Prepared for:

Board of Public Works

Natural Resources Commission

Recreation Commission

Town of Wellesley, MA

COMPREHENSIVE PLAN FOR THE MANAGEMENT OF MORSES POND

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Introduction

Morses Pond is a shallow lake that covers approximately 105 acres, mostly in the Town of Wellesley with a small portion in the Town of Natick. It was created by human action in the early 1700s and has been enlarged several times. Morses Pond is fed by a 5300-acre watershed of mostly developed land, 78% of which is outside Town boundaries. Water enters the pond primarily through tributaries, including Jennings Brook, Bogle Brook, and Boulder Brook. These tributaries all converge in the northern basin of Morses Pond and contribute large loads of contaminants during storm events. Direct drainage from Wellesley and Natick also contributes water and nutrients. Water leaving Morses Pond discharges into Paintshop Pond, Lake Waban and ultimately to the Charles River.

Morses Pond is an important indirect source of public drinking water for the Town through adjacent wells, supplying more than 40% of Town supply. The Town operates a public access area near the outlet at the southern end of the pond, including a beach, swimming area, non-motorized boat launch, and picnic area. Historically, the entire pond has been used extensively for recreational purposes, including swimming, boating and fishing. The Morses Pond wellfield is a major component of the Town's water supply system. Hiking trails are also maintained throughout the Town’s pond property.

Because of the importance of Morses Pond as a multiple use resource, the Town, through the dedicated efforts and cooperation of various departments, boards, commissions, and residents, has actively worked towards the management, improvement, and protection of the pond. Past in-lake management efforts have included the use of algaecides (copper sulfate), phosphorus inactivation (using aluminum sulfate, a coagulant), weed harvesting, and dredging. Monitoring has been performed almost every year since 1981, with sporadic monitoring prior to that date, accumulating a useful database from which management decisions can be made. Outside of the pond, a number of treatment improvements have been made in association with the Town wells adjacent to Morses Pond to meet Safe Drinking Water Act requirements. These improvements protect consumers but have no direct impact on the pond. Town bylaws relating to water supply protection and discharges to the Town storm water drainage system have been developed, and a plan for storm water management has been prepared under the National Pollutant Discharge Elimination System Phase II regulations promulgated under the Federal Clean Water Act. However, some uses of the pond are not adequately supported. The need for a comprehensive plan has been recognized, one which incorporates input from as many parties as possible and examines the complete range of management options for both the short- and long-term.

Problem Statement

Since at least the early 1970s the pond has exhibited symptoms of overfertilization including recurrent algal blooms, reduced transparency, and dense aquatic vegetation growths that have impaired recreational water uses and important aesthetic and wildlife habitat functions. A large watershed area with a substantial portion developed for residential and commercial uses subjects Morses Pond to low water clarity through input of suspended sediment and nutrients that fuel algae growth. The shallow nature of the pond and hospitable soft sediments that have accumulated over many years support dense growths of rooted aquatic plants, with a majority of biomass represented by invading non-native nuisance species. To meet use goals, water clarity must be increased and rooted plant biomass must be decreased.

As a result of these problems, the number of visits to the pond beach has decreased. Boating activity has been significantly curtailed. The aesthetics of the pond environment have been negatively impacted.

Plan Development and Public Participation Process

In 2004 the Board of Public Works, the Natural Resources Commission, and the Recreation Commission formed the Morses Pond Ad Hoc Committee (MPAHC), comprised of representatives of Town boards and civic groups, to develop a comprehensive management plan for Morses Pond. All interested parties have been encouraged to attend public forums offered during plan development. The Town solicited proposals and engaged ENSR Corporation for technical assistance with plan development. The MPAHC has assessed existing conditions, current uses, condition and use goals, priorities for management, and options for achieving the use goals. In deciding which options were most suitable for managing Morses Pond and its watershed, probability of success, cost and acceptability within the existing regulatory framework were carefully considered on various levels.

The MPAHC met regularly and involvement by Town boards, commissions, civic organizations and the public at large was sought in special meetings and forums. A residential questionnaire was used to broaden input on use goals and priorities. Review of management options involved many committee meetings, solicited input from Town boards and commissions, and three publicly advertised meetings to garner input on a wide variety of possible approaches. Options were evaluated based on three key questions:

- Is it technically feasible with a high probability of success?
- Is it affordable over the short-term and long-term?
- Is it acceptable to the regulatory community and a large majority of interested parties?

Evaluation of the draft report encompassed both review of the written report and public meetings to explain the decision process and resulting recommendations, with changes made as needed in response to both written and verbal reviews.

Goals and Priorities for the Use of Morses Pond

While the two general goals of improved water clarity and reduced rooted plant biomass have been apparent to MPAHC members from an early stage of the planning process, a public process of goal development and priority setting was implemented to ensure that as many viewpoints as possible were represented and that important aspects of both the aquatic system and public interest were adequately addressed. The resulting goals and priorities provide guidance for considering possible management actions in light of the range of possible impacts (both beneficial and deleterious) on the complete suite of goals, in the priority order gleaned from substantial input. As determined by this process, goals and priorities include:

1. **Top Level Priority:**

- **Drinking Water** - Insure that no actions of this plan will have adverse impacts on the long-term quantity and quality of drinking water pumped from the nearby wells.

