided in Table 1 below. We are awaiting results from the lab.

Wet weather sampling of the tributary was conducted on April 27, 2010. Four other locations were sampling during this wet weather event. These locations are:

BHPBS-1	Behind School - Parking lot runoff
BHPBS-2	Behind School - Detention basin outlet
BHP-SFP	Soccer field drainage pipe discharging to tributary
BHP-T1	Tributary downstream of Pond Road, downstream of soccer field pipe confluence
BHPSF-1	Soccer field behind fence at baseball diamond - small buried pipe discharge

In-situ measurements of temperature, DO, pH and specific conduct ivy were recorded at all but one location (BHPSF-1). The flow at sample location BHPSF-1 was very low and the drainage channel did not contain enough water to immerse the sampling equipment. Grab samples were collected at all locations and sent to Berkshire Enviro Labs for analysis of TP, DP and TSS. Results of the sampling are provided in Table 1. A total of 0.18 inches of precipitation was measured at the Fitchburg Airport during this rain event.

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Table 1. Bare Hill Pond Watershed Sampling Results 2010.

Weather Condition	Station	Date	Time	Temp (C)	DO (mg/L)	pH (SU)	Spec Cond (us/cm)	TP (mg/L)	DP	TSS (mg/L)
Dry	BHPT-1	6/9/2010	13:15	14.1	8.6	7.7	423			
Wet	BHP-T1	4/27/2010	16:30	10.2	9.9	8.5	273	0.556	0.065	136
	BHPBS-1	4/27/2010	16:07	12.0	8.8	8.0	105	1.293	0.150	344
	BHPBS-2	4/27/2010	16:12	11.8	8.8	7.7	1075	0.041	0.022	6
	BHP-SFP	4/27/2010	16:44	8.5	10.2	7.8	750	0.022	0.018	<1
	BHPSF-1	4/27/2010	16:25	no in-situ sample				0.063	0.030	26

Conductivity in the dry weather tributary sample was higher than the wet weather sample. This suggests a possible dilution effect of dissolved ions. This is difficult to confirm without additional data, however. Temperature and pH were higher than under dry conditions.

Concentrations of TP and DP were greatest at BHPBS-1 (parking lot runoff), with the tributary sample containing the second highest concentration. These values are high and are typical of stormwater runoff. The tributary provides a larger flow volume and is therefore suspected to generate the highest load of all these sample locations. TSS concentrations were also highest at these locations and suggest a higher sediment load from these locations. However, this evaluation is based on a single sampling and additional sampling is needed to confirm this assertion. Concentrations at the other stations were only slightly elevated, except BHPBS-2 which was relatively low for a stormwater sample. It should be noted that this event was a passing but intense thunderstorm. Additional data are needed to assess other magnitudes of wet weather events.

In-Lake Sampling

Dry weather in-lake sampling was conducted on June 21, 2010. In-situ water depth profiles measurements of temperature, DO, pH and specific conduct ivy were recorded at two locations: shallow south basin BHP-1 and deep hole in the north basin BHP-2. These data are presented in Table 2. Figure 1 provides a graphical representation of the temperature and DO data.

The temperature and dissolved oxygen profiles suggest that the lake is beginning to thermally stratify. The metalimnion (middle transitional layer) is starting to appear at 10 feet. Dissolved oxygen rapidly declines at around eight feet, with DO concentrations less than 2.0 mg/L appearing at 16 feet. A DO value of above 5-6 mg/L is desirable for fish. The surface pH level is neutral to slightly basic and increases in acidity with water depth. Specific conductivity is within a desirable range, values above 200 can be indicative of dissolved pollutants and high productivity.

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Table 2. Bare Hill Pond Water Depth Profiles

6/21/2010		BHP-1		
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec Cond (us/cm)
0	25.9	8.5	8.6	141
2	25.9	8.6	8.3	141
4	25.9	8.6	8.2	141
6	24.8	8.9	8.1	140
8	23.9	8.6	8	140
10	21.6	8	7.9	139
12	20.9	5.7	7.6	139

6/21/2010		BHP-2		
Depth (ft)	Temp (C)	DO (mg/L)	pH (SU)	Spec Cond (us/cm)
0	25.1	8.5	8.6	136
2	25	8.6	7.8	137
4	24.9	8.7	7.7	136
6	24.1	8.7	7.7	136
8	23.1	8.6	7.6	136
10	20.3	6.4	7.5	135
12	19.2	4.8	7.4	135
14	16.7	3.4	7.3	136
16	14.6	1.5	7.2	136
18	12.6	0.9	7.1	139
20	11.8	0.3	6.9	155
22	11.3	0.2	6.8	188

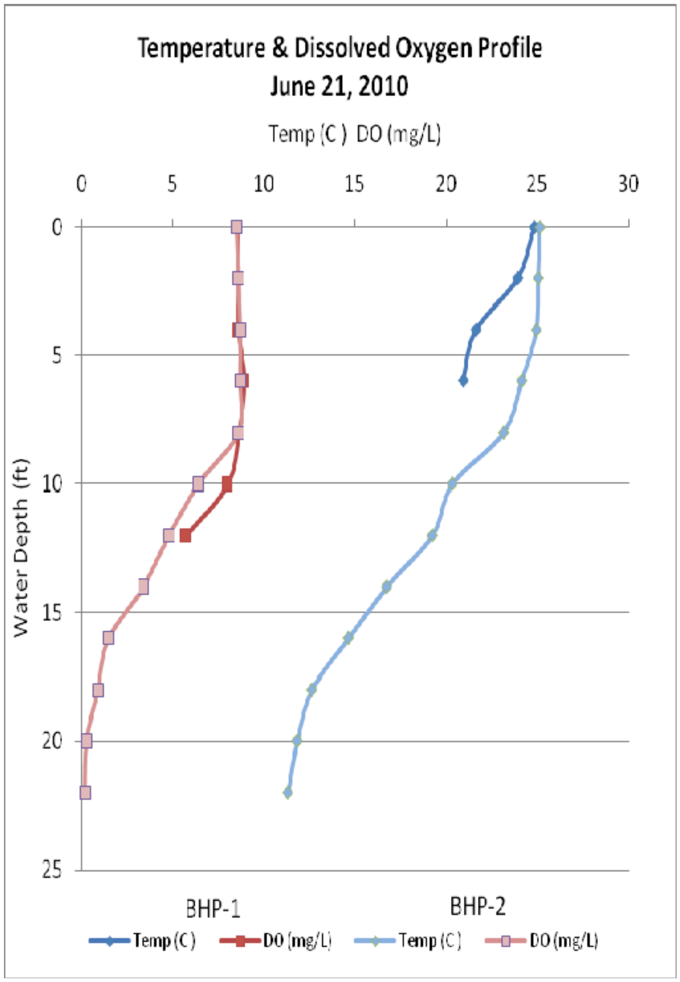

Figure 1. Temperature and Dissolved Oxygen Profiles.

Attachment 4

Shoreline Photos
100’ sites

Location
Ten 100' Segment Sites

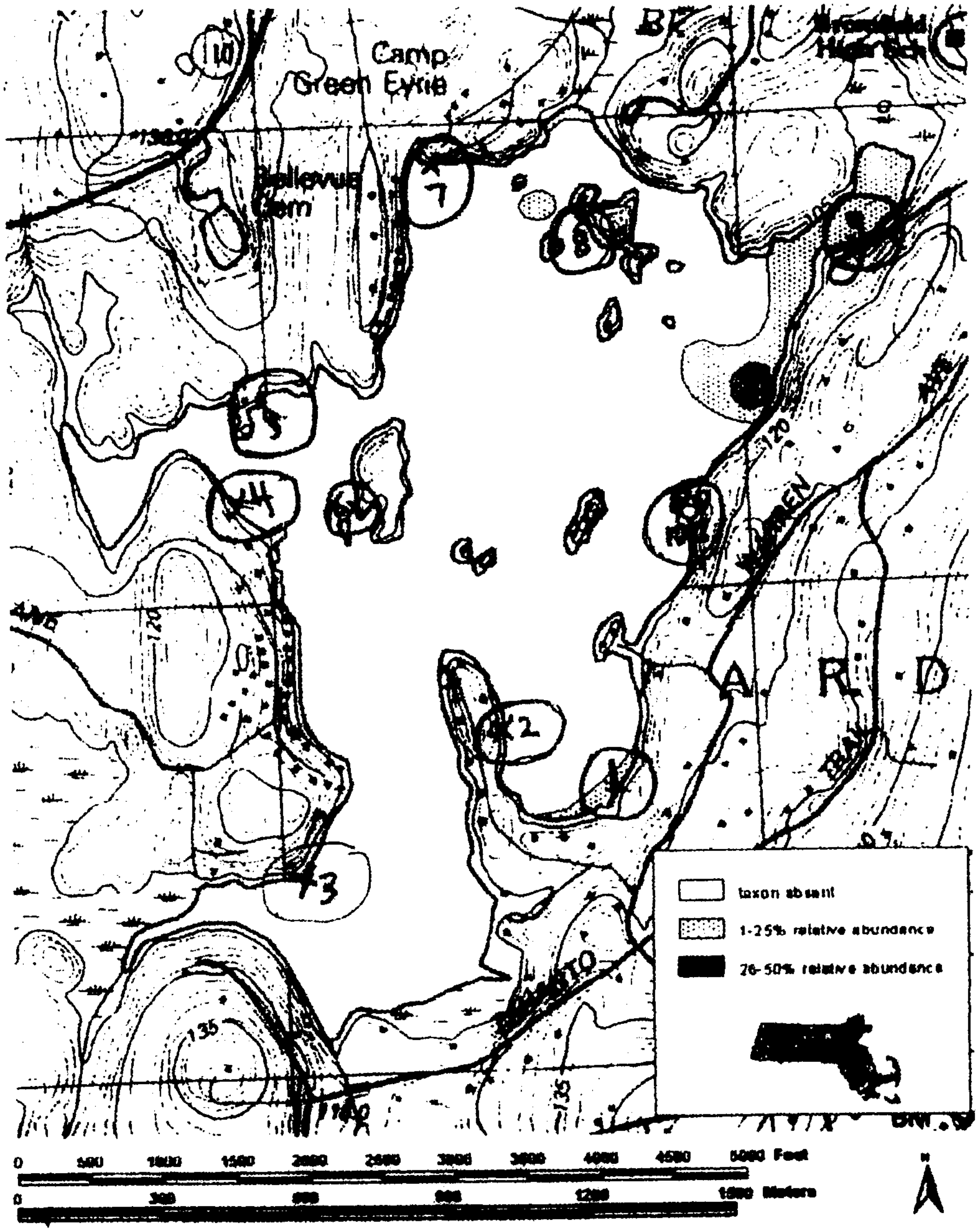

Figure 5. Distribution and relative abundance of fanwort (*Cabomba caroliniana*) in Bare Hill Pond in October 2001, from data in Appendix A.

These 2 are of Outer Clapps Brook Site 5

These 2 are of site 7

Site 10

Site 10

Site 7

Site 10

Site 1

Site 2

Site 1

site 2

These are all Site 2

Attachment 5

Clapps Brook Photos – Waterchestnut Clearance and Shoreline Native Plant Restoration







Attachment 6

Clapps Brook Drawdown Photos




Attachment 7

Mussel Photos

Attachment 8

QAAP

Prepared for:

Bare Hill Pond Watershed Management Committee and the Town of Harvard, MA

QUALITY ASSURANCE PROJECT PLAN

FOR THE BARE HILL POND NOXIOUS PLANT REDUCTION PROJECT

Prepared By:

ENSR INTERNATIONAL

2 Technology Park Drive
Westford, MA 01886

PROJECT NUMBER 08742-044
MAY 2004

QUALITY ASSURANCE PROJECT PLAN FOR BARE HILL POND NOXIOUS PLANT REDUCTION PROJECT

DATE: MAY 2004

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(KENNETH J WAGNER) (DATE)

MADEP QUALITY ASSURANCE OFFICER: ______________________

(ARTHUR SCREPETIS) (DATE)

EPA REGION 1 PROGRAM MANAGER: ______________________

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BARE HILL POND WATERSHED COMMITTEE CHAIRPERSON:

____

(BILL JOHNSON) (DATE)

TOWN OF HARVARD CONSERVATION COMMISSION:

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(MICHELE GIRARD) (DATE)

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FIGURES

DISTRIBUTION LIST

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- Bare Hill Pond Watershed Management Commission
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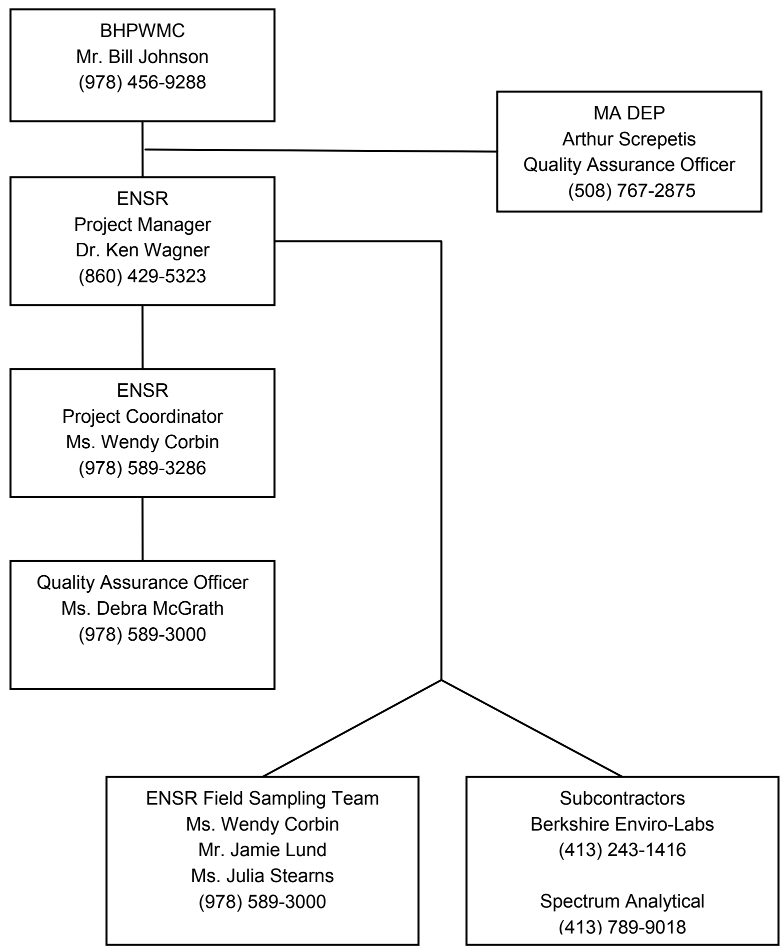
  Harvard, MA 01451

1.0 PROJECT ORGANIZATION

Funding for this project is made available by the United States Environmental Protection Agency (USEPA), the Massachusetts Department of Environmental Management (MADEP), and the Bare Hill Pond Watershed Management Committee (BHPWMC). Mr. Bill Johnson is the project coordinator for the BHPWMC and is primarily responsible for working with ENSR to insure that the project scope is met. Mr. Scripts of the MADEP is involved in the review and approval of the Quality Assurance Project Plan (QAPP) presented here. Dr. Ken Wagner is ENSR's Project Manager for this investigation and is responsible for coordinating specific details of the project and insuring that the work completed by ENSR meets the scope and objectives of the project. Ms. Wendy Corbin is ENSR's Project Coordinator for this investigation and will coordinate all aspects of the project including the sampling surveys, data analysis, and report preparation. Dr. Wagner and Ms. Corbin will be working closely with all interested parties to formulate an effective sampling plan and solicit feedback regarding sampling efforts. Mr. Wagner is also responsible for all ENSR's budgetary constraints of the project. Ms. Debra McGrath is ENSR's Quality Assurance Officer. Her primary responsibility will be to insure that the data collected throughout this investigation meet the quality objectives set forth in this QAPP.

A team of ENSR scientists and Bare Hill Pond volunteers will complete the field data collection portion of the investigation. The ENSR field team will have the responsibility of carrying out all of the tasks described in this QAPP. Volunteers have additional responsibilities in this project and may assist ENSR to learn for future applications. Berkshire Environ-Labs located in Lee, MA will analyze the water samples and Spectrum Analytical located in Agawam, MA will analyze the sediment samples collected during this investigation. Figure 1-1 is an organizational chart outlining the parties involved in this investigation.

Figure 1-1: Organizational chart outlining the relationship between the parties involved in the Bare Hill Pond Noxious Plant Reduction Project.



2.0 PROBLEM DEFINITION/BACKGROUND

Bare Hill Pond is a Great Pond located in the Town of Harvard Massachusetts. This shallow (average depth 12 feet) 316 acre lake suffers from several conditions contrary to optimal recreational pursuits including poor water quality, algal blooms, dense growth of rooted aquatic plants, and loss of water depth from sediment accumulation.