2. Second Level Priorities:

- **Contact Recreation** - Support Town use of the beach area, promoting water clarity, health standards and aesthetics of the beach area, and promote overall lake conditions conducive to lakewide contact recreation.
- **Flood Control** - Maintain current flood control measures and establish on-going policy measures to achieve flood control.

3. Third Level Priorities:

- **Non-motorized Boating** - Enhance canoeing, kayaking, sailing and rowing, improving and maintaining access for non-motorized boats.
- **Environment and Wildlife Protection** - Protect wetlands and vernal pool habitats, protect wildlife habitat (both within the pond and around it), preserve open space within the watershed area, secure conservation restrictions protecting property within the watershed from development, and prevent bank/land erosion and restore where possible.
- **Fishing** - Enhance fishing opportunities.
- **Other Non-contact Uses** - Enhance non-contact recreational opportunities including walking, nature watching, education and general aesthetics, and maintain access for non-contact uses.

The No Additional Management Alternative and Its Consequences

Taking no additional management actions at Morses Pond means that current approaches will be continued. The result of no additional management action will be that most recreational water use goals will not be met and pond conditions are likely to continue to deteriorate.

Weed harvesting can continue to provide some benefits, but the current harvesting equipment and manpower allocation are inadequate to maintain desirable conditions in all targeted areas. Continued annual hydroraking can minimize plant biomass and debris accumulation in the Town swimming area. Treatment with copper and/or aluminum compounds in the southernmost part of the pond can be used to maintain water clarity in the Town swimming area, and the existing circulation system will provide limited but beneficial mixing in that area. Water purification through natural soil filtration and active treatment upon withdrawal from the wells will facilitate a continued supply of safe drinking water, although treatment costs may increase over time. Overall, however, recreational utility and habitat quality can be expected to decline as the northern basin continues to fill in over the next 20 years and algal blooms become more frequent and possibly more severe in the southern basin. Continued high density of invasive rooted plants will impair swimming and boating uses away from the Town beach and diminish visual enjoyment of Morses Pond.

Evaluation of Management Options to Achieve Use Goals

A wide variety of techniques for managing algae/water clarity and rooted plant composition/biomass have been reviewed and applicability to Morses Pond has been evaluated.

In order to support the desired uses of Morses Pond, the following technical objectives must be achieved by the accumulated actions of a successful management plan:

1. Reduce the average phosphorus loading and concentration by 33% to achieve an in-lake average phosphorus level of 20 ppb, visibility of 4 ft visibility at all times and >6 ft visibility most of the time.

2. Eliminate invading, non-native, nuisance plant species to the extent possible, at least reducing them to a minor component of the plant community.
3. Reduce plant bottom cover and overall plant biomass by approximately 50% in areas <10 ft deep, eliminating interference with swimming and boating.
4. All actions taken must comply with existing Town policies, specifically the Integrated Pest Management (IPM) Policy.

Water Quality Improvement

Controlling algae and other suspended solids that affect water clarity is most effectively accomplished by watershed management in the case of Morses Pond, with both pollutant source control and trapping as viable approaches from a technical perspective. The focus would be on storm water inputs in this watershed. In lake methods will constitute maintenance in this case, with repeated application necessary. Evaluated methods for achieving the water clarity goal include:

Watershed Actions

- Watershed resident education – education is essential to minimizing inputs from developed areas and for gaining support for overall management efforts.
- Altered bylaws and regulations – existing bylaws should limit increased impact from developed areas, but supplemental regulatory actions targeting storm water management are needed to achieve desired loading reductions.
- Widespread localized storm water management through on-site, low impact techniques – localized controls will require an extended implementation period and active support, but has the potential to achieve desired contaminant control.
- Development of larger, upstream detention facilities – holding storm water for both natural purification and flood control is desirable, and detention could also involve actively treating the storm water, but both are expensive and difficult to implement in this watershed.

In-Lake Actions

- Storm water treatment – aluminum compounds appear to offer the greatest potential to achieve the desired level of control; treatment in the northern basin of the pond could be very effective.
- Dredging - dredging of at least the northern basin is needed to restore the detention capacity of that area and to support the alum treatment over an extended period of years; additional dredging beyond the northern basin could also be beneficial, but the high cost is not justified solely for improved detention in Morses Pond.
- Mixing – circulation strategies could reduce blue-green algal scums, but will not control phosphorus and suspended solids to the desired level.
- Algaecides – directly killing algae remains a management option, but it is preferable to control the nutrients that fuel algal growth.
- Periodic alum treatments beyond the northern basin – lakewide treatment could maximize water clarity during summer, but would be less efficient than treatment near the point of entry (e.g., the northern basin).
- Biomanipulation - enhanced grazing on algae by fostering a more abundant population of larger zooplankton is desirable but not practical before the plant community is managed at a much lower density.
- Wetlands creation – use of wetlands in and around the northern basin could enhance water quality in the rest of the pond, but a thorough dredging of the northern basin to maximize detention capacity is preferred.