Water quality within the lake is less than desirable. The pond is highly colored and contains elevated concentrations of phosphorus, which limits water clarity. Phosphorus by itself does not reduce water clarity, but biological expression of excessive phosphorus as algal biomass often limits recreation. Previous investigations, including the *Bare Hill Pond Total Maximum Daily Load (TMDL)* (MADEP 1999), have identified storm water and in-lake recycling as primary sources of phosphorus in Bare Hill Pond. The TMDL recommended watershed best management practices through public outreach and education regarding phosphorus loading.

Although phosphorus is an important variable in maintaining desirable water quality within Bare Hill Pond, it is extensive rooted plant growth in the pond that is the main source of recreational and habitat limitation in this water body. Past investigations have concluded that dense plant growths generally occur at water depths less than six feet with approximately 55% of this area covered in dense macrophyte growth in 1998, even after harvesting (ENSR 1998). The cove areas contained the highest density of plant biomass. These areas substantially reduce recreational pursuits and poses entanglement hazards to swimmers. Dominant species included variable milfoil (*Myriophyllum heterophyllum*), Robbin's pondweed (*Potamogeton Robbinsii*), bladderwort (*Utricularia spp*.), white water lily (*Nymphaea odorata*), yellow water lily (*Nuphar variegatum*), watershield (*Brasenia Schreberi*), and smartweed (*Polygonum sp*.). Fanwort (Cabomba caroliniana) has more recently invaded the lake and may be increasing in abundance.

Excessive rooted plant density was not the focus of the TMDL, yet the TMDL recommended in-lake controls for rooted macrophyte control through harvesting and winter drawdown. The Town currently performs both management activities on a regular basis but currently the water level drawdown is limited to a depth of four feet by physical constraints of the outlet structure. In order to increase water level drawdown effectiveness, a floating mounted pump will be designed enabling the implementation of a larger water level drawdown thereby increasing the impacted area.

This QAPP has been prepared for the monitoring program designed to assess the efficacy of the proposed increased water level drawdown and continued watershed sampling to measure any benefits gained through education and outreach activities.

3.0 PROJECT/TASK DESCRIPTION AND SCHEDULE

3.1 Overview

The BHPWMC has taken on a Bare Hill Pond Noxious Plant Reduction project with financial assistance from the Town of Harvard, MADEP and EPA through a Clean Water Act Section 319 Non-Point Source Management Program grant. This project entails the following:

1. Develop and implement a QAPP (subject of this document);
2. Develop a floating pump station to facilitate expanded drawdown;
3. Continue gravity feed drawdown, weed harvesting and manual weed pulling to reduce macrophyte growth;
4. Perform a non-point source (NPS) survey of the lake and watershed; and
5. Develop a community outreach and education program to improve watershed management and reduce phosphorus inputs.

This QAPP provides quality control and assurance procedures designed specifically for measuring the efficacy of the in-lake and watershed management activities. Rooted plant surveys will be performed prior to drawdown initiation and the year following a successful drawdown. Pre-drawdown survey data (current year plus plant data collected in 1998 and 2001) will be compared to post drawdown (scheduled for 2005). Data will be subjected to statistical analysis to determine if significant changes have occurred as a result of in-lake rooted plant management. In-lake and watershed sampling during a variety of weather conditions (dry, wet and post-wet) will occur over a three-year period to document pre- and post- watershed management conditions.

In addition, sediment samples will be collected for sediment chemical composition. Four locations will be sampled and analyzed for variables necessary to characterize sediment for dredging and disposal and seven locations will be sampled for sediment phosphorus to estimate potential internal recycling.

3.2 Task Description

A series of field surveys will be performed over a three year period. These surveys include:

- Two macrophyte surveys
- Nine in-lake water quality surveys (three surveys per year over a three year period)
- Nine watershed surveys (three surveys per year over a three year period)
- One sediment survey

3.2.1 Macrophyte Surveys

ENSR will map Bare Hill Pond vegetation along the five transects established in 1998 and utilized again in 2001 (Figure 3-1) following the methods applied in 1998. The survey will focus on macroscopic fully submerged, floating-leaved (e.g., milfoil), and/or floating plants (e.g., duckweed). Plant cover, biovolume, and taxonomic composition of the aquatic vegetation will be recorded at 52 points along the five transects originally outlined in the 1998 survey. As in 1998, a semi-quantitative 0-5 scale will be used to estimate a plant cover and biovolume. Water depth and sediment type (boulders, rocks, muck, etc.) will also be recorded at each transect point.

Plant mapping will occur during periods of peak biomass (summer) in 2004 and the year following a targeted drawdown that meets specific criteria for success (total of two surveys). Data will be subjected to statistical analysis to determine the efficacy of drawdown for plant biomass and cover control.

Unfortunately, it is difficult to use volunteers for the macrophyte sampling. Minimizing sampling error by keeping methods and even personnel consistent will be imperative for this type of sampling since statistical correlations are being evaluated in this study. Having trained biologists, consistent sampling techniques and equipment will minimize sampling error. It is therefore not recommended that volunteers perform the macrophyte surveys in this case.

3.2.2 In-lake Surveys

ENSR will collect two samples (surface and bottom) at two stations (North and South locations) within Bare Hill Pond three times per year, over a period of three years (Figure 3-2). One sample will be collected each year for quality control (QC). A total of 39 samples will be collected over the three year period (2 stations x 2 depths x 3 times/yr = 12 samples/yr plus one QC sample/yr = 13 samples/yr; 13 samples x 3 years = 39 samples). Samples will be analyzed for total and dissolved phosphorus by a Massachusetts State Certified laboratory. In-situ measurements of temperature and dissolved oxygen will be recorded at one location (deepest station) during each sampling event. Results will be compared to data collected during previous investigations and literature values.

In-lake sampling is essential for documenting existing conditions within the pond in terms of nutrient enrichment, measuring the impacts of BMPs applied in the watershed, and assessing future management alternatives for the protection and enhancement of this aquatic resource. Sampling by ENSR will maintain consistency throughout the project and with previous investigations conducted by ENSR. In ENSR's experience, compliance from volunteers has been inconsistent on previous projects and therefore is not recommended. Reducing the number of samples will reduce the amount of variability we are able to measure and would not be appropriate since before/after comparisons will be made. Increased sampling exceeds budgetary limitations.

3.2.3 Watershed Surveys

ENSR will collect a series of samples to characterize water quality during three different weather conditions (dry, wet and post-wet) at four locations (two major tributaries and two stormwater drainage locations or small tributaries) in each of three years (Figure 3-3). The four proposed locations will be sampled three times during a period of dry weather, provided flowing water is present. These stations will be sampled again during a wet and post-wet weather event. One QC sample will be taken each year. A total of 39 samples will be collected per weather condition over a three year period (4 stations x 3 times/yr + 1 QC/yr = 13 samples/yr; 13 samples x 3 years = 39 samples X 3 weather conditions = 117 total samples over a 3-year period). It is possible that fewer samples will be taken since some locations will not be flowing during all weather conditions.

All samples will be delivered to a Massachusetts State Certified laboratory and analyzed for total and dissolved phosphorus. Results will be compared to data collected during previous investigations and literature values.

Watershed sampling is essential for documenting the incoming water quality in terms of nutrient loading, potential mitigation afforded by implementation of education and outreach, and assessing future management alternatives for water quality improvement within the watershed. Sampling by ENSR will maintain consistency throughout the project and with previous investigations conducted by ENSR. In ENSR's experience, compliance from volunteers has been inconsistent on previous projects, especially during periods of inclement weather, and therefore is not recommended. Reducing the number of samples will reduce the amount of variability we are able to measure and would not be appropriate since before/after comparisons will be made. Increased sampling exceeds budgetary limitations.

Sampling during each weather period allows for conclusions regarding the type of management necessary to control nutrient sources. For example, high loading during dry weather as opposed to wet weather may indicate a constant source such as wastewater and a corresponding form of management may be warranted. If the reverse is true, where stormwater provides both higher flows and concentrations, it will be important to understand at what point the worst condition exists. If only first flush concentrations are elevated, treatment of only a portion of the incoming water will be necessary, thereby reducing the amount of treated water and cost associated with treatment.

3.2.4 Sediment Survey

ENSR will collect sediment samples at four locations (beach, outlet, and proximal to two tributaries) once during the three year period (Figure 3-4). Sediment samples will be analyzed by a State Certified laboratory for sediment quality variables necessary to characterize sediment for dredging and disposal. Sediment quality variables will include extractable petroleum hydrocarbons, total petroleum hydrocarbons, polynuclear aromatic hydrocarbons, select metals (Ar, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni and Zn), pesticides, polychlorinated biphenyls, total organic carbon, total solids, total volatile solids, and grain size. In addition, seven locations (two near the tributaries plus the five stations sampled in 2003) will be sampled for loosely-sorbed phosphorus, iron-bound phosphorus, total iron and total solids near the end of the three year period (Figure 3-4). Results will be compared to data collected during previous investigations and literature values.

Volunteers are not recommended for this task as sampling involves specialized equipment and knowledge of the sediment fractions targeted to be most representative and meaningful.

3.3 Schedule

A tentative schedule of field survey activities is provided in Table 3-1. While the weather conditions for each survey are fixed, the general timing of each survey may be altered from that represented in Table 3-1. Such alterations may occur to either take advantage of optimal weather conditions or to streamline the sample collection process and meet budgetary restrictions through enhanced efficiency.

3.3.1 In-lake Macrophyte Survey

A pre-drawdown macrophyte survey will occur before the scheduled drawdown (2004) during a period of peak biomass (summer). A post-drawdown survey will be conducted during a period of peak biomass following a successful drawdown. A drawdown is defined as successful when:

- The desired drawdown depth is achieved;
- The weather during drawdown is such that temperatures are sufficiently low to freeze exposed areas without an insulating snow cover for a period longer than 30 days;
- The pond is refilled in the spring to average water level.

3.3.2 In-lake and Watershed Water Sampling

A series of watershed water quality samples will be collected during three different weather conditions (dry, wet, and post-wet) once per year for a period of three years (2004-2006). In-lake water quality sampling will occur three times per year for a period of three years during dry weather in summer months (June-early September).

3.3.3 In-lake Sediment Sampling

Sediment samples at four locations will be collected once during the three year period. Sampling will occur during dry weather in the summer of 2005.

Table 3-1 Proposed Project Schedule

	2004				2005				2006			
Survey	**June**	**July**	**Aug**	**Sept**	**June**	**July**	**Aug**	**Sept**	**June**	**July**	**Aug**	**Sept**
Macrophyte Survey		X	X			X	X					
Watershed Sampling	X	X	X	X	X	X	X	X	X	X	X	X
In-lake Sampling	X	X	X		X	X	X		X	X	X	
Sediment Sampling							X					

Figure 3-1. Bare Hill Pond macrophyte sampling transects

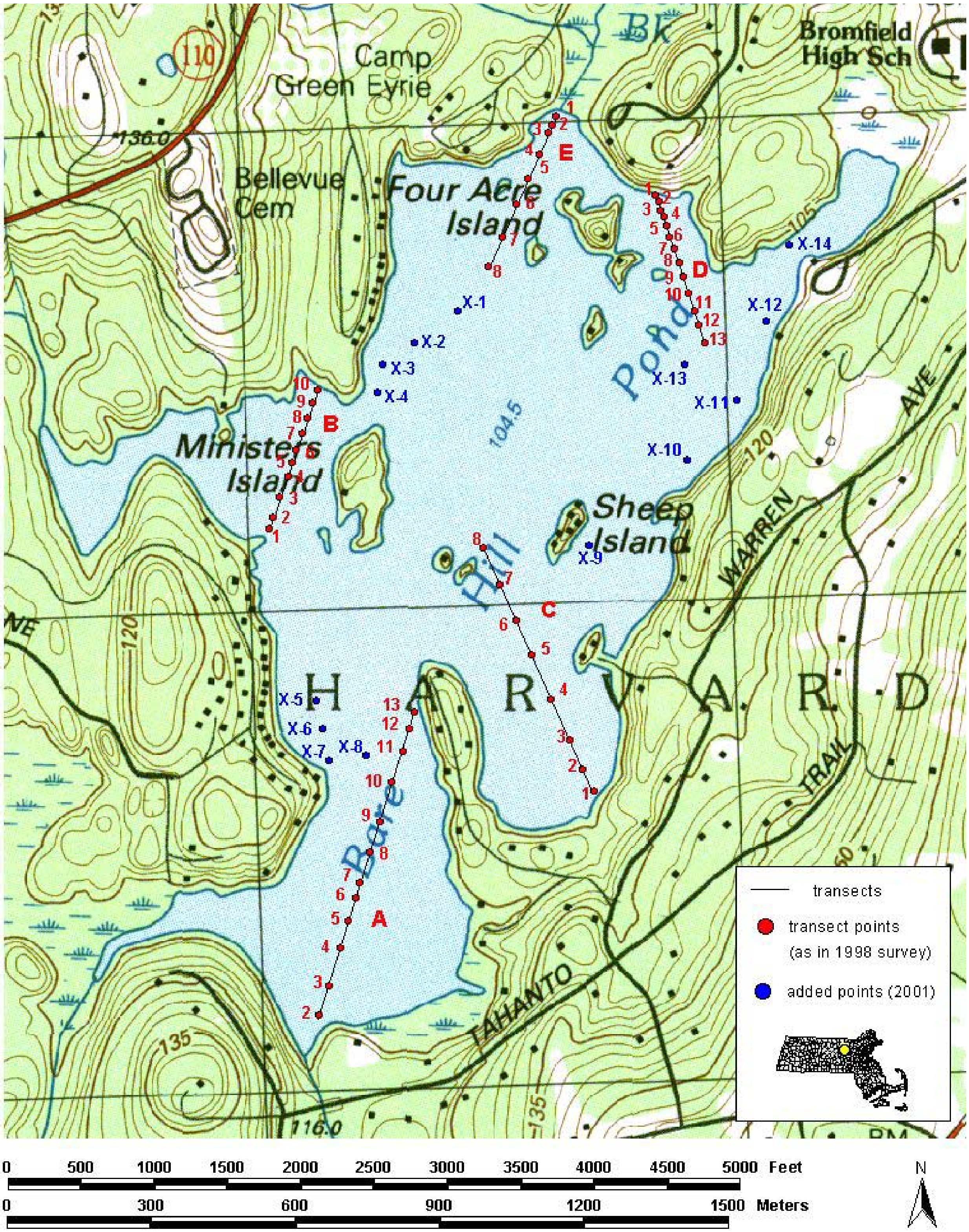


Figure 3-2. Bare Hill Pond in-lake water sampling locations

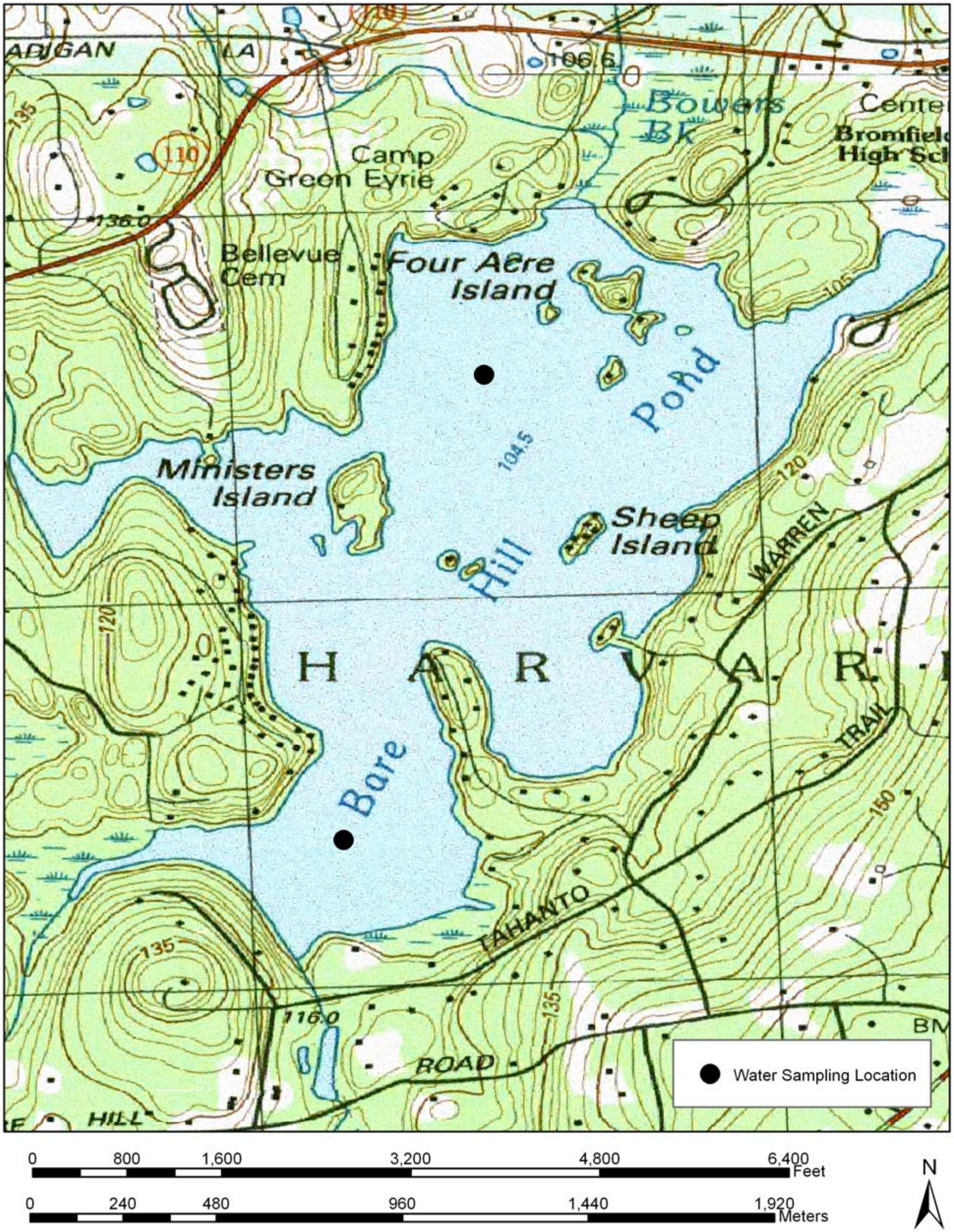


Figure 3-3. Bare Hill Pond watershed water sampling locations

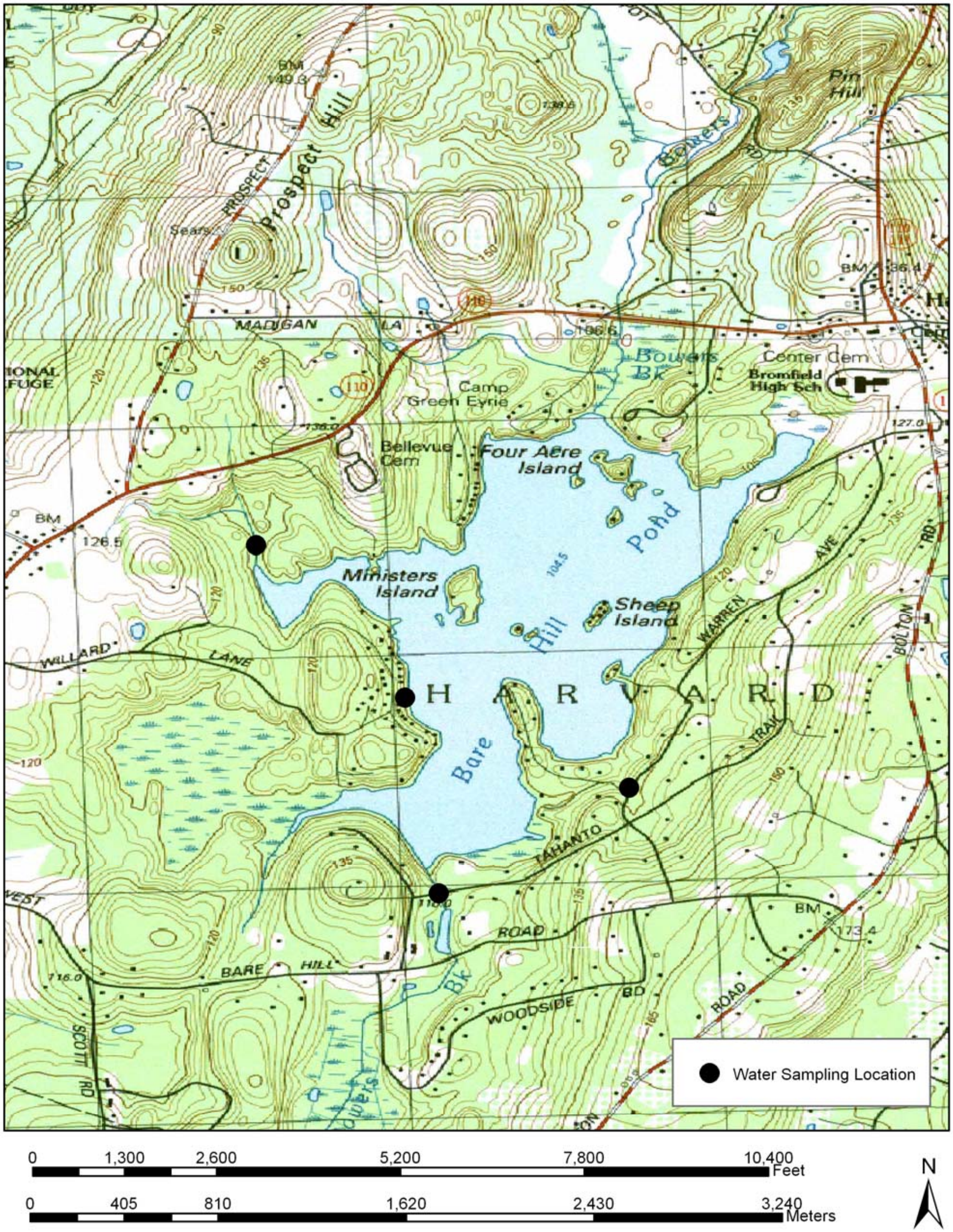
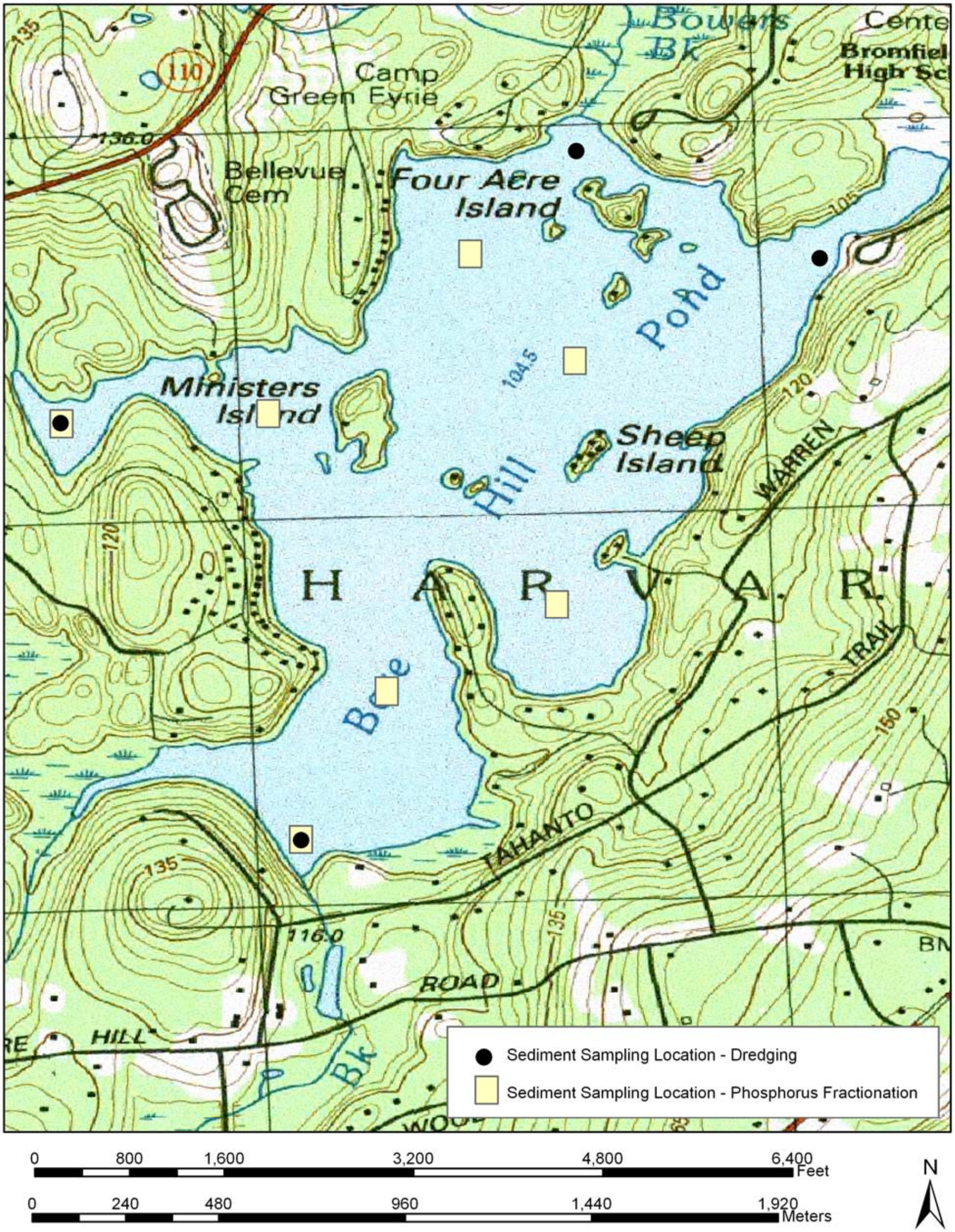


Figure 3-4. Bare Hill Pond sediment sampling locations



4.0 DATA QUALITY OBJECTIVES FOR MEASUREMENT DATA

4.1 Quality Objectives

There are several data quality objectives for this investigation. For the macrophyte surveys, it will be important to adequately quantify the abundance of rooted plant material in the pond and accurate identify species composition. For the water quality sampling (in-lake and watershed) it will be important to insure that sample frequency and locations will adequately quantify nutrient conditions in the system under varying weather conditions pre- and post-watershed education program. Objectives for the sediment sampling are to accurately characterize the chemical composition of sediments to evaluate dredging disposal alternatives and estimate potential internal phosphorus load in this system.

These objectives will be met by using well-maintained instruments, following any pre- and post-calibration procedures, and following through with the comprehensive sampling plan presented in the Scope of Services and outlined in this document.

Measurement Performance Criteria

The method employed by ENSR's experienced biologists for rooted plant surveys will ensure that plant biomass will be adequately quantified and species composition will be accurately determined. To meet water quality objectives, a review of previous investigations was performed to determine appropriate sampling stations, sampling frequency, and selected weather conditions to determine phosphorus loading from the watershed and resulting in-lake concentrations. Sediment sampling locations were selected based on areas identified as potential dredging locations by the BHPWMC and those sampled during previous locations. The careful review of previous investigations and sample location selection ensures that this sampling program is representative of in-lake and watershed conditions.

A certain level of precision, accuracy, and method detection limits (MDL's) is desired for chemical analysis. Water and sediment quality parameters and desired performance criteria are presented in Table 4-1. It should be noted that the actual MDL provided for sediment is the desired value, which may change depending on the cleanliness of sediment samples. Due to budget restraints, blank samples will not be analyzed.

Table 4-1: Desired precision, accuracy and MDL for water and sediment quality parameters based on the quality objectives set forth in this QAPP.

Parameter	Field Precision	Lab Precision	Accuracy	MDL
Water Quality				
Temperature	0.5 C	NA (in-situ)	<0.5 difference between duplicates	0 C
Dissolved Oxygen	0.5 mg/L	NA (in-situ)	+/- 0.5 C between duplicates	0 mg/L
Total Phosphorus	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.01 mg/L
Dissolved Phosphorus	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.01 mg/L
Sediment Quality				
Extractable Petroleum Hydrocarbons	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	1 – 10 mg/kg
Total Petroleum Hydrocarbons	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	10 mg/kg
Polynuclear Aromatic Hydrocarbons	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.7 – 1000 mg/kg
Arsenic	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.3 mg/kg
Cadmium	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.8 mg/kg
Chromium	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.2 mg/kg
Copper	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.5 mg/kg
Iron	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	5 mg/kg
Lead	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.5 mg/kg
Manganese	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.5 mg/kg
Mercury	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.2 mg/kg
Nickel	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.3 mg/kg
Zinc	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.5 mg/kg
Pesticides	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.02 – 0.3 mg/kg
Polychlorinated Biphenyls	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.1 mg/kg
Total Organic Carbon	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	200 mg/kg
Total Volatile Solids	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	0.01%
Total Phosphorus	< 30% of RPD	< 20% of RPD	75-100% recovery for either blank or matrix spike.	10 mg/kg

5.0 SPECIAL TRAINING REQUIREMENTS

5.1 Training and Certification

This investigation includes no non-routine field sampling techniques, field analyses, laboratory analyses, or data validation. Specialized training is therefore not required however; all field personnel are experienced in standard protocols for vegetation surveys and water and sediment sampling using the equipment identified within this QAPP. Certifications relevant to implementing this plan are not required.

6.0 DOCUMENTATION AND RECORDS

6.1 Information Included in the Reporting Packages

The project file will be the central repository for all documents, which constitutes all materials relevant to surveys, sampling and analysis activities as described in this QAPP. ENSR is the custodian of the project files and maintains the contents of the project files for the investigation, including all relevant records, reports, logs, field notebooks, pictures, subcontractor reports, and data reviews in a secured, limited access area and under custody of the ENSR Project Manager.

The final project files will include at a minimum:

- Field logbooks,
- Field data and data deliverables,
- Photographs, and drawings,
- Sample collection logs,
- Laboratory data deliverables,
- Data validation reports and data assessment reports,
- Progress reports, QA reports, interim project reports, etc.,
- All documentation (forms, airbills, etc.)

7.0 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

7.1 Scheduled Project Activities, Including Measurement Activities

The field survey portion of this investigation will be performed from June 2004 through September 2006. It is anticipated that all of the planned activities will take place according to the schedule provided in Section 3. Flexibility in survey scheduling is required in order to collect measurements under conditions appropriate to support project objectives (e.g., wet-weather surveys).

7.2 Rationale for the Design

The sampling program detailed in this QAPP has been designed to:

- measure impacts associated with watershed BMPs;
- measure impacts associated with in-lake winter water level drawdown;
- estimate potential internal phosphorus loading from sediments; and
- determine the chemical composition of pond sediment as it relates to dredging disposal alternatives

The study has been designed to effectively quantify rooted vegetation biomass, incoming phosphorus from the watershed under wet and dry weather conditions, potential internal phosphorus loading from the sediment and characterize sediment quality for potential dredging.

7.3 Procedures for Locating and Selecting Sampling Stations

Macrophyte transects and sampling points have been identified during previous investigation (Figure 3-1). Water quality and sediment sampling stations are identified on US Geological Survey topographic map (Figures 3-2 through 3-4). If selected locations prove to be inaccessible, sampling stations will be relocated in close proximity of the original station, at the discretion of the field crew and ENSR's Project Manager. Field personnel will carry maps of the study area during all sampling operations.

8.0 SAMPLING METHODS REQUIREMENT

8.1 Macrophyte Surveys

ENSR will map Bare Hill Pond vegetation along the five transects established in 1998 and utilized again in 2001 (Figure 3-1). The survey will follow the methods applied in 1998. The survey will focus on macroscopic fully submerged, floating-leaved, and/or floating plants. Plant cover, biovolume, and taxonomic composition of the aquatic vegetation will be recorded at 52 points along the five transects originally outlined in the 1998 survey.

Observations will be made from a boat, viewing an area covering ~3 ft (~1 m) around each transect point. An AquaView submergible video display will be used, with a camera lens lowered down to the lake bottom at each point. Plant taxa will be identified *in situ*, upon visual inspection, and supplemented by sampling with a plant rake as needed.

Plant cover will be expressed as the proportion of the view area covered by living plant material. As in 1998, a semi-quantitative 0-5 scale will be used, with zero expressing absence of vegetation and 5 expressing 100% cover (i.e., sediments not visible in the view area). Values of 1-4 represent 25% cover increments. Likewise, a 0-5 scale will be used to express plant biovolume, defined as living plant material filling the water column above the view area (5 = 100% = entire water column filled with living plants). As in 1998, the percent relative abundance of each taxon will be assessed at each point. Percent relative abundance is based on total biovolume (i.e., each taxon comprising a percent of the total biovolume at each transect point). Water depth and sediment type (boulders, rocks, muck, etc.) will also be recorded at each transect point. All estimates will be made by both biologists. One transect will be repeated for quality assurance purposes.

Plant mapping will occur during periods of peak biomass (summer) this year and following a successful drawdown (total of two surveys). Data will be categorized by water depth (2-4', 4-6', 6-8' and >8') before and after drawdown and subjected to non-parametric statistical analysis (such as Kruskal-Wallis Test or the Wilcoxon Signed Ranks Test) to determine the efficacy of drawdown for plant biomass and cover control.

8.2 In-lake Surveys

ENSR will collect two grab samples (surface and bottom) at two stations (Figure 3-2) within Bare Hill Pond three times per year, over a period of three years. An Alpha-bottle will be used to collect all samples. The Alpha-bottle will be rinsed with the sample water prior to collecting a sample. Surface water samples will be collected approximately 2" below the air-water interface thereby avoiding particles floating on the water surface. Bottom samples will be collected at depth. Water within the Alpha bottle will be used to fill the pre-preserved laboratory bottles labeled for total phosphorus analysis. Sample water will be filtered through a 0.45 μm filter prior to filling the pre-preserved laboratory bottles labeled for dissolved phosphorus analysis. The filter will be rinsed with sample water before each sample collection. Filtrate will be discarded into the lake. Samples will be shipped overnight to Berkshire Enviro-Labs in Lee, Massachusetts to be analyzed for total and dissolved phosphorus. The holding time for total phosphorus is 28 days and 24 hours for dissolved phosphorus and will be met by shipping the samples on ice overnight next business morning.