Rooted Plant Control

Control of rooted plants can be accomplished by several means, and it may require multiple techniques to address the suite of introduced and native nuisance species in Morses Pond. In-lake action is necessary because past inputs will support plant growths independent of any watershed management. Evaluated methods for achieving the plant biomass control goal include:

- Mechanical Harvesting – mechanical cutting and removal of plant biomass could provide the desired level of control, and might shift the community toward a more desirable mix of species over time if conducted carefully over multiple years with equipment capable of addressing all target areas in an appropriately rapid amount of time.
- Hand harvesting – although impractical at the scale necessary to control rooted plants throughout Morses Pond, selectively pulling out unwanted plants can be a valuable local control technique to prevent infestation of new nuisance species or maintain control once achieved by other methods.
- Benthic barriers - although too expensive at the scale necessary to control rooted plants throughout Morses Pond, covering small patches of unwanted plants can be a valuable local control technique.
- Hydroraking - although too expensive and disruptive at the scale necessary to control rooted plants throughout Morses Pond, selective hydroraking can provide plant control and debris removal in heavily used recreation areas.
- Herbicide application - the herbicide fluridone is most applicable to Morses Pond, and can be used in water supplies, but current Natural Resource Commission IPM policy prohibits the use of herbicides in Morses Pond at this time.
- Dredging – removal of sediment would remove plants and their root systems, seed beds and accumulated sediment, effectively setting the pond back in time, but at great cost and with limited control over later regrowth, which is likely to be substantial and could involve undesirable invasive species without continued management by other techniques.
- Drawdown – reduction in water level is expected to have serious negative impacts on the water supply and is not appropriate for Morses Pond.
- Biocontrol agents - grass carp are illegal for use in Massachusetts lakes and the milfoil weevil will attack only one of many problem species in Morses Pond; there is a beetle that is applicable to the emergent invasive purple loosestrife, but control of this wetland plant is considered peripheral to this management plan.

Permitting

Permitting for management actions for the improvement of Morses Pond consists mainly of approval under the Wetlands Protection Act and Wellesley Wetlands Bylaw. Additional permitting processes apply for dredging and any chemical additions to the pond. Rejection or modification of projects through relevant permitting processes is possible, and recommended actions should be crafted to be acceptable under existing regulations. However, nearly all recommended actions have been permitted for Morses Pond in the past.

Recommended Management Program

Most of the current management actions have merit for maintaining uses of Morses Pond, but additional actions are needed to completely achieve use goals, and may reduce or eliminate the need for some current management activities. Recommended management actions intended to meet use goals include:

A. General

1. **Professional Lake Manager Assistance** – Retain the services of a professional lake manager to oversee and coordinate all core management activities. This represents a commitment to getting knowledgeable leadership for the preparation of requests for proposals, bid evaluation, activity scheduling, grant applications, budget and technical planning support, data evaluation, and program coordination and adjustment. The Lake Manager would not have to be a Town employee, but would have a clear commitment to the management of Morses Pond with possible extension to other Town ponds and would devote a set amount of time per year to associated tasks as laid out in a contract. The Lake Manager would report to a designated supervisor and would communicate regularly with all interested Town boards and commissions. The cost over a 5 year period is projected at $230,000.

B. Algae and Water Clarity Control:

1. **Phosphorus and Sediment Inactivation** - Install a buffered alum dosing station serving the northern basin (Area 1 in the accompanying figure, listed as Figure 3 of this report) and operate it from May through June, with possible use in July and August as warranted. Target storm events to get a reduction in phosphorus concentration and suspended solids (including algae, sediment, and even bacteria) that meets water clarity goals. Monitor phosphorus and turbidity on a weekly basis while the system is in operation. Monitor the build-up of settled material in the northern basin on an annual basis. The total cost over a 5 year period is estimated at $312,000.

2. **Northern Basin Dredging** – Hydraulically dredge the northern basin (Area 1). Remove all soft sediment and some additional material to maximize detention, targeting 20,000 cy of sediment. Coagulate and belt press the removed material to minimize the containment area needs, most likely working near the beach complex between early September and late November. Ultimate disposal location is to be determined, but material has beneficial uses and is not a large quantity by construction standards. Conduct this dredging after at least two years of monitoring of the alum treatment system, to allow determination of the accumulation of solids relating to alum application and any necessary adjustments to protect the investment represented by dredging. The total cost over a 5 year period is expected to be $650,000.

3. **Watershed Education** – Conduct an ongoing education program, utilizing the Education Coordinator currently supported by the Town, with a focus on reducing loading of pollutants from residential areas of the watershed, shown in the accompanying figure (Figure 2 from this report). Emphasize the need to infiltrate precipitation into the ground rather than allowing runoff to occur, providing background on low impact runoff control techniques that property owners can employ. Also stress the lack of a need for phosphorus in fertilizers for established lawns and the need to contain yard wastes. Create a website and a supporting brochure, and generate media coverage of the effort. Populate the website with interactive information about the best approaches for minimizing the impacts of urbanization on water resources in general and Morses Pond specifically. Utilize this website as a resource for teaching watershed residents, supporting information needs for desirable property management and addressing issues, questions and concerns by property owners. The website can also serve as a resource for education in the school system. Costs may be internalized to some degree, but

estimates for outside assistance are provided here. The total cost over a 5 year period is projected at $110,200.

4. **Review and Development of Land Management Bylaws** – Perform a thorough review of existing Town bylaws and related regulations (including state and federal statutes) to determine where improvements are needed to more adequately protect Morses Pond. Develop improved or new bylaws to meet protection needs and support other management efforts such as Low Impact Development. Enhancements may include application of existing rules or policies on a smaller scale (e.g., to all parcels, not just those above certain thresholds) or development of new bylaws to address problems associated with new construction (e.g., limiting impervious surface area). Assist the Town in moving any new or revised bylaws through the approval process. The total cost over a 5 year period is expected to be $75,000.

5. **Low Impact Development Program** - Implement Low Impact Development techniques on new and existing residential sites. Build on the education program that informs residents of the need and opportunities for storm water management, providing support and incentives to manage storm water. Conduct demonstration projects on Town property in various locations to showcase this approach. Support private application with technical advice, design support and monitoring assistance. Encourage adoption of this approach in Natick and Weston as well. The total cost to the Town over a 5 year period is estimated at $142,000; private costs in excess of $1,000,000 are expected and extension to Weston and Natick is advised.

C. Rooted Plant Biomass Control:

1. **Enhanced Mechanical Harvesting** – Purchase harvesting equipment capable of harvesting plants over a 41-acre area in under 5 weeks and commit to the labor necessary to aggressively harvest in Areas 2, 3, 4 and 6 for 4 months per year. Harvest from mid-May through June, after which the harvester can be used in other ponds (if the expected level of control is achieved) until mid-August, when harvesting in Morses Pond would resume through mid-September. Gradually shift the focus from overall plant biomass reduction to control of nuisance species with encouragement of desirable species. Monitor plants at established locations on an annual basis in September. Consider installing a floating plant fragment barrier around major harvesting areas or the Town swimming area if fragment entry to the swimming area is unacceptably high. The total cost over a 5 year period is estimated at $553,200.

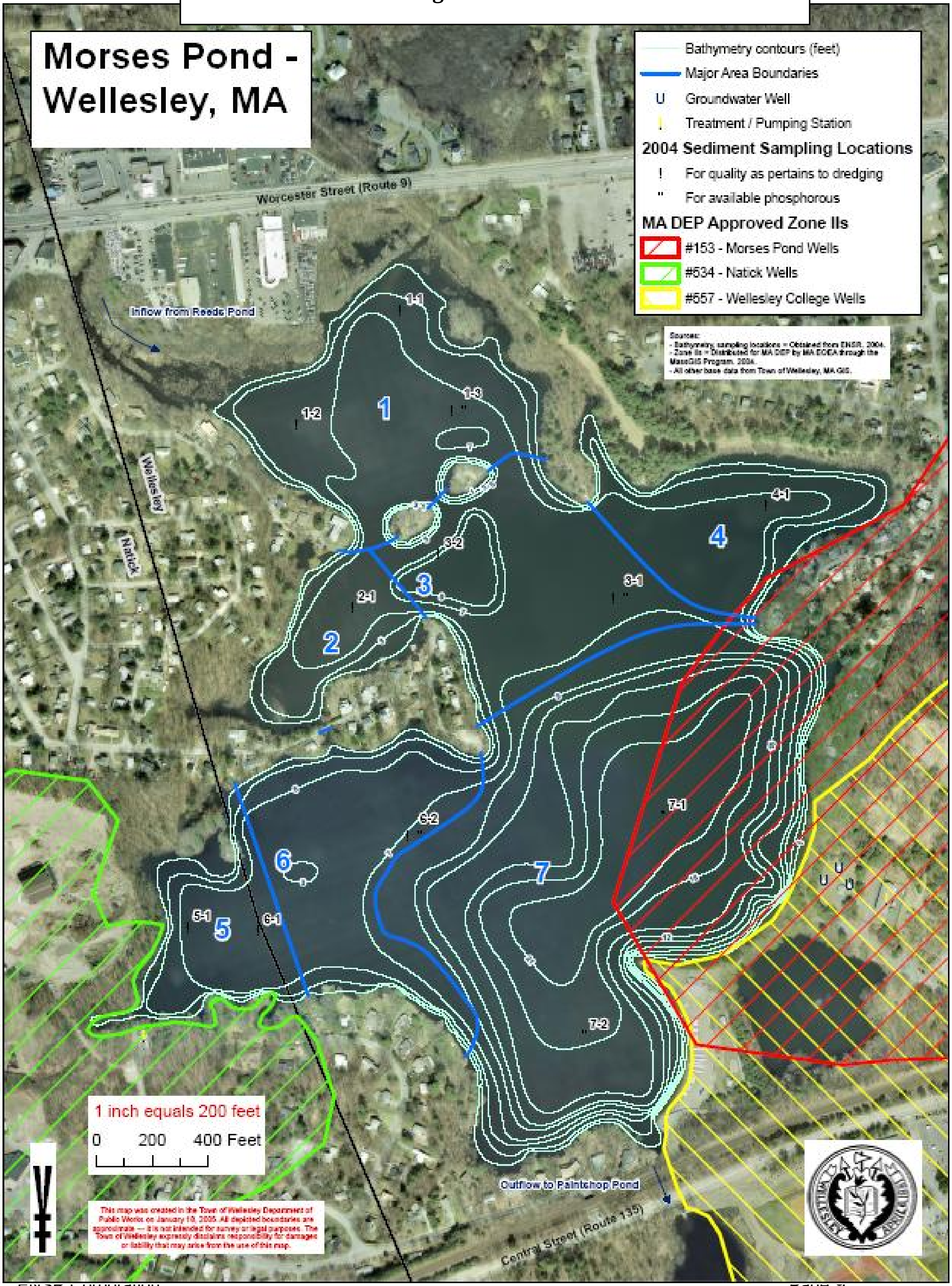
2. **Manual Harvesting and Benthic Barrier Placement** – Continue the water chestnut harvesting program, which has been a volunteer effort, providing equipment to enhance efficiency and comfort for the volunteers as warranted. Encourage shoreline residents to manage weeds in shallow areas not accessible to the mechanical harvester and around docks and other structures where the harvester cannot work effectively. Such management would involve hand pulling or manually raking plants in <2 feet of water and applying benthic barrier around docks or other structures as needed to supplement control by harvesting. Facilitate acquisition of a permit under the Wetlands Protection Act to allow all interested shoreline residents who would like to apply these techniques to do so. The total cost to the Town over a 5 year period is estimated at $19,100; up to $180,000 might be spent by private users, although much of the labor might be by volunteers