Water samples will be collected using clean laboratory bottles dedicated to each location and collection and filtration devices (Alpha-bottle and disposable plastic filters) will be rinsed with sample water. Decontamination of equipment therefore is not required. Investigation-derived waste (IDW) includes only the disposable filters. These filters will be taken back to ENSR for proper disposal.

One sample will be collected each year for quality control (QC). A total of 39 samples will be collected over the three year period (2 stations x 2 depths x 3 times/yr = 12 samples/yr plus one QC sample/yr = 13 samples/yr; 13 samples x 3 years = 39 samples). Additional QA/QC steps are applied by the lab as a part of their routine operation and will be noted. Also, we have multiple years of QA/QC data for this lab and its personnel and know what level of detection and variability to expect.

In-situ measurements of temperature and dissolved oxygen will be recorded at one location (deepest station) during each sampling event using a YSI® portable water quality instrument, immediately following collection of in-lake water samples. The YSI® meters used during this investigation will be able to measure temperature and dissolved oxygen simultaneously to increase sampling efficiency. The YSI® water quality probe will be lowered at 1 foot increments (measured with a graduated cable) throughout the water column. Each of the readings will be allowed to become stable before a value is reported in the field notebook.

8.3 Watershed Surveys

ENSR will collect a series of grab samples to characterize water quality during three different weather conditions (dry, wet and post-wet) at four locations (two major tributaries and two stormwater drainage locations or small tributaries; Figure 3-3) in each of three years. The four proposed locations will be sampled three times during a period of dry weather, provided flowing water is present. Dry weather is defined as a period of 72 hours of no measurable precipitation preceding the sampling.

Sampling will occur in flowing water mid-channel at mid-depth. A laboratory pre-cleaned plastic sample bottle will be rinsed three times with prior to filling with sample water. A pre-preserved laboratory bottle labeled for total phosphorus analysis will be filled using sample water. For dissolved phosphorus samples, water will be filtered through a 0.45 μm filter prior to filling the pre-preserved laboratory bottles. The filter will be rinsed with sample water before each sample collection. Filtrate will be discarded into mid-channel. Samples will be shipped overnight to Berkshire Enviro-Labs in Lee, Massachusetts to be analyzed for total and dissolved phosphorus. The holding time for total phosphorus is 28 days and 24 hours for dissolved phosphorus and will be met by shipping the samples on ice overnight next business morning.

Stations will be sampled during a wet weather event (precipitation event yielding greater than 0.1 inch) on the rising limb of a hydrograph (first flush). If an ENSR scientist cannot be onsite during first flush, a passive stormwater sampler will be utilized to collect the sample (Figure 8-1). This device consists of a sample bottle fixed to a pole within the stream channel. The bottle is held upright, with the two tubes of unequal length extending out of the top of the bottle. During the dry sample collection survey, a pre-clean unpreserved wet sample bottle will be placed within the stream channel so that one of the tubes is just above the water surface and the second is well above the water surface. In this way, the bottle will fill as stage increases immediately after a rain event. As this happens, air will be released out of the second tube.

The sample bottle will be retrieved immediately following the rain event. Total phosphorus samples will be poured into pre-preserved sample bottles. Dissolved phosphorus samples will be filtered through a 0.45 µm filter prior to filling the pre-preserved laboratory bottles. The filter will be rinsed with sample water before each sample collection. Filtrate will be discarded into mid-channel. All samples will be placed in an ice filled cooler for transport to Berkshire Enviro-Labs for analyses. By collecting samples in this fashion the “first-flush” of phosphorus through the system will be evaluated.

Post-wet sampling is defined as the period when flows are dropping back to “normal” conditions (i.e., waning hydrograph). Post-wet samples will be collected in the same manner as the dry-weather sampling. Sampling will occur in flowing water mid-channel at mid-depth.

One QC sample will be taken each year. A total of 39 samples will be collected per weather condition over a three year period (4 stations x 3 times/yr + 1 QC/yr = 13 samples/yr; 13 samples x 3 years = 39 samples X 3 weather conditions = 117 total samples over a 3-year period). It is possible that fewer samples will be taken since some locations will not be flowing during all weather conditions.

All samples will be delivered to Berkshire Enviro-labs and analyzed for total and dissolved phosphorus. There are no preservative requirements for these analyses other than temperature. The holding time for phosphorus is generally 48 hours and will be met by shipping the samples on ice overnight next business morning.

8.4 Sediment Survey

ENSR will collect sediment samples at four locations (beach, outlet, and near two tributaries) once during the three year period. Sediment samples will be analyzed by a State Certified laboratory for sediment quality variables necessary to characterize sediment for dredging and disposal. Sediment quality variables will include extractable petroleum hydrocarbons, total petroleum hydrocarbons, polynuclear aromatic hydrocarbons, select metals (Ar, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni and Zn), pesticides, polychlorinated biphenyls, total organic carbon, total solids, total volatile solids, and grain size.

Sediment cores will be collected using a gravity-coring device (Eijelkamp or equivalent), allowing collection of an intact core over the intended depth at each location. The depth of sampling will correspond to the anticipated depth of possible dredging, which is assumed to be the depth of soft sediment. Up to three cores will be collected from each of the four locations. A physical description of each core will be recorded in the field. Cores will be composited within each sample location to provide one representative sample per location.

In addition, seven locations (two near the tributaries plus the five stations sampled in 2003) will be sampled for loosely-sorbed phosphorus, iron-bound phosphorus, total iron and total solids near the end of the three year period. Grab samples of the upper 2" of sediment will be collected using an Ekman dredge at each of the seven locations.

Samples will be collected in a laboratory cleaned glass jar and kept in a cooler on ice and transported back to ENSR. There are no preservatives required for these analyses other than temperature. Spectrum Analytical will pick up the samples at ENSR within the respective holding times (24 hours). There is currently no budget for separate QA/QC testing therefore the laboratory QA/QC program will be relied upon (duplicates and spike analyses). Results will be compared to published thresholds and criteria.

8.5 Sampling/Measurement System Failure Response and Corrective Action Process

Corrective action in the field may be needed when the sample network is changed (i.e., more/less samples, sampling locations other than those specified in the QAPP, etc.), or when sampling procedures and/or field analytical procedures require modification, etc. due to unexpected conditions. In general, the field team may identify the need for corrective action. The field staff in consultation with the ENSR Project Coordinator will recommend a corrective action. The ENSR Project Manager will approve the corrective measure, which will be implemented by the field team. It will be the responsibility of the ENSR Project Manager to insure the corrective action has been implemented.

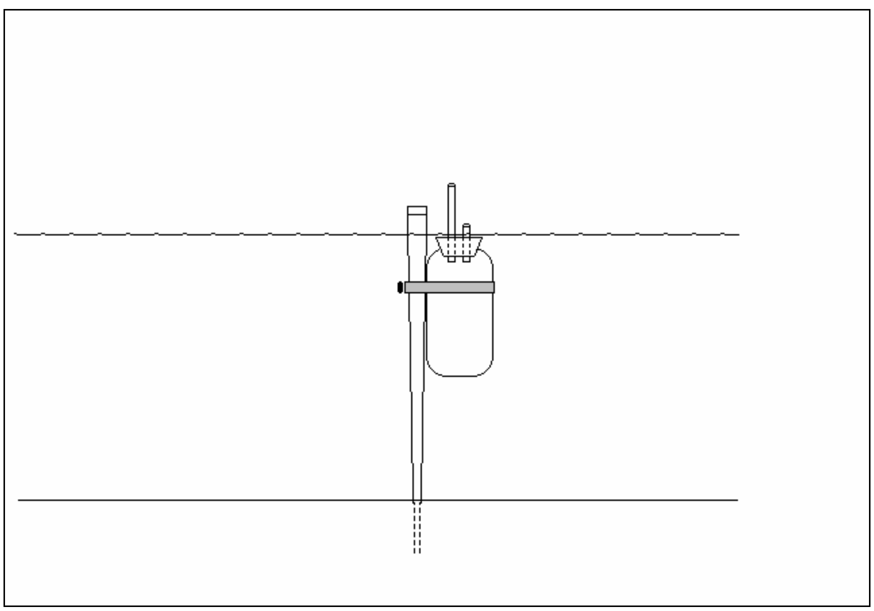
Corrective actions will be implemented and documented in the field record book. No staff member will initiate corrective action without prior communication of findings through the proper channels.

Corrective action in the laboratory may occur prior to, during, and after initial analyses. A number of conditions such as broken sample containers, unusual meter readings, and potentially high concentration samples may be identified during sample log-in or just prior to analysis. Following consultation with laboratory analysts and Section Supervisors, it may be necessary for the Laboratory QA/QC Officer to approve the implementation of corrective action.

The bench chemist will identify the need for corrective action. The Section Supervisor, in consultation with the staff, will approve the required corrective action to be implemented by the laboratory staff. The Laboratory QA/QC Officer will insure implementation and documentation of the corrective action.

These corrective actions are performed prior to release of the data from the laboratory. The corrective action will be documented in both the laboratory's corrective action files, and the narrative data report sent from the laboratory to the ENSR Project Coordinator. If the corrective action does not rectify the situation, the laboratory will contact the ENSR Project Coordinator.

Figure 8-1: Illustration of passive surface water sampler for sampling the "first flush" of storm related flow in a stream channel.



9.0 SAMPLING HANDLING AND CUSTODY REQUIREMENTS

9.1 Sample Custody Procedure

Field logbooks will provide the means of recording the data collecting activities performed during the investigation. As such, entries will be described in as much detail as possible so that persons going to the site could reconstruct a particular situation without reliance on memory.

Field logbooks will be bound field survey books or notebooks. Logbooks will be assigned to field personnel, but will be stored in the project files when not in use. The project-specific document number will identify each logbook.

The title page of each logbook will contain the following:

- Person to whom the logbook is assigned,
- The logbook number,
- Project name and number,
- Project start date, and
- End date.

Entries into the logbook will contain myriad information. At the beginning of each entry, the date, start time, weather, names of all sampling team members present, and the signature of the person making the entry will be entered. The names of visitors to the site, field sampling or investigation team personnel, and the purpose of their visit, will also be recorded in the field logbook.

Measurements made and samples collected will be recorded. Weather permitting, all entries will be made in ink, signed, and dated and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark, which is signed and dated by the sampler. Whenever a sample is collected, or a measurement is made, a detailed description of the sampling location will be recorded. The number of photographs taken of the sampling location, if any, will be noted.

The equipment used to collect samples will be noted, along with the time of sampling, sample description, depth at which the sample was collected, volume, and number of containers. Sample identification numbers will be assigned prior to sample collection and remain consistent throughout the project.

Sample labels will include the name of the water body, the date and time of collection, the sample unique ID, preservation type, and the type of analysis required. All of the sample label information excepting the date and time of sample collection will be filled on the self-adhesive label prior to the collection of the sample.

The sample packaging and shipment procedures summarized below will insure that the samples will arrive at the laboratory with the chain-of-custody intact.

- The field sampler is personally responsible for the care and custody of the samples until they are transferred or dispatched properly. Field procedures have been designed such that as few people as possible will handle the samples.

- All bottles will be identified by the use of sample labels with sample numbers, sampling locations, date/time of collection, preservation type, and type of analysis. Sample labels will be completed for each sample using ink.

- A properly completed chain-of-custody form will accompany samples. The sample numbers will be listed on the chain-of-custody form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents the transfer of custody of water samples from the sampler the laboratory for analysis.

- Samples will be properly packaged on ice at 4°C for shipment and dispatched to the appropriate laboratory for analysis within the prescribed holding times for the analytes.

Information regarding the sample ID number, the date and time of sample collection, the method of preservation and filtration and other relevant information will be recorded on a chain-of-custody form. This form will be filled out by each of the water quality sampling teams after collection and prior to the transfer of the samples to the laboratory. Upon arrival of the samples at the laboratory the chain-of-custody will be used to insure that each of the samples is accounted for by going through each sample with the technician at hand.

10.0 ANALYTICAL METHODS REQUIREMENTS

10.1 Preparation of the Samples

Water sampling devices such as an Alpha-bottle, sampling container and disposable filters will be rinsed with sample water prior to collection of sample. Pre-preserved bottles (sulfuric acid) will be obtained from the laboratory eliminating the need to spike samples in-situ. All dissolved phosphorus samples will be filtered on-site prior to filling pre-preserved laboratory sample bottles. Samples will labeled and placed in a cooler on ice for overnight transport to the laboratory. Sediment samples require no sample preparation other than proper labeling and storage on ice for transport to the laboratory.

10.2 Analytical Methods

All water samples will be analyzed at Berkshire Enviro-Labs using the methods and detection limits listed in Table 10-1. Sediment samples will be analyzed by Spectrum Analytical using methods and detection limits listed on Table 10-2. These detection limits provide the level of accuracy needed for the investigation.

Table 10-1 Methods of detection for water sample analytes

Parameter	Method of Detection	Reporting Detection Limit
Total Phosphorus	SM 4500-P-B, E	0.01 mg/L
Dissolved Phosphorus	SM 4500-P-B, E	0.01 mg/L

Table 10-2 Methods of detection for sediment sample analytes

Parameter	Method of Detection	Detection Limit
Extractable Petroleum Hydrocarbons	EPH-98-1	@1-10 mg/kg
Total Petroleum Hydrocarbons	EPA SW-846 8440	10 mg/kg
Polynuclear Aromatic Hydrocarbons	EPA SW-846 8310	0.7 mg/kg
Arsenic	EPA SW-846 6010B	0.3 mg/kg
Cadmium	EPA SW-846 6010B	0.8 mg/kg
Chromium	EPA SW-846 6010B	0.2 mg/kg
Copper	EPA SW-846 6010B	0.5 mg/kg
Iron	EPA SW-846 6010B	5 mg/kg
Lead	EPA SW-846 6010B	0.5 mg/kg
Manganese	EPA SW-846 6010B	0.5 mg/kg
Mercury	EPA SW-846 7471	0.2 mg/kg
Nickel	EPA SW-846 6010B	0.3 mg/kg
Zinc	EPA SW-846 6010B	0.5 mg/kg
Pesticides	EPA SW-846 8081A	0.02 – 0.3 mg/kg
Polychlorinated Biphenyls	EPA SW-846 8082	0.1 mg/kg
Total Organic Carbon	EPA SW-846 9060	200 mg/kg
Total Volatile Solids	SM 2540-G	0.01%
Total Phosphorus	SM 4500-P-F	10 mg/kg

11.0 QUALITY CONTROL REQUIREMENTS

11.1 QC Procedures

The macrophyte survey will be conducted by the same biologist, if possible, to minimize any sampler bias in the process.

In-lake field duplicates will be collected once per three rounds of sampling in each year for a total three in-lake duplicated (a frequency of 8.3% of total number of samples). One duplicate sample will be collected per year for each of the weather conditions sampling events (three samples will be collected per year total). A total of nine watershed duplicates will be collected over a three year period (a frequency of 8.3% of total number of samples). Field duplicates will be collected at the aforementioned frequency for water samples to be forwarded to Berkshire Enviro-Labs for analysis.

The laboratory, Berkshire Enviro-Labs, routinely conducts an in-house quality control plan whereby laboratory duplicates, spiked samples, and laboratory blanks are analyzed. On days when samples are analyzed, laboratory QC data may be obtained from the laboratory and reviewed to insure acceptable ranges are maintained.

Due the expense of sediment sampling analyses, duplicate samples for sediment samples will not be collected. There is currently no budget for separate QA/QC sediment testing therefore the laboratory QA/QC program will be relied upon (duplicates and spike analyses).

12.0 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE REQUIREMENTS

12.1 Testing, Inspection, and Maintenance

The YSI® water quality meter used during this investigation will be visually inspected prior to use and tested. The sediment sampling equipment will also be visually inspected and tested prior to use in the field.

12.2 Instrument Calibration and Frequency

Each survey day, the water quality meter will be pre-calibrated prior to the commencement of field activities and post-calibrated following the completion of field activities in accordance with manufacturer's instructions.

12.2.1 Document the Calibration Method that Will Be Used for Each Instrument

The YSI® water quality meter used in this investigation will be calibrated for dissolved oxygen. Dissolved oxygen will be calibrated to air saturation. This method allows the meter to measure the dissolved oxygen concentration in moist air at a given temperature and barometric pressure. After the meter makes a stable reading the instrument is calibrated by forcing it to consider that the reading under those conditions is at 100% saturation. Any deviation between the two measurements will be recorded in the field notebook.

12.2.2 Document the Calibration Standards

All standard solutions used during the calibration process for the water quality instrumentation will be unused, within any expiration data, will be purchased from a reputable manufacturer, and will be specifically designed for the instrument(s) being calibrated.

12.2.3 Document Calibration Frequency

All instruments will be calibrated twice per sampling day. Once prior to the collection of water quality data at the beginning of the day and once at the end of the day to verify that the instrument has remained calibrated throughout the day and that the instrument has not drifted from the original calibration. The following limits are proposed as a verification of drift as 5-10% (depending on the parameter) of the range of values expected to be measured; pH $\pm$ 0.20 S.U., conductivity, $\pm$ 50 uS/cm, temperature $\pm$ $1^{o}C$, and dissolved oxygen, $\pm$ 1.0 mg/L. All pre- and post-calibration procedures will always be recorded in the field notebook.

13.0 DATA ACQUISITION REQUIREMENTS

13.1 Acquisition of Non-Direct Measurement Data

Accuracy of laboratory analysis will be assessed for compliance with the criteria established in Section 4 of the QAPP using the analytical results of method blanks, MS/MSD samples, and LCSs. The percent recovery (%R) for MS/MSD samples will be determined according to the following equation:

$$\%R = \frac{(Amount\ in\ Spiked\ Sample - Amount\ in\ Sample)}{Known\ \mathrm{A}mount\ \mathrm{A}dded}\ x\,100$$

%R for LCSs will be determined according to the following equation:

$$\%R = \frac{Experimental\ Concentration}{Known\ Amount\ \mathrm{A}dded}\ x\,100$$

The relative percent difference (RPD) between the matrix spike and matrix spike duplicate, or sample and sample duplicate in the case of metals, and field duplicate pair is calculated to compare to the criteria in Section 3 of this QAPP. The RPD will be calculated according to the following formula.

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

Completeness is the ratio of the number of valid sample results to the total number of samples analyzed with a specific matrix and/or analysis. Following completion of the analytical testing, the percent completeness will be calculated by the following equation:

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

13.2 Tracking and Quality Verification of Supplies and Consumables

For this project, critical supplies will be tracked through ENSR's system in the following manner outlined in Table 13-1.

Table 13-1 Summary of supplies, inspection requirements, and responsible party

Critical Supplies and Consumables	Inspection Requirements and Acceptance Criteria	Responsible Personnel
Sample bottles	Visually inspected upon receipt for cracks, breakage, cleanliness, presence of preservative	Field team
Chemicals and reagents	Visually inspected for proper labeling, expiration dates, appropriate grade	Field team
Water quality monitoring equipment	Functional checks to insure proper calibration and operating capacity	Field team
Sampling equipment	Visually inspected for obvious defects, damage, and contamination	Field team

No chemicals or reagents will be used by the field team during the investigation other than the pre-preserved sample bottles. Supplies and consumables not meeting acceptance criteria will initiate the appropriate corrective action, e.g., replacement, return to vendor.

14.0 DATA MANAGEMENT

Data Recording

Data that is transposed from field notebooks to an electronic database, and from laboratory reports to an electronic database, will be checked 100% after transcription.

Data Validation

Detail the process of data validation to insure that the system performs the intended function consistently, reliable, and accurately in generating the data.

Data Transformation

It is expected that data transformations made during this investigation will be relatively simplistic and all calculations made during data transformation will be checked 100% prior to dissemination of the transformed information.

Data Transmittal

During the transfer of data from one place (field notebook or data report) to another (electronic data spreadsheet) the data will be copied and checked by one individual and then checked 100% by a second individual to insure accuracy.

Data Reduction

Raw data from field measurements will be recorded directly in field notebooks or on sample logs. If errors are made, results will be legibly crossed out, initialed and dated by the person recording the data, and corrected in a space adjacent to the original (erroneous) entry. Logbooks will be periodically reviewed by the ENSR Project Assistant Manager to insure that records are complete, accurate, and legible.

Reduction of all monitoring data will be made by entering all field-collected data in an Excel® computer spreadsheet. The use of a spreadsheet is desired to facilitate east access and graphic representation of the information.

Laboratory data reduction procedures will be performed according to the following protocol. All information related to analysis will be documented in controlled laboratory logbooks, instrument printouts, or other approved forms. All entries that are not generated by an automated data system will be made neatly and legibly in waterproof ink. Information will not be erased or obliterated. Corrections will be made by drawing a single line through the error and entering the correct information adjacent to the cross out. All changes will be initialed, dated, and, if appropriate, accompanied by a brief explanation. Unused pages or portions of pages will be crossed out to prevent future data entry. Analytical laboratory records will be reviewed by the Project Coordinator on a regular basis and by the Laboratory QA/QC Officer periodically, to verify adherence to documentation requirements.

Prior to being released as final, laboratory data will proceed through a tiered review process. Each analyst will be responsible for reviewing the analytical and QC data that he/she has generated. As part of this review, the analyst will verify that:

- The appropriate methodology was used,
- Instrumentation was functioning properly,
- QC analyses were performed at the proper frequency and the analyses met the acceptance criteria,
- Samples were analyzed within holding times,
- All analytes were quantitated within the calibration range,
- Matrix interference problems were confirmed,
- Method-specific analytical requirements were met (e.g., correlation coefficients), and
- Calculations, dilution factors, and detection limits were verified.

Prior to releasing the final data, the Project Coordinator will review the data to:

- Verify the appropriate methodology was used,
- Verify QC analyses were performed at the proper frequency and the analyses met the acceptance criteria,
- Verify samples were analyzed within holding times,
- Verify data in logbooks and instrument printouts were correctly entered into LIMS,
- Review and document problems encountered during the analysis, and
- Prepare case narratives.

The final data report will be reviewed and approved by the Laboratory QA/QC Officer, Project Coordinator, and Project Manager prior to its release. This review will verify that the report format and content meet client specifications, that the data were reported correctly, and that analytical or QA problems were addressed, documented in the file, and, if appropriate, described in the case narrative.

Representativeness of laboratory procedures will be insured by proper handling, storage and analysis of samples so that the material analyzed reflects the material collected as accurately as possible.

Data Analysis

The data generated during this investigation will be used to compare pre and post-management implementation. Water quality concentrations will be used to calculated differences in loadings pre and post-BMPs. Vegetation data will be used to determine efficacy of a successful winter water level drawdown on plant biomass or cover. Sediment data will be used to determine the feasibility of dredging and calculate the potential internal phosphorus load within Bare Hill Pond.

Data Tracking

Data will be recorded in the field notebooks and upon return completion of the associated date collection information will be transposed to an electronic spreadsheet format. Copies of field data will be made and stored in project file on a daily basis. Laboratory data will also be transposed to an electronic spreadsheet format upon receipt.

Data Storage and Retrieval

Data will be maintained in electronic format using Microsoft Excel® for data analyses and presentation purposes. Backup copies of all data files will be made intermittently throughout the project and upon completion of the project a CD containing all of the electronic data will be burned with copies available for distribution.

15.0 ASSESSMENTS AND RESPONSE ACTIONS

15.1 Assessment of the Subsidiary Organizations

The laboratory as part of their QA Program will conduct laboratory performance and system audits. System audits will be done on an annual basis, at a minimum and will include an examination of laboratory documentation on sample receiving, sample log-in, sample storage, chain-of-custody procedures, sample preparation and analysis, instrument operating records, etc

15.2 Assessment of Project Activities

Field audits will include examination of field sampling records, field screening results, field instrument operating records, sample collection, handling, and packaging in compliance with the established procedures, maintenance of QA procedures, chain-of-custody, etc. Follow-up audits will be conducted to correct deficiencies, and to verify that QA procedures are maintained throughout the investigation. The audits will involve review of field measurement records, instrumentation calibration records, and sample documentation. This will occur once during the investigation.

15.3 Documentation of Assessments and Response Actions

Corrective action is the process of identifying, recommending, approving, and implementing measures to counter unacceptable procedures or out-of-limit QC performance that can affect data quality. Corrective action can occur during field activities, laboratory analyses, data validation, and data assessment. All corrective action proposed and implemented should be documented in the QA sections of project deliverables. Corrective action should only be implemented after approval by the ENSR Project Manager, or his designee. If immediate corrective action is required, approvals secured by telephone from the ENSR Project Manager should be documented in an additional memorandum.

For noncompliance problems, a formal corrective action program will be determined and implemented at the time the problem is identified. The person who identifies the problem is responsible for notifying the ENSR Project Manager.

Any nonconformance with the established QC procedures in the QAPP will be identified and corrected in accordance with the QAPP. The ENSR Project Manager, or his designee, will issue a nonconformance report for each nonconformance condition.

16.0 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

16.1 Data Review

Sampling Design

Sample collection plans will be developed and used during the sample collection periods. These plans will include a detailed map of the sample locations, and the types of samples to be collected. The project manager will brief the sample collection team on the objectives of the sampling.

Calibration

Suspect calibration information will be highlighted in the field data notebook upon discovery of the information. Data collected during the period of suspect information will be footnoted as being questionable.

Data Reduction and Processing

Once these goals and objectives are evaluated and chosen, analytical data quality will be assessed to determine if the objectives have been met. In addition, the data will be reviewed by ENSR's Quality Assurance Officer for indications of interference to results caused by sample matrices, cross contamination during sampling, cross contamination in the laboratory, and sample preservation and storage anomalies (e.g., sample holding time or analytical instrument problems).

16.2 Validation and Verification Methods

Process for Validating and Verifying Data

The procedures used to evaluate field data will include checking procedures utilized in the field, ensuring that field measurement equipment was properly calibrated, checking for transcription errors, and comparing the data to historic data or verifying its "reasonableness". Evaluation of the field data will be the responsibility of the Project Coordinator or her designee.

An independent assessment of the data will be performed by ENSR. The overall completeness of the data package will be evaluated. Completeness checks will be administered on all data to determine whether deliverables specified in the QAPP are present. At a minimum, deliverables will include sample chain-of-custody forms, analytical results, and QC summaries. The reviewer will determine whether all required items are present and request copies of missing deliverables. In addition, holding times and the results of all blanks, MS/MSDs, LCSs, and duplicate analyses be reviewed/evaluated.

The need for corrective action may be identified during either data validation or data assessment. Potential types of corrective action may include re-sampling by the field team or re-injection/reanalysis of samples by the laboratory. These actions are dependent upon the ability to mobilize the field team and whether the data to be collected is necessary to meet the required QA objectives (e.g., the holding time for samples is not exceeded, etc.). If the ENSR data assessor identifies a corrective action situation, it is the ENSR Project Manager who will be responsible for approving the implementation of corrective action, including re-sampling, during data assessment. All corrective actions of this type will be documented by the ENSR Project Coordinator.

17.0 RECONCILIATION WITH DATA QUALITY OBJECTIVES

The Project Manager will review data collected and compare these data to the QC goals of the project. Data not meeting these objectives (exceed holding times, potential container contamination, etc.) will not be used in this investigation. Field data will be examined and compared to the sampling program. Any site sampling location changes must be noted and approved by the Project Manager. The Project Manager will approve all data prior to running any calculations or draw any conclusions.

Appropriate statistical tests will be approved by the ENSR Project Manager, Project Coordinator, and QC Officer prior to use. Any data not used for statistical analysis will be explained in the final report.

Macrophyte data will be categorized for statistical comparisons by water depth (>2', 2-4', 4-6', 6-8', and >8'). Statistical analysis, such as the Wilcoxon Matched-Pairs Rank-Sum Test will be used to determine if there is a significant difference of plant biovolume and cover between pre and post-drawdown. Plant cover and biovolume categories will be ordered and compared. Additionally, literature derived biomass values will be applied to biovolume categories, resulting in an estimate of plant biomass in grams. Pre- and post drawdown biomass estimates will be compared. The null-hypothesis (no difference before and after drawdown) will be rejected if $P<0.10$. The same statistic will be used to compare water quality data pre and post-BMP implementation.

Sediment data will be compared to the Massachusetts Contingency Plan Soil-1 Reportable Concentrations (S-1) to provide guidance on dredging feasibility. Concentrations less than S-1 are generally clean which substantially reduces disposal costs. Sediment phosphorus fractionation data will be used to calculate the potential internal phosphorus load within Bare Hill Pond using methods provided in Rydin and Welch 1998 and 1999.

18.0 REPORTS

Annual letter reports will be generated by December 31st of each sampling year. The report will contain methods used to collect and analyze data, interpret results and provide conclusion and recommendations, if appropriate.

At the end of the three year sampling period a final project report will be prepared that summarizes all data presented in each annual report. Three hard copies of the draft version of the final report will be distributed to the BHPWMC. Additional copies will be provided electronically if necessary. The BHPWMC will be responsible for re-distribution of the draft report to other interested parties (MADEP, Town of Harvard Conservation Commission, etc), unless previously agreed upon by the BHPWMC and ENSR. ENSR will provide one round of edits/comments before the report is finalized. It will be the responsibility of the BHPWMC to consolidate all comments/edits from all interested parties for submission to ENSR. Provided the comments are not substantial, the final report will be issued within two weeks of receiving the comments/edits. Up to 10 copies of the final report will be provided in total to be kept by the BHPWMC or for re-distribution. Additional copies will be provided electronically via email.

19.0 REFERENCES

ENSR 1998. Bare Hill Pond Water Quality and Aquatic Plant Evaluation

ENSR 2003. Bare Hill Pond Sediment Sampling. Letter Report.

MADEP 1999. Bare Hill Pond TMDL MA81007-1999-001 July, 1999

Rydin, E. and E.B. Welch. 1998. Aluminum Dose Required to Inactivate Phosphate in Lake Sediments. Wat. Res. Vol. 32, No. 10, pp. 2969-2976.

Rydin, E. and E.B. Welch. 1999. Dosing Alum to Wisconsin Lake Sediments Based on in vitro Formulation of Aluminum Bound Phosphate. Journal of Lake and Reservoir Management. 15(4): pp. 324-331.

Whitman & Howard, Inc. 1987. Diagnostic/Feasibility Study, Bare Hill Pond, Harvard, Massachusetts

Attachment 9

GEIR

Introduction and Drawdown Section

1.0 INTRODUCTION

1.1 BACKGROUND

1.1.1 The Commonwealth's Policy on Lake and Pond Management

The focus of this Generic Environmental Impact Report is to fully evaluate available lake management techniques for the control of nutrients and aquatic plants in order to support the Commonwealth's 1994 Policy on Lake and Pond Management. That policy is:

> Massachusetts advocates a holistic approach to lake and pond management and planning which integrates watershed management, in-lake management, pollution prevention and education. Lake management in Massachusetts will be designed with consideration of the quality of the lake's ecosystem, its designated uses and other desired uses, the ability of the ecosystem to sustain those uses, and the long term costs, benefits and impacts of available management options.

The policy has the following goals:

- ➢ To promote a holistic approach to lake management which is based on sound scientific principles and emphasizes the integrated use of watershed management, in-lake management, pollution prevention and education.
- ➢ To promote sound planning and management of lakes and their surrounding watersheds by providing guidance to municipal agencies, local organizations, and the public.
- ➢ To streamline the permitting process for in-lake management projects
- ➢ To promote the importance of lakes within ecosystems, acknowledging all associated wetland habitats, including open water, and the biological resources they support.
- ➢ To assure that decisions on the use of lake and watershed management techniques to remediate the impacts of eutrophication and non-native/invasive species consider long-term issues as well as immediate costs, benefits and impacts of available management options.

1.1.2 The Audience

The expected audience includes a diverse array of people who are involved in planning and implementing lake management and includes professional lake managers, community and state officials, and citizens concerned about the quality of specific lakes and ponds. For the purposes of brevity in this review, use of the term "lake" also includes "pond" and "impoundment".

1.1.3 The Purpose

Lakes are important resources. They provide for basic human needs of drinking water, irrigation, generation of electricity, and flood protection, as well as other needs such as fishing, boating, swimming, tourism, and aesthetic enjoyment. Lakes are also vital elements in the biodiversity of the environment, providing crucial habitat for many species. There are many reasons for managing lakes, including restoration of natural conditions disturbed by human impacts; enhancement or maintenance of recreation, water supply, irrigation or other uses; enhancement or protection of fisheries, habitat or endangered species; maintenance of public health and safety, or control of non-native species. However, there is no simple formula that guarantees successful lake management.

Lakes are also home to many non-human users whose use of these lakes might be severely curtailed in the absence of any controls on how humans manage lakes. At the same time, many of our lakes would not even exist without prior human effort in damming streams. Thus, many lakes are already heavily "managed" systems, even though most of the "management" is not planned in a methodical way. Lake management should be guided by principles that protect the wide variety of potential uses and established priorities in each case.

Our purpose is to seek a rational approach to managing lakes in Massachusetts. Lake management should protect public and environmental health, encourage ecological diversity and diverse human use, and preserve the quality of aquatic life that we recognize as an important part of Massachusetts. This almost certainly means that most lakes need more management than they currently receive, especially if we include protection from further impacts as one of the management goals. The alternative to intelligent management is unplanned and often undesirable changes in lake water quality.