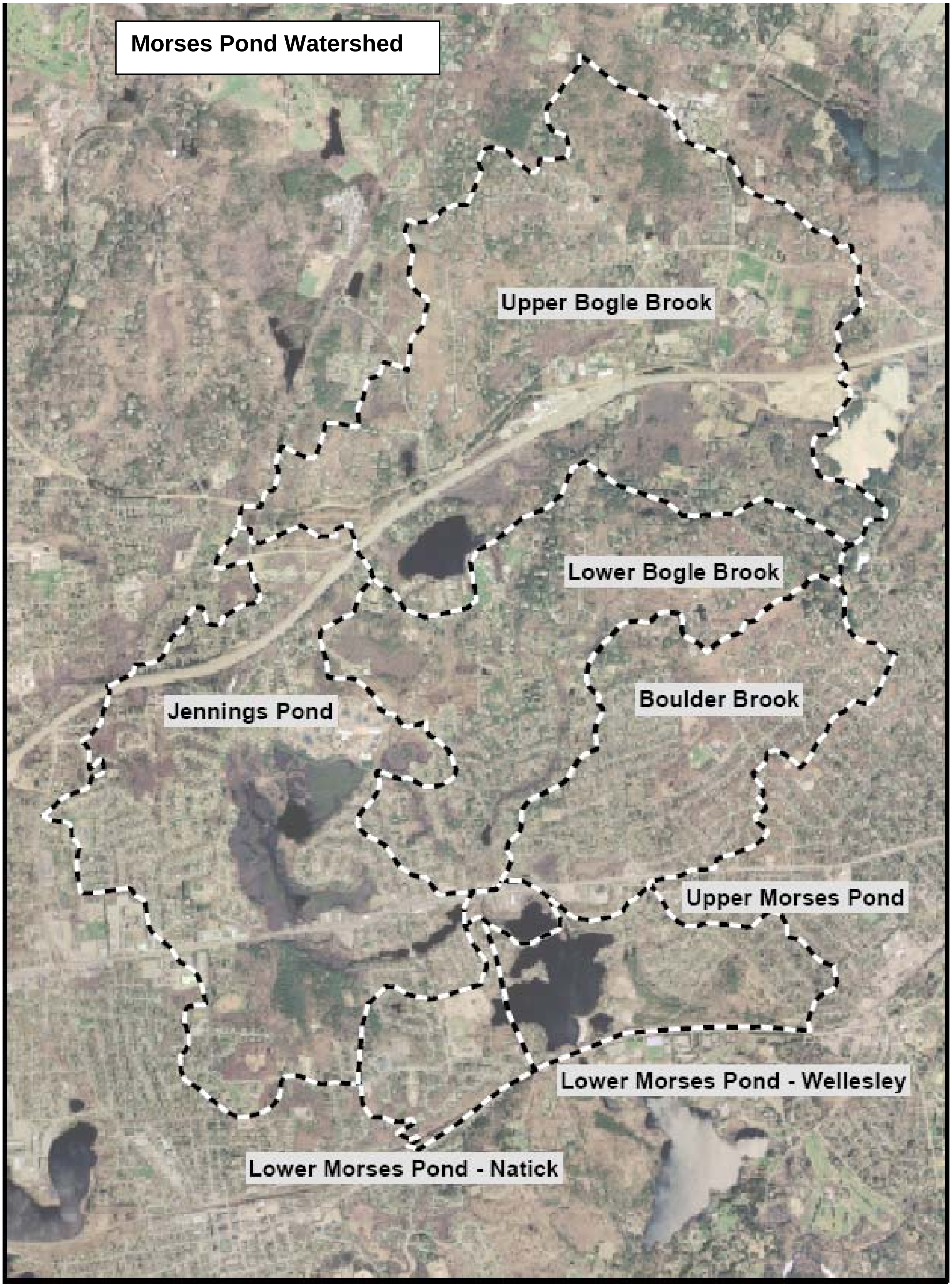
3. **Selective Planting** – It is likely that desirable native species will not colonize and become dominant in response to any plant control technique fast enough to provide maximum limitation of nuisance species invasion. While several years of rooted plant management and monitoring should be conducted before proceeding with any plant introduction, the active addition of desirable species through planting should be considered. Planting programs are still somewhat experimental and methods are under development and refinement. Assume an actual planting cost of $10,000 per acre, based on recent programs, with Areas 2 and 4 (15 acres) as the likely initial targets. The total cost over a 5 year period is projected at $170,000.