Lake management is not based on science alone, but requires a blend of understanding of interrelated and complex natural processes and balancing societal needs and desires. The best lake management plan will incorporate a balance between local needs and the concerns of resource managers at the state level. Understanding the ecology of lakes in general and that of the specific lake is crucial to the development of an effective strategy for lake management. Section 1.2 describes key elements in the structure and function of lakes that bear strongly on the choices available to the prospective lake manager and form the basis of the recommendations in this report.

Management must also consider the human alterations that have occurred, the degree to which either cultural or natural conditions can be changed and at what cost, and the natural and cultural ramifications of management. Sound lake management must focus on the possible, not the perfect. Lake management will seek to: (1) be effective, (2) be inexpensive, or at least affordable, (3) cause few adverse impacts, and (4) be socially, politically and scientifically feasible. Section 1.4 describes the process of developing a lake management plan. The plan incorporates information on the lake ecosystem, the designated and desired uses, the ability of the lake ecosystem to sustain those uses and the long term costs, benefits and impacts of the available management options.

Sections 1.2-1.4 are not intended to be comprehensive treatments of the science of limnology (the study of freshwater ecosystems), the tools available to lake managers for problem diagnosis and evaluation, or the techniques for developing a lake management plan. Other texts provide a more thorough treatment of the science of limnology (Horne and Goldman, 1994; Kalff, 2002), available tools (Holdren et al., 2001; Cooke et al., 1993a; Kishbaugh et al., 1990), developing resource priorities and organizing community support (Holdren et al., 2001), or monitoring (Tetra Tech, 1998; Simpson, 1991). Rather, this introduction provides a basic overview of each so that all parties in the decision process may share a basic common understanding.

The principal function of this GEIR is to create a resource that documents existing lake management practices and determines the conditions under which their use is acceptable in Massachusetts. This information will promote rational lake problem assessment and successful lake management. It does not sanction the indiscriminant selection or rejection of any of the accepted methods without reasonable evidence that the lake to be managed meets the criteria for use or non-use of that particular management practice. Meeting this burden of proof can be accomplished through the process of developing a management plan and will probably require water quality monitoring, assistance by professional lake managers, community involvement, and significant funding. There is no generic lake management plan; each lake is a special case made unique by the many interrelated natural and cultural factors that must be considered. By providing a summary of the techniques, a review of the scientific literature and local experience, guidance for use, and review of relevant regulations, the GEIR will make portions of that process much easier. For very small ponds or limited treatment, the task may be relatively simple; for large lakes or complex treatments, the task will require significant time and effort.

1.2 UNDERSTANDING THE LAKE ECOSYSTEM

1.2.1 Overview

The lakes in Massachusetts were created in two principal ways. Many lakes resulted from glacial activity approximately 12,000 years ago. Others were created by damming streams or by enhancing a small lake by damming its outflow. Most damming occurred during the early industrial age of the country when water power was a critical resource. Through natural processes, most lakes become shallower and more eutrophic (nutrient-rich) and eventually fill in with sediment until they become wet meadows. The aging process is not identical for all lakes, however, and not all start out in the same condition. Many lakes that were formed by the glaciers no longer exist while others have changed little in 12,000 years. Yet lake aging is reversible. The rate of aging is determined by many factors including the depth of the lake, the nutrient richness of the surrounding watershed, the size of the watershed relative to the size of the lake, erosion rates, and human induced inputs of nutrients and other contaminants.

Existing lakes can be subdivided into four categories. Nutrient-poor lakes are termed oligotrophic, nutrient-rich lakes are eutrophic, and those in between are mesotrophic. A fourth category includes lakes following a different path; these typically result in peat bogs and are termed dystrophic lakes. They are often strongly tea colored. Lakes in one part of the Commonwealth may share many characteristics (depth, hydrology, fertility of surrounding soils) that cause them to be generally more nutrient-rich while another region may generally have nutrient-poor lakes.

Lakes that are created by damming streams often follow a different course of aging than natural lakes. At first, they may be eutrophic as nutrients in the previous stream's floodplain are released to the water column. Over a period of decades, that source of productivity tends to decline until the impoundment takes on conditions governed more by the entire watershed, just as for natural

4.2 DRAWDOWN

4.2.1 Water Level Lowering

Drawdown is a multipurpose lake management tool that can be used for aquatic plant control. The water level is lowered by pumping, siphoning, or opening a pipe or gate in the dam. Historically, water level drawdown has been used in waterfowl impoundments and wetlands for periods of a year or more, including the growing season, to improve the quality of wetlands for waterfowl breeding and feeding habitat (Kadlec, 1962; Harris and Marshall, 1963). It has also been a common fishery management method. Until a few decades ago, drawdowns of recreational lakes were primarily for the purpose of flood control and allowing access for near-shore clean ups and repairs to structures, with macrophyte control as an auxiliary benefit. While this technique is not effective on all submergent species, it does decrease the abundance of some of the chief nuisance species, particularly those that rely on vegetative propagules for overwintering and expansion (Cooke et al., 1993a). If there is an existing drawdown capability, lowering the water level provides an inexpensive means to control some macrophytes. Additional benefits may include opportunities for shoreline maintenance and oxidation or removal of nutrient-rich sediments.

The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level.

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

Aside from direct impact on target plants, drawdown can also indirectly and gradually affect the plant community by changing the substrate composition in the drawdown zone. If there is sufficient slope, finer sediments will be transported to deeper waters, leaving behind a coarser substrate. If there is a thick muck layer present in the drawdown zone, there is probably not adequate slope to allow its movement. However, where light sediment has accumulated over sand, gravel or rock, repetitive drawdowns can restore the coarse substrate and limit plant growths.

Desirable side effects associated with drawdowns include the opportunity to clean up the shoreline, repair previous erosion damage, repair docks and retaining walls, and search for septic system breakouts. (Nichols and Shaw, 1983; Cooke et al., 1993a; WDNR, 1989). Some authors (Cooke 1980) have reported that game fishing often improves after a drawdown, but this is not the case in Massachusetts or New England. Since emergent shoreline vegetation tends to be favored by drawdowns, populations of furbearers are expected to benefit (WDNR 1989), although direct negative impacts may be caused if lodges and food caches are exposed. The consolidation of loose sediments and sloughing of soft sediment deposits into deeper water is perceived as a benefit by shoreline homeowners (Cooke et al., 1993a; WDNR 1989).

The actual conduct of a drawdown involves facilitating more outflow than inflow for a sustained period on the order of several weeks or months. After the target water level is reached, outflow is roughly matched to inflow to maintain the drawdown for the desired period, usually at least a month and often up to 3 months, usually over the winter. At a time picked to allow refill before any undesirable spring impacts can occur, outflow is reduced (although it should not be eliminated) and "excess" inflow causes the water level to rise. In some cases, refill is commenced after an inch or two of ice forms, ripping up plants and bottom material. This "extreme disturbance" approach may be a preferable alternative where sediments will not dewater sufficiently to provide the level of freezing and desiccation desired. It also should be noted that this approach may disturb overwintering organisms. Impacts and effectiveness have not been documented, although observations by practitioners seem to favor this approach as more effective than just freezing.

4.2.2 Effectiveness

4.2.2.1 Short-Term

The factors that determine the effectiveness of a drawdown for rooted plant control include:

1. Sensitivity of species to dehydration (Nichols, 1975); see Table 4-2 for sample tolerance listings.
2. Sediment composition and slope. Clay or muck soils will dry out much slower than sandy soil. The rate and degree of desiccation achieved will limit effectiveness (Pieterse and Murphy, 1990). Steeper slopes allow movement of finer sediment out of the area, leaving a less hospitable substrate for growth of plants.
3. The depth of the drawdown; in lakes that have macrophyte beds at varying depths, greater effectiveness is achieved on macrophyte beds that are completely exposed during the drawdown (Siver et al., 1985).
4. Weather during drawdown. Some species, such as *Nuphar*, may require a prolonged period of frost in order for the drawdown to be effective (Cooke et al., 1993a). Repeated rain will offset dewatering. Mild winter temperatures will limit freezing effects. Snowfall can insulate plants, preventing adequate freezing and desiccation.
5. Pattern and rate of groundwater seepage into lake sediments (Cooke, 1980). Groundwater inputs can offset dewatering.
6. Plant density at the time of drawdown. When the canopy dries out it can form a covering over other plants and root systems and prevent dehydration (Pieterse and Murphy, 1990).

To reduce impacts to non-target plants and animals during the growing season, drawdowns in Massachusetts are normally conducted in fall and winter. Most of these factors act upon success over several months, with successful drawdowns resulting in reduced plant density the following growing season. Consequently, short-term impacts are not readily noticeable in most cases. If the following growing season is considered to represent "short-term" effects, then drawdown has variable effectiveness in accordance with the above-listed factors.

The effectiveness of drawdown as an aquatic plant control technique depends foremost on the susceptibility of the target species to drawdown. Some species are sensitive to drawdown, while others are resistant or even stimulated by it (Table 4-2). Species that depend upon vegetative propagation and overwintering strategies (most perennials) will likely to be impacted, while species that depend upon seed reproduction (annuals) may not be impacted. Seeds are not adversely impacted, and germination may be stimulated. If the root systems of perennials can be dried and frozen, density reductions can be striking.

Drawdown has been applied for many years in lake management and tends to reduce rooted plant density in the drawdown zone, even if not always intended as a plant control technique (Dunst et al., 1974; Wlosinski and Koljord, 1996). Winter drawdowns of Candlewood Lake in Connecticut (Siver et al., 1986) reduced nuisance species by as much as 90% after initial drawdown. Drawdowns in Wisconsin lakes have resulted in reductions in plant coverage and biomass of 40 to 92% in targeted areas (Dunst et al., 1974). In one Wisconsin case, Beard (1973) reported that winter drawdown of Murphy Flowage opened 64 out of 75 acres to recreation and improved fishing.

The effect of drawdown on plants is not always predictable or desirable, however. Reductions in plant biomass of 44% to 57% were observed in Blue Lake in Oregon (Geiger, 1983) following drawdown, but certain nuisance species actually increased and herbicides were eventually applied to regain control. Drawdown of Lake Bomoseen in Vermont (VANR, 1990) caused a major reduction in many species, many of which were not targeted for biomass reductions. The Lake Bomoseen drawdown was effective at reducing Eurasian watermilfoil in the areas exposed (down to four feet), but most of the milfoil was present in deeper areas and quickly recolonized. A slow refill of Indian Lake in Worcester in the spring (refill started in May) allowed plants at deeper depths to grow and reach the surface, hindering recreational use (G. Gonyea, MDEP, pers. comm., 1996). Reviewing drawdown effectiveness in a variety of lakes, Nichols and Shaw (1983) noted the species-specific effects of drawdown, with a number of possible benefits and drawbacks. A system-specific review of likely and potential impacts is highly advisable prior to conducting a drawdown.

Algal control by drawdown is dependent upon oxidation of sediments to reduce the potential for internal recycling in subsequent growing seasons. Unfortunately, increases in available nutrients have been as common as decreases, as decomposition makes nutrients more readily available. Where flushing is high, the released nutrients may be out of the lake by the next growing season, but highly flushed systems usually have problems with external loading and may have reduced algal biomass just by virtue of the flushing activity. Short-term impacts of drawdown on algae are therefore not reliably predictable.

Table 4-2 Anticipated response off some aquatic plants to winter drawdown.
(After Cooke et al., 1993a)

	Change in Relative Abundance		
	Increase	No Change	Decrease
Acorus calamus (sweet flag)	E		
Alternanthera philoxeroides (alligator weed)	E		
Asclepias incarnata (swamp milkweed)			E
Brasenia schreberi (watershield)			S
Cabomba caroliniana (fanwort)			S
Cephalanthus occidentalis (buttonbush)	E		
Ceratophyllum demersum (coontail)			S
Egeria densa (Brazilian Elodea)			S
Eichhornia crassipes (water hyacinth)		E/S	
Eleocharis acicularis (needle spikerush)	S	S	S
Elodea canadensis (waterweed)	S	S	S
Glyceria borealis (mannagrass)	E		
Hydrilla verticllata (hydrilla)	S		
Leersia oryzoides (rice cutgrass)	E		
Myrica gale (sweetgale)		E	
Myriophyllum spp. (milfoil)			S
Najas flexilis (bushy pondweed)	S		
Najas guadalupensis (southern naiad)			S
Nuphar spp. (yellow water lily)			E/S
*Nymphaea odorata (*water lily)			S
Polygonum amphibium (water smartweed)		E/S	
Polygonum coccineum (smartweed)	E		
Potamogeton epihydrus (leafy pondweed)	S		
Potamogeton robbinsii (Robbins' pondweed)			S
Potentilla palustris (marsh cinquefoil)			E/S
Scirpus americanus (three square rush)	E		
Scirpus cyperinus (wooly grass)	E		
Scirpus validus (great bulrush)	E		
Sium suave (water parsnip)	E		
Typha latifolia (common cattail)	E	E	
Zizania aquatic (wild rice)		E	

E=emergent growth form; S=submergent growth form (includes rooted species with floating leaves); E/S=emergent and submergent forms

4.2.2.2 Long-Term

The intended overall effect of a drawdown is a change in the composition of the plant community and a reduction in assemblage biomass. The former goal is usually achieved if the target species are sensitive to drawdown. Achieving the latter goal is partly a function of sediment type and slope, but can be achieved with careful drawdown management in many cases. Annual drawdowns maximize long term effectiveness, although repeated drawdowns may result in dominance of drawdown resistant species which could limit the long term effectiveness of this control method (Nichols, 1975). Nuisance conditions caused by drawdown resistant species usually occur in shallow, minimally sloped areas where the substrate is hospitable.

Lake Garfield in Monterey is a good example of the switch from drawdown sensitive to drawdown tolerant species. An 8 ft drawdown limits Eurasian watermilfoil growth but promotes dense stands of the seed-producing, annual, broad-leaf pondweed (*Potamogeton amplifolius*) in that lake (BEC, 1992b). In Candlewood Lake, CT, however, two species of the seed producing, annual, naiad (*Najas*) increased following drawdown, but have not impeded lake uses. After two winter drawdowns during 1983-84 and 1984-85 the biomass of *Myriophyllum spicatum* (Eurasian watermilfoil) was significantly reduced (Siver et al., 1985) and remains an effective control method for milfoil in Candlewood Lake (R. Larsen, NE Utilities, pers. comm., 1995).

Drawdowns at Lake Lashaway (East and North Brookfield, Massachusetts) in the mid-1980s were successful at reducing plant growth for six sequential growing seasons (Haynes, 1990). Previous attempts to control fanwort (*Cabomba caroliniana*) and naiad (*Najas flexilis*) with chemicals had been inadequate in Lake Lashaway, while the drawdowns controlled both species (Haynes, 1990). Drawdown has been applied to many lakes in the Berkshire region since the 1960s or earlier, and plant composition and density in the drawdown zone clearly indicates that species such as Eurasian watermilfoil can be controlled at the lake periphery by this technique. In Stockbridge Bowl there is little milfoil out to a water depth of 3 to 4 ft, owing to an 18-inch drawdown and about 2 ft of ice contact (ENSR, 2002b). Drawdown kept areas of Richmond Pond <6 ft deep largely free of milfoil for over 30 years (BEC, 1990a). Lake Buel, by comparison, has no water level controls and has dense milfoil growth right to the shoreline. It is also true, however, that milfoil grows at depths much greater than drawdown can typically reach, so recolonization after cessation of drawdown may only take a few years.

Otis Reservoir was studied in detail in 2000 (ENSR, 2001c). It has experienced a drawdown of 8 ft, 3 inches on an annual basis for several decades. The drawdown is conducted by the MDCR with a primary goal of protecting structures around the lake from ice damage, but the plant control effect is striking. Where the slope is more than about 1:4 (at least 1 ft of vertical change for every 4 ft of horizontal change), there is almost no soft sediment in the drawdown zone, and the habitat is rock, sand and gravel with few plants. Where the slope is lower, muck sediments are present and seed-producing annual plants native to the area are abundant but not overly dense, creating excellent habitat for fish and invertebrates. Below the drawdown zone, a band of plants encircles the lake, again providing desirable habitat but not interfering with recreation. No invasive species of aquatic plants were found in the lake, despite high levels of boating by visitors.

Indian Lake in Becket has been the subject of six years of study, three pre-drawdown and three post-drawdown (ENSR, 2001d). This drawdown targeted a number of native species that were perceived as expanding toward nuisance levels. The first winter drawdown in 1999-2000 stimulated seed producers but failed to kill vegetative propagators, given the mild winter. The second drawdown in the better suited winter of 2000-2001 greatly reduced the biomass of the plant assemblage, but left areal coverage similar to past years. No species were lost, and overall diversity was higher. Recreation and habitat value were both considered to have been enhanced, based on fewer impediments to sailing and swimming by lower plant growths that had expanded coverage and added species in this lake.

From the data available, it can be concluded that sensitive species (i.e., those overwintering and reproducing by vegetative means) can be controlled within the drawdown zone by exposure over a period of at least a month to drying and freezing conditions. To maintain control, a successful drawdown is needed every other to every third year. However, as success is partly weather dependent, it is generally desirable to plan for annual drawdown and to abort plans when conditions have been acceptable for the previous year or when weather conditions suggest little benefit. When first using drawdown as a management technique, it may be necessary to apply it for several consecutive years, and use of drawdown for certain other purposes (e.g., protection of structures from ice damage, flood prevention) may dictate annual drawdown. The ability of drawdown to reduce overall assemblage density is largely a function of sediment features and regrowth rates. Where a coarse substrate is maintained by drawdown, plant growth is likely to be limited. Where soft sediment is abundant, drawdown-resistant plants can be expected to grow. Whether those resistant plants create nuisance conditions will be a function of which species become dominant.

Long-term control of algae by drawdown depends on reduced release of nutrients from the sediment to the water column. This is only likely when the sediment in the drawdown zone is converted from nutrient-rich muck to sand or coarser substrates. This is sometimes accomplished by focusing of sediments into deeper areas, but only where the slope is adequate. There have been claims that this focusing has negative water quality impacts, but this is unlikely; oxidized sediment arriving in deep waters buries other sediment that was interacting with the water column, and the area of sediment-water interaction is largely unchanged. However, unless a major drawdown is conducted, one in which most of the lake sediment is exposed and altered, it seems unlikely that this approach will yield major algal benefits.

4.2.3 Impacts to Non-Target Organisms

4.2.3.1 Short-Term

Undesirable possible side effects of drawdown include loss or reduction of desirable plant species, facilitation of invasion by drawdown-resistant, undesirable plants, reduced attractiveness to waterfowl (considered an advantage by some), possible fish kills if oxygen demand exceeds re-aeration during a prolonged drawdown, altered littoral habitat for fish and invertebrates, mortality among hibernating reptiles and amphibians, impacts to connected wetlands, shoreline erosion during drawdown, loss of aesthetic appeal during drawdown, more frequent algal blooms after refill in some cases, reduction in water supply, impairment of recreational access during the drawdown, and downstream flow impacts (Nichols and Shaw, 1983; Cooke et al., 1993a).

Careful planning can often avoid at least some of these negative side effects, but managers should be aware of the potential consequences of reduced water level.

Non-target species of plants that depend on vegetative means of overwintering or reproducing may indeed be reduced in abundance along with the targeted species. Resistant species, mainly those overwintering by seed, or species abundant below the drawdown zone, may become more abundant in the drawdown zone. Open substrate created through drawdown may be colonized by invasive species, although most of the problematic nuisance species are sensitive to drawdown. Drawdown for nuisance plant control is intended to cause shifts in plant assemblage composition and abundance, but not all shifts will necessarily be desirable.

The impact of drawdowns on wetlands that are hydraulically connected to the lake is often a major concern of environmental agencies. Available data do not suggest major effects, positive or negative, from winter drawdowns (Van der Valk and Davis, 1980; ENSR, 2002c; 2001d). This is believed to be a result of dormancy by most plants and frozen soil conditions is some areas; wetlands are generally adapted to fluctuating water levels and fluctuations in the winter are of least concern.

Hydrology is generally considered the master variable of wetland ecosystems (Carter, 1986), controlling recruitment, growth and succession of wetland species (Conner et al., 1981). It is apparent that the depth, timing, duration and frequency of water level fluctuations are important with regard to severity of impacts to adjacent wetlands (Kusler and Brooks, 1988). It is also apparent that the specific composition of a wetland plant community prior to drawdown plays a role in determining impacts.

The naturally-occurring hydrologic regime is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. Hydroperiod is the seasonal pattern of water levels in a wetland and is like a hydrologic signature of each wetland type. It is unique to each type of wetland and its constancy from year to year ensures reasonable stability for that wetland (Mitsch and Gosselink, 1986). Significant changes in hydroperiod can produce significant changes in vegetative species zonation in non-forested wetlands (Brinson et al., 1981). However, most drawdowns for lake management purposes constitute only a temporary influence on hydrologic regime, and will not necessarily have a detectable, widespread effect as evidenced in recent studies (ENSR, 2000c; 2000d).

Duration and timing of the drawdown are important factors in limiting impacts to associated wetlands. Drawdown of the water level in summer, if more than a week or two in duration, leads to desiccation and stress of wetland species in most cases. In contrast, a similar drawdown practiced during late fall or early winter is expected to have little impact on dormant emergent plants, but should have a destructive effect on exposed littoral zone.

Most wetland plants are very well adapted for existence during conditions of fluctuating water level. In fact, a prolonged stable water level is known to lead towards dominance by single species in emergent wetland communities; nearly pure stands of common cattail or sedges/grasses are the most common manifestations of this phenomenon (Van der Valk and Davis, 1980). Some water level fluctuation is required for elevated species diversity.

The nature of the wetland soils will influence wetland response to a drawdown. Generally the water table in a peat or muck soil is within one or two feet of the average ground surface (Bay, 1966). The upper layer of a peat soil has been termed the active layer, the layer in which plant roots exist and the layer with the greatest water level fluctuation (Romanov, 1968). The total porosity of the undecomposed raw peat moss horizon exceeds 95%, but the porosity of decomposed peat is only 83%. While this may not seem to be a major difference, lowering the water table in loose, porous, undecomposed peat removes 60 to 80% of the water in a given horizon, but an equal lowering in a decomposed peat removes only approximately 10% of the water (Bay, 1966). Where a substantial layer of decomposing organic matter underlies the wetland, as is expected in most wetlands associated with Massachusetts lakes, dewatering will be very slow and impacts from winter drawdown will be minimized.

In the lake itself, lowering of the water level results in a temporary loss of habitat and possible impacts to fish, invertebrates and algae (Manuel, 1994). Frogs, turtles, beavers and other vertebrates may also be impacted, but there is little scientific documentation. One study of Lake Sebasticook, Maine, found that a large population of freshwater mussels largely disappeared after a lake drawdown (Samad and Stanley, 1986). After a second drawdown in the same lake the only area with live mussels was a small area near the inlet. Although the movement rate of mussels of 1 to 16 mm/min would have allowed escape as the water receded, the direction of movement of mussels was random (Samad and Stanley, 1986). Similar impacts on mollusks (clams and snails) were observed in the Lake Bomoseen drawdown in Vermont (VANR, 1990). Paterson and Fernando (1969) reported that much of the benthic fauna (mostly oligochaete worms, nematodes and chironomid fly larva) was destroyed following drawdown of the Laurel Creek Reservoir in Ontario. Drawdown has been reported to alter the movement and behavior of predatory fish such as northern pike and largemouth bass (Rogers and Bergersen, 1995), and the range of possible impacts on spawning success is wide. Muskrat houses left exposed during drawdowns may also lead to increased predation on muskrats. Likewise, exposure of beaver lodges and food caches cannot be interpreted as a benefit to the beavers.

Post-refill algal blooms, lowered dissolved oxygen, poor access to spawning areas, desiccation of eggs, sedimentation impacts on eggs, and lowered food resources have all been cited as possible causes of damage to fishery resources from drawdowns (R. Hartley, L. Daley and R. Keller, MDFG, pers. comm., 1995). However, no scientific studies have been conducted in Massachusetts, and the literature for other states suggests mixed benefits and detriments (Wlosinski and Koljord, 1996).

Observations by L. Daley suggest that Richmond Pond in Richmond suffered a loss of rainbow smelt and depletions of largemouth bass, brown trout and crayfish populations coincident with drawdowns in the 1970's (MDFG, pers. comm., 1995). Smelt runs were noticeably absent in both Goose Pond in Lee and Greenwater Pond in Becket following drawdowns. Drawdown could indeed have caused such effects, especially since these drawdowns have a flood control component and were held as long as possible in the spring, but scientific study to document cause and effect has been lacking.

It is certainly possible to cause negative impacts to lake fauna through drawdown if the program is not carefully planned and implemented, and it is true that some impacts may occur even with the best of planning, given the dependency of the technique on weather conditions. The timing of the drawdown and refill is critical to the ability of fish to spawn successfully, but cannot be tightly controlled in most cases. Loss of fish through unscreened outlets is possible, and the MDFG recommends half-inch grates at the outflow during drawdowns to minimize fish escape. Minimally mobile invertebrates such as molluscs would seem to be susceptible to drawdowns initiated while they are in shallow water. However, many invertebrates (particularly snails) move offshore for the winter (Jokinen, 1992), limiting impacts if drawdown is delayed. There are few scientific studies that document impacts from later drawdowns, so it is essential to consider each aspect of the ecology of the targeted lake when planning a drawdown.

There may be impacts downstream as a result of increased flows during drawdown, but a properly conducted drawdown should not involve flows outside the normal range for the stream channel. Of greater concern are reduced spring flows during refill, although a properly conducted drawdown should allow for continued downstream flow during refill. Changes in streamflow can have an impact on fish populations as different species habitats are dictated by depth, current velocity and area, as well as stability of flow (Bain et al., 1988; Lewis, 1969). Obviously, a lack of flow during spring could be very detrimental.

Impairment of water supply during a drawdown is a primary concern. Processing or cooling water intakes may be exposed, reducing or eliminating intake capacity. The water level in wells with hydraulic connections to the lake will decline, with the potential for reduced yield, altered water quality and pumping difficulties. Drawdowns of Cedar Lake and Forge Pond in Massachusetts in the late 1980s resulted in impairment of well water supplies (K. Wagner, ENSR, pers. obs.1987-1989), but there is little mention of impairment of well production in the reviewed literature.

Recreational facilities and pursuits may be adversely impacted during a drawdown. Swimming areas will shrink and beach areas will enlarge during a drawdown. Boating may be restricted both by available lake area and by access to the lake. Winter drawdown will avoid most of these disadvantages, although lack of control over winter water levels can make ice conditions unsafe for fishing or skating. Additionally, outlet structures, docks and retaining walls may be subject to damage from freeze/thaw processes during overwinter drawdowns, if the water level is not lowered beyond all contact with structures.

4.2.3.2 Long-Term

Although there have been claims of devastating effects following a single drawdown (e.g., VANR, 1990), aquatic biota tend to be very resilient and impacts from any one drawdown are usually only temporary (Wlosinski and Koljord, 1996). Even complete loss of a year class of fish or elimination of molluscs from part of a lake will have little impact on overall lake ecology on a one-time basis. However, repetition of such impacts on an annual basis could alter biological communities in an undesirable and more prolonged manner, and for drawdown to be effective, it must be applied on a repetitive basis. Short-term impacts may therefore result in long-term impacts if drawdown is conducted on an annual or regular basis.

Fish populations can suffer from a loss of plant cover, changes in plant species composition, a loss of invertebrate food sources, and by a loss of annual recruitment if the timing of the drawdown overlaps and impacts spawning. Non-target organisms from the lake, downstream and adjacent wetlands could be impacted if there is difficulty refilling the lake in the spring (Haynes, 1990; Cooke et al., 1993a). Impacts may be highly system-specific, necessitating evaluation of possible impacts during the planning stage and follow-up monitoring to document any impacts.

Very few studies have been conducted over an extended period of time on lakes in Massachusetts that have experienced drawdown over multiple years. Three years of post-drawdown evaluation of Indian Lake in Becket, coupled with three years of pre-drawdown assessment (ENSR, 2002c) is the best available example of an extended study, but it does not cover all possible impacts. The ability of drawdown to control certain nuisance species in the drawdown zone has been well documented through multiple studies at individual lakes (e.g., Onota Lake in Pittsfield, Lake Lashaway in Brookfield). However, avoidance or prevention of impacts to non-target species has not been documented in a scientific fashion. Lakes such as Richmond Pond in Richmond and Otis Reservoir in Tolland have thriving fish, reptile, amphibian, avian and mammal communities, based on observations included in the D/F studies for these lakes (BEC, 1990a; ENSR, 2001c) but it cannot be definitively stated that there have been no negative impacts to the fauna from drawdown. The overall effect of drawdown appears positive in many cases, but negative impacts to specific components of system biology are plausible and probable.

In summary, there are a variety of possible negative consequences of drawdown for non-target species. Potential adverse impacts of an individual drawdown may not be manifest or may be temporary, yet repetitive application of drawdown could induce long-term impacts if temporary impacts are caused repeatedly. Therefore, drawdown should be preceded by an evaluation of possible impacts. If drawdown appears feasible under regulatory constraints, an appropriate monitoring plan should be developed that will signal adverse impacts if they occur and facilitate mitigative action. Assumption of impacts without a system-specific evaluation is unjustified, but prevention of unacceptable impacts is likely to require careful planning, implementation and monitoring, and may be difficult in some situations.

4.2.4 Impacts to Water Quality

4.2.4.1 Short-Term

Drawdown may affect water quality, particularly the parameters of clarity and dissolved oxygen concentration. Clarity will be a function of algal production and suspension of non-living particles. Algal production is most often related to phosphorus availability. By oxidizing exposed sediments, later release of phosphorus may be reduced through binding under oxic conditions, although post-drawdown algal blooms suggest that this mechanism may not be effective for all lakes. Decomposition during drawdown could make nutrients more available for release, but this is not a routinely observed phenomenon (Cooke et al., 1993a). It is likely that binding of iron and phosphorus influences phosphorus availability after drawdown, and the interplay between oxygen and levels of iron, sulfur and phosphorus is likely to vary among aquatic systems, resulting in variable nutrient availability. Calcium may also play a role in variable phosphorus availability in Berkshire lakes. Furthermore, the degree of flushing in the spring may be an important variable; lakes that require most of the spring flow to refill after drawdown have a higher probability of experiencing an increase in nutrient levels than those that flush once or more after spring refill.

Turbidity induced by sediment resuspension is likely during refill at rapid rates, but in many lakes the rise in water level is not fast enough to resuspend sediments by itself. Wind action in shallow waters (previously exposed areas) could promote increased short-term turbidity, if sediments are not consolidated after drawdown. Compaction of sediment during drawdown varies with sediment type and dewatering potential, but any resulting compaction tends to last after refilling, reducing resuspension potential and post-drawdown turbidity (Kadlec, 1962; Bay, 1966; Cooke et al., 1993a).

Interaction between unexposed sediments and the lesser volume of water in the lake during drawdown can lead to depressed oxygen levels if oxygen demand exceeds aeration and sources of inflow are slight (Cooke et al., 1993a; WDNR, 1989). Under ice, this can lead to fish kills, but such occurrences appear rare in Massachusetts, based on fish kill reports on file with the MDFG. Decreased detention time in response to lower lake volume and colder water temperatures may be countering the potentially elevated impact of sediment oxygen demand on a smaller lake volume.

4.2.4.2 Long-Term

Impacts to water quality are likely to be temporary, unless drawdown causes an actual change in sediment features. Drawdown may consolidate sediments or cause fine sediment to move into deeper water, thereby reducing turbidity in response to wind action (Cooke et al., 1993a). Such sediment changes may also reduce internal recycling, as flux is related to the area of nutrient-rich sediment interacting with the overlying water column. To achieve such benefits, however, a large portion of the lake area must be exposed, and this may lead to detrimental impacts that are likely to limit the application of drawdown. However, detailed studies of long-term water quality changes that might be linked to drawdown of lakes in Massachusetts have not been conducted.

4.2.5 Applicability to Saltwater Ponds

Drawdown is generally not applicable to saltwater ponds due to the low elevation relative to the ocean and the need to use pumps to remove water from the pond. Shellfish may be destroyed in a saltwater pond drawdown.

4.2.6 Implementation Guidance

4.2.6.1 Key Data Requirements

The listing of key considerations provided in Table 4-3 indicates the extensive data needs for proper implementation of this technique. Maps should be produced to show the areas affected and the present distribution of aquatic macrophytes. Expected ice depth should also be considered when determining the volume of water in the lake during drawdown. Biological surveys will undoubtedly be needed where non-target populations are perceived to be at risk from drawdown. Drawdown should not be conducted unless there is sufficient inflow to fill the lake by early spring, necessitating a thorough hydrologic evaluation. Correct identification of plant species is essential, as some species are reduced by lake drawdown, while others are unaffected or can increase. A carefully crafted monitoring program is critical to overall project success.

4.2.6.2 Factors that Favor this Approach

The following considerations are indicative of appropriate application of drawdown for the control of plants in lakes:

1. The lake periphery is dominated by undesirable species that are susceptible to drying and freezing.
2. Drawdown can be achieved by gravity outflow via an existing outlet structure, or such a structure can be established for a reasonable cost.
3. Drawdown can reach a depth that impacts enough of the targeted plants to detectably improve recreation (e.g., allow more access, increase safety) and enhance habitat (provide nearshore open water, reduce density of invasive species of limited habitat value).
4. Areas to be exposed have sediments and slopes that facilitate proper draining and freezing.
5. Drawdown and refill can be accomplished within a few weeks under typical flow conditions and without causing downstream flows outside the natural range.
6. Drawdown can be timed to avoid key migration and spawning periods for non-target organisms.
7. Populations of molluscs or other nearshore-dwelling organisms of limited mobility are not significant.
8. The lake is not used for water supply, and nearby wells are deep.
9. Flood storage capacity generated by drawdown prevents downstream flood impacts.