Application of this program over a 5 year period will allow phasing of core elements, evaluation of overall success and fine tuning for the future. Ongoing management expenses are to be expected, but will be reduced after the initial 5 year period. The accompanying table, which is also Table 6 from the Recommendations section of this report, outlines the costs and general timeline for expenses over a 5 year period. Additional considerations and details are included in the implementation table that follows it (Table 8 from this report). The total 5 year expense is estimated at almost $2.3 million and is expected to eliminate most current management costs for Morses Pond, estimated at $130,000 for that same 5 year period. Continuation of the recommended program for another 15 years beyond the initial 5 year period described above is projected to cost an additional $2.4 million. Supplemental management options, to be considered only if needs are not met by the core elements, have been identified for possible implementation over a hypothetical period of 5 to 8 years, but these options may not be needed at all, some options are mutually exclusive, and the timing of application is flexible and will affect costs. Projecting management needs and expenses beyond 5 years is very speculative and should be subject to review and revision as the program proceeds. A 5 year program at a cost of $2.3 million is therefore recommended.

This recommended management plan will enable the Town to meet the stated goals for Morses Pond within the context of stated priorities and will allow progress to be measured against clear plan objectives.

Delineated Management Areas of Morses Pond




Morses Pond Watershed
Upper Bogle Brook
Lower Bogle Brook
Boulder Brook
Jennings Pond
Upper Morses Pond
Lower Morses Pond - Wellesley
Lower Morses Pond - Natick

Morses Pond Core Management Plan Elements, Five Year Plan, Timeline and Cost

	Cost ($) over Time					
Element	**FY07**	**FY08**	**FY09**	**FY10**	**FY11**	**Total**
Core Elements (planned management)						
Professional Lake Manager	$20,000	$51,000	$52,020	$53,060	$54,122	**$230,202**
Water Clarity						
Phosphorus/sediment Inactivation						
Design, permitting, other support	$20,000					$20,000
Construction	$133,000					$133,000
Operation	$25,000	$25,500	$26,010	$26,530	$27,061	$130,101
Monitoring		$7,000	$7,140	$7,283	$7,428	$28,851
Subtotal						**$311,952**
Dredging Area 1						
Design, permitting, other support		$100,000				$100,000
Construction			$500,000			$500,000
Monitoring			$25,000	$25,000		$50,000
Subtotal						**$650,000**
Education						
Website design and population	$30,000	$20,000				$50,000
Brochure		$30,000				$30,000
Updates/expansion			$4,000	$4,080	$4,162	$12,242
Monitoring	$5,000		$6,000		$7,000	$18,000
Subtotal						**$110,242**
Bylaw review and enhancement						
Bylaw review and development		$50,000	$25,000			$75,000
Subtotal						**$75,000**
Low impact development						
Design, permitting, other support		$50,000	$20,000	$20,000	$10,000	$100,000
Construction - Town demonstration		$25,000				$25,000
Construction - Private parties			Private	Private	Private	$0
Monitoring		$3,500	$4,000	$4,500	$5,000	$17,000
Subtotal						**$142,000**
Rooted Plants						
Enhanced harvesting						
Design, permitting, other support	$40,000					$40,000
Equipment purchase	$250,000					$250,000
Operation	$20,000	$56,000	$57,120	$58,262	$59,428	$250,810
Monitoring		$3,000	$3,060	$3,121	$3,184	$12,365
Subtotal						**$553,175**
Manual harvesting/benthic barriers						
Design, permitting, other support		$10,000				$10,000
Hand harvesting labor	Volunteer	Volunteer	Volunteer	Volunteer	Volunteer	$0
Hand harvesting support	$5,000					$5,000
Benthic barrier materials		Private	Private	Private	Private	$0
Benthic barrier labor		Volunteer	Volunteer	Volunteer	Volunteer	$0
Monitoring		$1,000	$1,020	$1,040	$1,061	$4,122
Subtotal						**$19,122**
Selective planting						
Design, permitting and other support			$10,000			$10,000
Planting				$75,000	$75,000	$150,000
Monitoring				$4,000	$4,000	$8,000
Subtotal						**$168,000**
Total	**$548,000**	**$432,000**	**$740,370**	**$281,877**	**$257,445**	**$2,259,692**