Table 4-3 Key Considerations for Drawdown

Reasons for Drawdown
Access to structures for maintenance or construction – note that other permits may apply
Access to sediments for removal (dredging) – additional permits apply
Flood control – a major late winter benefit, but minimally available in spring with regulatory refill date
Prevention of ice damage to shoreline and structures – control of late winter water level needed
Sediment compaction – only if sediments dewater sufficiently
Rooted plant control – for species that rely on vegetative forms to overwinter
Fish reclamation – if the community is extremely out of balance and a management program exists

Necessary Drawdown Planning Information
Target level of drawdown – depth of water lost
Pond bathymetry – detailed contours for calculation exposed area
Area to be exposed – area of sediment at water depth < target depth, plus ice contact zone
Volume to remain – quantity of water available for habitat and supply during drawdown
Timing and frequency of drawdown – initiation/duration and whether annual or less frequent event
Outlet control features – method for controling outflow
Climatological data – frequency of sub-freezing weather, precipitation and snow cover data
Normal range of outflow – maximum, minimum and average over expected time of drawdown
Outflow during drawdown and refill – provisions for downstream flow control (high and low)
Time to drawdown or refill – rate of water level change, number of days to achieve target level

In-Lake and Downstream Water Quality
Possible change in nutrient levels – any expected increases due to oxidation of sediments
Possible change in oxygen levels – any expected increase through oxidation or decrease under ice
Possible change in pH levels – any expected shift due to interactions with smaller volume
Other water quality issues – any expected changes as a function of drawdown

Water Supply
Use of lake water as a supply – dependence on water availability and impact of drawdown
Presence/depths of supply wells – potential for supply impairment
Alternative water supplies – options or supplying water to impacted parties
Emergency response system – ability to detect and address supply problems during drawdown
Downstream flow restrictions – maintenance of appropriate flows for downstream habitat and uses

Sediments
Particle size distribution (or general sediment type) – dewatering potential
Solids and organic content – dewatering potential, nutrient content
Potential for sloughing – potential for coarse sediment to be exposed in drawdown zone
Potential for shoreline erosion – threat of erosive impacts to bank resources
Potential for dewatering and compaction – possibility of sediment alteration and depth increase
Potential for odors – emissions from exposed area
Access and safety considerations – issues for use of lake during drawdown

Flood Control
Anticipated storage needs – ability to meet needs with target drawdown
Flood storage gained – volume available to hold incoming runoff
Effects on peak flows – dampening effect on downstream velocities and discharge

Table 4-3 (continued) Key considerations for drawdown

Protected Species
Presence of protected species – NHESP designated species may require special protection
Potential for impact – assessment of possible damage to protected populations
Possible mitigative measures – options for avoiding adverse impacts

In-lake Vegetation
Composition of plant community – details of species present and susceptibility to drawdown
Areal distribution of plants – mapping of plant locations relative to drawdown impact zone
Plant density – quantity of plants present
Seed-bearing vs. vegetative propagation – drawdown will only control vegetative propagators
Impacts to target and non-target species – analysis of which species will be impacted

Vegetation of Connected Wetlands
Composition of plant community – details of species present and susceptibility to drawdown
Areal distribution of plants – mapping of plant locations relative to drawdown impact zone
Plant density – quantity of plants present
Temporal dormancy of key species – potential for seasonal impacts
Anticipated impacts – analysis of likely effects of drawdown

Macroinvertebrates, Fish and Wildlife
Composition of fauna – types of animals present
Association with areas to be exposed – when and how drawdown zone is used on a regular basis
Breeding and feeding considerations – use of drawdown for breeding or food on intermittent basis
Expected effects on target and non-target species – analysis of likely faunal impacts

Downstream Resources
Erosion or flooding potential – susceptibility to impacts from varying flow
Possible habitat alterations – potential for impacts
Water quality impacts – potential for alteration
Direct biotic impacts – possible scour or low flow effects on biota
Recreational impacts – effects on downstream recreational uses
Supply impacts – effects on downstream supply uses

Access to the Pond
Alteration of normal accessibility – issues for seasonal use of pond by humans and wildlife
Possible mitigation measures – options for minimizing impacts

Associated Costs
Structural alteration to facilitate drawdown by gravity – expense for any needed changes to outlet
Pumping or alternative technology – operational expense for pumped or siphoned outflow
Monitoring program – cost of adequate tracking of drawdown and assessment of impacts

Other Mitigating Factors
Monitoring program elements – may be very lake specific and vary over years
Watershed management needs – additional actions beyond drawdown may be warranted
Ancillary project plans (dredging, shoreline stabilization) – additional actions may require separate planning and permitting

4.2.6.3 Performance Guidelines

Planning and Implementation

Drawdown is a relatively simple technique, but there are many considerations that must be addressed before it can occur. Table 4-3 lists a range of issues to be addressed. Logistics of drawdown will vary somewhat from lake to lake, but the basic pattern involves increasing the outflow during the fall to a level greater than the inflow within the constraints of what the downstream system can handle. This elevated outflow is held until the target water level is reached, with a target rate of water level decline typically of no more than about 2-3 inches per day. Ideally, the drawdown process will take 2 weeks to a month. Once the target level is reached, outflow is matched to inflow to the maximum extent practical for at least one month of freezing conditions. Holding the drawdown until spring ice-out may be an option, as might refill after an inch or two of ice has formed, depending upon project goals and constraints. Refill by early April is usually desired. Refill is accomplished by restricting outflow to a level lower than inflow, but not so low as to impact downstream resources. Restricted outflow continues until full lake level is achieved, ideally several weeks to 2 months later.

Water fluctuations generally are greater in man-made impoundments, thus permitting restrictions can be more relaxed for these water bodies, as biotic communities are somewhat adapted to water level variations. The relatively stable lakes (particularly natural lakes) should be more protected from unnatural drawdowns so as to protect endemic species which may be less tolerant of water level fluctuations.

The MDFG has offered the following guidelines to meet fish and wildlife management goals where drawdowns have been determined to have desired benefits:

- Limit drawdown to 3 ft or contact the MDFG for assistance in evaluating impacts of greater drawdown; however, exceeding this level may meet DFG guidelines if justified in the NOI or lake management plan. The DFG policy is to review drawdowns in excess of three feet.
- Commence drawdown after the beginning of November.
- Achieve the target drawdown depth by the beginning of December.
- Achieve full lake level by the beginning of April.
- Keep outflow during drawdown below a discharge equivalent to 4 cfs per square mile of watershed. Once the target water level is achieved, match outflow to inflow to the greatest extent possible, maintaining a stable water level.
- Keep outflow during refill above a discharge equivalent to 0.5 cfs per square mile of watershed.

Monitoring and Maintenance

Monitoring of lake level is required to maintain effectiveness and minimize impacts. Any potential water supply impairment needs to be monitored and addressed quickly. Additional monitoring requirements will vary with the lake, but would be expected to include a quantitative pre- and post-drawdown plant community survey and similar assessment of representative populations considered at risk from the drawdown. Certain populations of fish, aquatic benthic invertebrates (especially molluscs), reptiles, amphibians, birds and mammals (especially beaver and muskrat) may be at risk. Some water quality monitoring might also be required, most often involving summer nutrient concentrations and winter oxygen levels. There is a need for detailed scientific investigation of possible drawdown impacts, and a need to develop inexpensive monitoring techniques that can signal impending impacts before they become too severe.

Drinking water wells around the lake should be evaluated to predict whether drawdown will limit water supply, as this is an impact that may halt a drawdown immediately. The threat of drawdown to water supplies has restricted the depth of drawdown in many systems and eliminated drawdown as a viable option in several cases (e.g., Forge Pond in Westford, Lower Chandler Mill Pond in Duxbury and Pembroke). Very shallow wells that may go dry should be replaced by deeper wells for health reasons, but there is little regulatory impetus to force such changes at the homeowner's expense. Slightly deeper wells will not go dry, but may have reduced production capacity as a function of a shorter water column in the well. If the well pump is sized for the original water depth, it may pump the well to the point at which the water level drops below the intake depth, causing an interruption of service until the water level in the well recovers. If the residence has a large enough storage tank, no supply limitation may be felt. However, where the residence is served by a small tank or no tank at all, elevated or even normal water use may result in a temporary water shortage. Provisions for water supply will be necessary in such cases, if drawdown is to be applied.

Maintenance needs are variable and generally limited for this technique. Dams (including berms, concrete walls and outlet structures) should be kept in good repair (see Office of Dam Safety regulations). Any areas of shoreline erosion should be stabilized.

<u>Mitigation</u>

Mitigation measures to minimize undesirable environmental impact from this method focus on maintaining the water level in non-target areas where feasible and adjusting the timing and duration of drawdown to minimize impacts on sensitive organisms. Water level can be maintained in inlet streams and along emergent wetland interfaces with temporary dams (e.g., sandbags, jersey barriers) if necessary, but blocking access by fish and wildlife may be an issue in such cases. Starting and ending the drawdown at times that minimize interference with migration and spawning activities is desirable, but not all biota will move or mate at the same time, creating possible conflicts. The MDFG suggests that many impacts can be lessened by controlling the timing and rate of drawdown and refill to permit spawning, or staggering drawdowns every other year or more to lessen impacts on fish recruitment. Restricting drawdown to late fall and winter will minimize impacts to many species. Maintenance of an adequate pool with sufficient oxygen will be critical to successful overwintering by most organisms. Water can be provided to anyone whose well is impaired during the drawdown, but ultimately a deeper well will be needed if drawdown is to be applied repeatedly.

4.2.7 Regulations

4.2.7.1 Applicable Statutes

In addition to the standard check for site restrictions or endangered species (Appendix II.), a Notice of Intent must be sent to the Conservation Commission with a copy to the Department of Environmental Protection Regional Office. If the proposed project occurs within an Estimated Habitat of Rare Wildlife in the most recent version of the Natural Heritage Atlas, a copy of the Notice of Intent must be submitted to the Natural Heritage and Endangered Species Program

(NHESP) within the MDFG for review (Appendix II). If the proposed project occurs within a Priority Habitat of Rare Species in the most recent version of the Natural Heritage Atlas, the project proponent must submit project plans to the NHESP for an impact determination. An Order of Conditions must be obtained prior to work.

The Department of Environmental Protection has issued a document (DEP, 2004) entitled "Guidance for Aquatic Plant Management in Lakes and Ponds as it relates to the Wetlands Protection Act" (Policy/SOP/Guideline# BRP/DWM/WW/GO4-1, effective April 8, 2004). This document provides guidance on preparation and review of Notices of Intent and includes information about projects subject to Wetlands Protection Act regulations, a description of limited projects and estimated habitats of rare wildlife. In addition it provides:

- Information required to evaluate impacts for all projects
- Additional information required for draw down projects
- Additional information required for herbicide/algaecide projects
- Additional information required for harvesting projects
- Additional information required for dredging projects
- Managing pioneer infestations of invasive plants
- Other related permits/licenses/certifications

Appendices provide sample conditions that conservation commissions can use in approving projects subject to the Wetlands Protection Act, guidance for complying with a wildlife habitat evaluation, and protocols for application of the herbicide 2,4-D to lakes and ponds. For further information on all permits see Appendix II.

4.2.7.2 Impacts Specific to Wetlands Protection Act

The following overall impact classification is offered as a generalization of impacts, with clarifying notes and caveats as warranted:

1. Protection of public and private water supply – Potential detriment (if adequate water for supply is not maintained), but can be neutral in some cases with proper management.
2. Protection of groundwater supply – Potential detriment (if lowered lake level lowers groundwater), but can be neutral (if adequate groundwater level is maintained or there is no significant interaction).
3. Flood control – Benefit (flood storage potential increased).
4. Storm damage prevention – Benefit (flood storage potential increased), but possible detriment as exposed areas may be subject to potentially damaging storm impacts.
5. Prevention of pollution – May provide benefit (water quality enhancement) or detriment (water quality deterioration), but impacts generally limited.
6. Protection of land containing shellfish – Detriment (shellfish potentially exposed), but impacts may be neutral in some cases, and shellfish habitat may be improved overall.
7. Protection of fisheries - Potential detriment by temporary habitat loss, potential benefit by habitat improvement (may have benefit and detriment to different species in same lake from same drawdown). Possible detriment to downstream fisheries from high or low flows.
8. Protection of wildlife habitat - Potential detriment by temporary habitat loss, potential benefit by habitat improvement (may have benefit and detriment to different species in same lake from same drawdown).

4.2.8 Costs

Drawdown is a relatively inexpensive lake management technique, if the means to conduct a drawdown are present. Where an outlet structure facilitates drawdown, the cost may be as little as what is required to obtain permits, open and close the discharge structure, and monitor. If pumps are required to lower the water level, the drawdown will be more expensive. The total project cost for the restoration of Lake Lashaway was $397,600, covering mainly the construction of an outflow structure (Haynes, 1990). The cost of a new outlet structure to facilitate drawdown of Forge Pond in Westford was about $80,000, including engineering and permitting costs (Turner, Westford CC, pers. comm., 1995). It is unusual to alter a dam these days for less than $100,000, but if the structure already supports water level control, costs of $3,000 to $10,000 per year would be a reasonable expectation for permitting and monitoring. Drawdowns of the past few decades had no monitoring requirement, but Conservation Commissions, the MDEP and the MDFG are requesting pre- and post-drawdown monitoring more often now. Where protected species are present, permitting may be difficult and monitoring and mitigation costs can escalate.

4.2.9 Future Research Needs

Evaluation of drawdown impacts on non-target species is a serious shortcoming in drawdown planning and permitting, and requires a major effort involving many species in multiple lakes over multiple drawdowns. A major program of study is needed at the state level. All referenced data from the MDFG on negative or positive impacts should be put in a report format and reviewed. Additional field studies should be sponsored by the Executive Office of Environmental Affairs as part of its Lake and Pond Initiative.

4.2.10 Summary

Drawdown is an effective and relatively inexpensive method to control susceptible rooted plants, and many lakes in Massachusetts have been lowered annually for decades. However, it also has substantial potential to cause adverse impacts to non-target organisms. Although it may need to be implemented on an annual or biennial basis in order to maintain effectiveness, the cost is limited to permitting and monitoring expenses, provided there is an existing outflow structure in place. Where the outflow structure must be altered, siphons installed, or pumps deployed, the cost will rise but may still be tolerable. Regulatory acceptance depends on identifying and minimizing potential impacts to a wide variety of aquatic resources and uses.

Drawdown can be an advantageous method for aquatic plant control where the target plants depend upon vegetative structures for reproduction and overwintering. It is not labor intensive and when performed in the winter will not interrupt most recreational lake uses or interfere with most ecological functions. Drawdown presents an opportunity for repairing docks and boat ramps, or employing other methods of lake management such as dredging or benthic barriers.

The disadvantages of drawdown are linked to reduced areal coverage by water and lowered water volume. Water supply from the lake or wells may be impaired, and species that depend upon the exposed area may be affected. Changes in exposed sediment features may affect water quality after refill. Downstream resources may be impacted as well. Repeated drawdown may result in the invasion of plants that are resistant to drawdowns, some of which may be nuisance species. Failure to refill the lake in time for spring spawning may affect fish populations. None of these impacts may be manifest, and various mitigative means may avoid or minimize them. However, it is difficult to predict the ecological impact to many non-target organisms, due largely to the lack of published information and site-specificity of many possible impacts. As the Wetlands Protection Act requires assurance that resources will not be significantly and adversely impacted, applicants must learn much about the targeted lake system. Monitoring can indicate impending impacts, but more scientific research is needed to answer long-standing questions about drawdown effects.

4.3 HARVESTING

4.3.1 Overview

Harvesting of nuisance aquatic plants includes a suite of techniques that vary in sophistication and cost from simply hand pulling of weeds to large-scale mechanical cutting and collection of plants. Harvesting can be an effective short-term treatment to control the growth of aquatic plants. With repeated application at appropriate intervals, it can produce long-term shifts in the plant community, but it is unlikely to reduce long-term plant density substantially. Harvesting is generally used seasonally to remove vegetation that limits lake uses such as boating and swimming. A significant nutrient reduction resulting from macrophyte harvest is rare (Engel, 1990, Cooke et al., 1993a). Harvesting is occasionally used to remove algal mats from water, but this is usually a very short-term method and is not practical on a large scale (McComas, 1993).

There are many variations on mechanical removal of macrophytes. Table 4-1 breaks these varied techniques into hand pulling, suction harvesting, cutting without collection, harvesting with collection, rototilling, and hydroraking. These techniques are often cited as being analogous to mowing the lawn (cutting or harvesting), weeding the garden (hand pulling), or tilling the soil (rototilling or hydroraking), and these are reasonable comparisons. Mechanical management of aquatic plants is not much different from managing terrestrial plants, except for the complications imposed by the water.

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

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