Morses Pond Core Management Five Year Plan Timeline Details

	Actions over Time				
Element	**FY07**	**FY08**	**FY09**	**FY10**	**FY11**
Core Elements (planned management)					
Professional Lake Manager	Hire manager by end of summer 2006, prepare RFPs for harvester and phosphorus inactivation by end of calendar year	Prepare RFP for dredging, follow up on implementation of harvesting and phosphorus inactivation	Follow up on implementation of all program elements	Follow up on implementation of all program elements	Follow up on implementation of all program elements
Water Clarity					
Phosphorus/sediment Inactivation					
Design, permitting, other support	Prepare design, acquire permits, get bids and select contractor(s) by February 2007				
Construction	Construct and test system by end of May 2007				
Operation	Operate in June 2007	Operate in July 2007, May-June 2008	Operate in July 2008, May-June 2009	Operate in July 2009, May-June 2010	Operate in July 2010, May-June 2011
Monitoring		Monitor in July 2007, May-June 2008	Monitor in July 2008, May-June 2009	Monitor in July 2009, May-June 2010	Monitor in July 2010, May-June 2011
Dredging Area 1					
Design, permitting, other support		Prepare design and acquire permits by June 2008, select contractor			
Construction			Perform dredging in Sept-Nov 2008; Follow up dredging as warranted in April-June 2009	Complete any containment area restoration by September 2009	
Monitoring			Construction monitoring during dredging	Results and restoration monitoring	
Education					
Website design and population	Design website and add relevant materials	Expand and improve website, use to support LID program			
Brochure		Prepare and distribute brochure			
Updates/expansion			Update as needed	Update as needed	Update as needed
Monitoring	Survey attitudes and practices prior to website and brochure		Survey attitudes and practices after website and brochure		Re-survey attitudes and practices after website and brochure

Morses Pond Core Management Five Year Plan Timeline Details, continued

	Actions over Time				
Element	**FY07**	**FY08**	**FY09**	**FY10**	**FY11**
Core Elements (planned management)					
Bylaw review and enhancement					
Bylaw review and development		Perform review, craft revisions and additions as warranted	Support approval process		
Low impact development					
Design, permitting, other support		Design systems for town properties, private ones as feasible	Assist private development to meet LID standards	Assist private development to meet LID standards	Assist private development to meet LID standards
Construction - Town demonstration		LID demonstration projects			
Construction - Private parties		Conduct LID projects	Conduct LID projects	Conduct LID projects	Conduct LID projects
Monitoring		Monitor results	Monitor results	Monitor results	Monitor results
Rooted Plants					
Enhanced harvesting					
Design, permitting, other support	Prepare bid specs by October 2006, acquire permits by April 2007, train operator(s) by May 2007				
Equipment purchase	Acquire new harvesting equipment by May 2007				
Operation	Harvest in May-June 2007	Harvest in July-Sept 2007, May-June 2008	Harvest in July-Sept 2008, May-June 2009	Harvest in July-Sept 2009, May-June 2010	Harvest in July-Sept 2010, May-June 2011
Monitoring		Plant community assessment in September 2007	Plant community assessment in September 2008	Plant community assessment in September 2009	Plant community assessment in September 2010
Manual harvesting/benthic barriers					
Design, permitting, other support		Develop program for interested shoreline residents, acquire permits, train potential users			
Hand harvesting labor	Remove water chestnut	Remove water chestnut andother invasive species	Remove water chestnut andother invasive species	Remove water chestnut andother invasive species	Remove water chestnut andother invasive species
Hand harvesting support	Acquire boat and equipment for volunteer group				
Benthic barrier materials		Get materials	Get materials	Get materials	Get materials
Benthic barrier labor		Apply barrier	Apply barrier	Apply barrier	Apply barrier
Monitoring		Inspect target areas	Inspect target areas	Inspect target areas	Inspect target areas
Selective planting					
Design, permitting and other support			Develop plan, acquire permits		
Planting				Perform planting	Perform planting
Monitoring				Monitor results	Monitor results

INTRODUCTION

Morses Pond covers 103 to 107 acres, depending upon the water level, in the Town of Wellesley with a small portion in the Town of Natick, Massachusetts. It is a shallow, eutrophic (fertile, receiving and processing many nutrients) pond, having a maximum depth of about 20 ft and an average depth of 8.2 ft (Figure 1). Three principal tributaries, draining a watershed of more than 5,300 acres, feed Morses Pond. The tributaries include Jennings Brook, Bogle Brook, and Boulder Brook, which drain parts of Wellesley, Natick, Weston and Wayland. Water leaving the pond discharges to Paintshop Pond, Lake Waban and ultimately to the Charles River. Land use within the watershed is largely residential and residential services (schools, parks, shops, roads), with some remaining forested land and extensive commercial development along Route 9 (Figure 2).

The pond was created by human action in the 1700s, with dam height raised on several occasions since then to yield the present pond configuration. In 1738, when Wellesley was part of Dedham, Edward Ward dammed his brook, creating a millpond where Morses Pond is today. The pond must not have been large or permanent, since an Ancient Plan of the Commonwealth dated 1771-75 shows no pond there. By the turn of the 19th century, however, a Broad Pond existed close to what is now Route 135, and miller Thomas Broad, or an unknown predecessor, may have built the historic cobbled stone structure now called Paintshop Dam. An 1831 survey map of Needham shows a small pond and milldam in the ownership of Daniel Morse. From this date onwards the pond is known as "Morses Pond."

In 1834, the Boston & Worcester Railroad constructed a 117-foot-long, stonewalled, brick-arched culvert on a log foundation to carry Waban Brook under the railroad line. That old brick culvert forms the central section of Morses Pond's sole outlet today. In 1848, the Henry Wood & Sons Paint Company bought the demand water rights and created Paintshop Pond. According to a study done in 1978 by hydrologist Elliot F. Childs, the changes backed water in the railroad culvert up to five feet deep and raised the level of Morses Pond by three to four feet. Both Morses Pond and Paintshop Pond are shown as existing on the 1856 and 1876 Maps of Needham.

By 1888, ice making had become a big business. The Russell Ice Company built an icehouse on the cove called Ice House Pond and started work on the present Morse Pond Dam, extending the brick outlet culvert to increase the size of the pond for ice harvesting. The Boston Ice Company bought the ice business in 1902, acquired more land from the Waban Rose Conservatories and the right to raise Morses Pond's water level. When the dam was raised, low-lying land was flooded nearly to Worcester Street. The ice business, however, collapsed in the 1920's with the advent of electric refrigerators.

When the Great Depression arrived, the Town was able to buy 84 park acres at Morses Pond for just $3000 and Wellesley's first bathing beach was developed with labor provided by federal relief programs. Wellesley's Department of Public Works bought an additional 16 acres of land designated as water works land. Morses Pond Well #1 and the present pump station were completed in June of 1938. In 1942, the Department of Public Works bought another 22 acres from the Boston & Albany Railroad. In 1953 a second well was installed, which was later abandoned and replaced with two wells in 1981. The original Morses Pond well was replaced in 1992, and all three existing wells remain active.

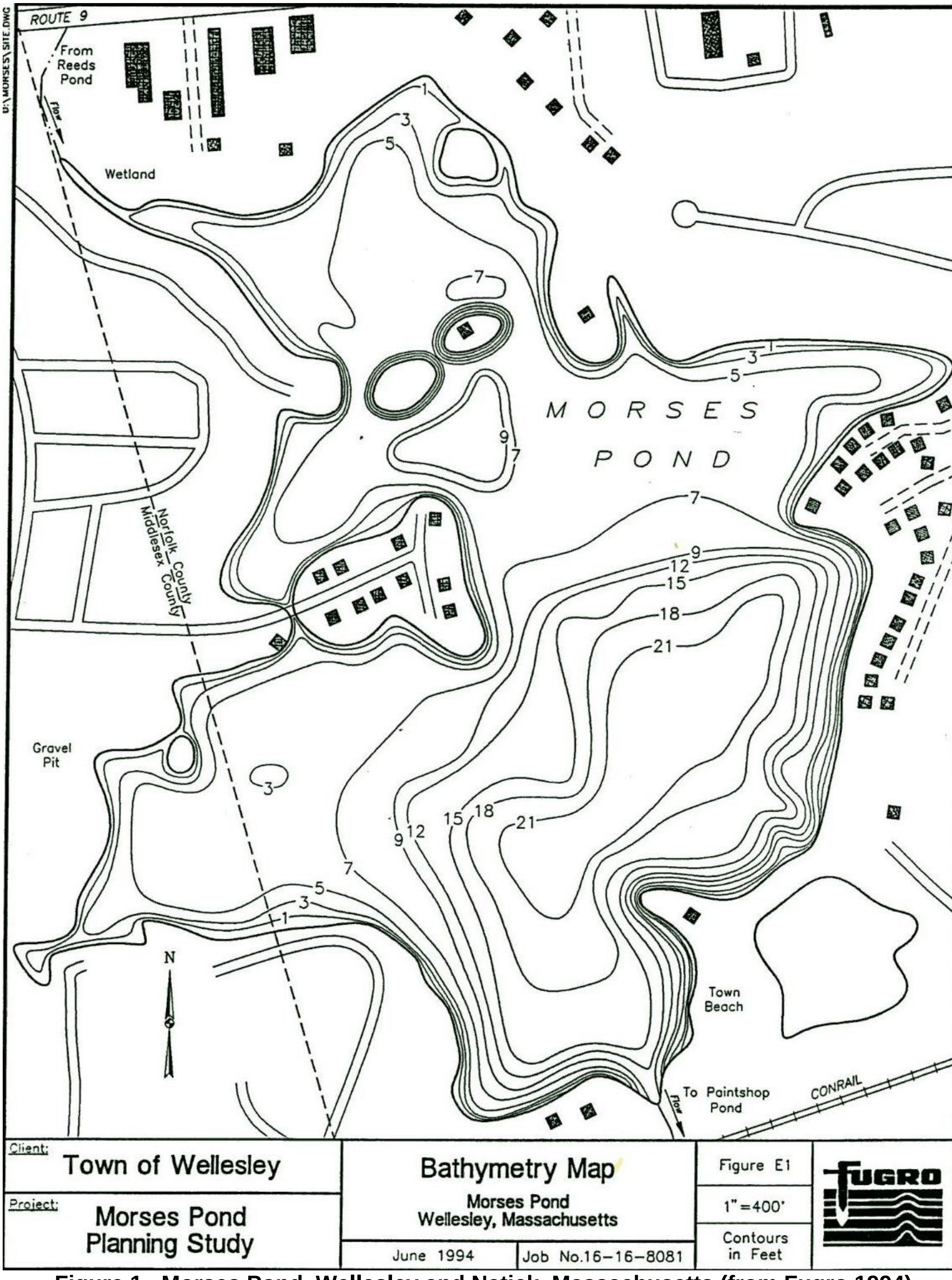


Figure 1. Morses Pond, Wellesley and Natick, Massachusetts (from Fugro 1994)

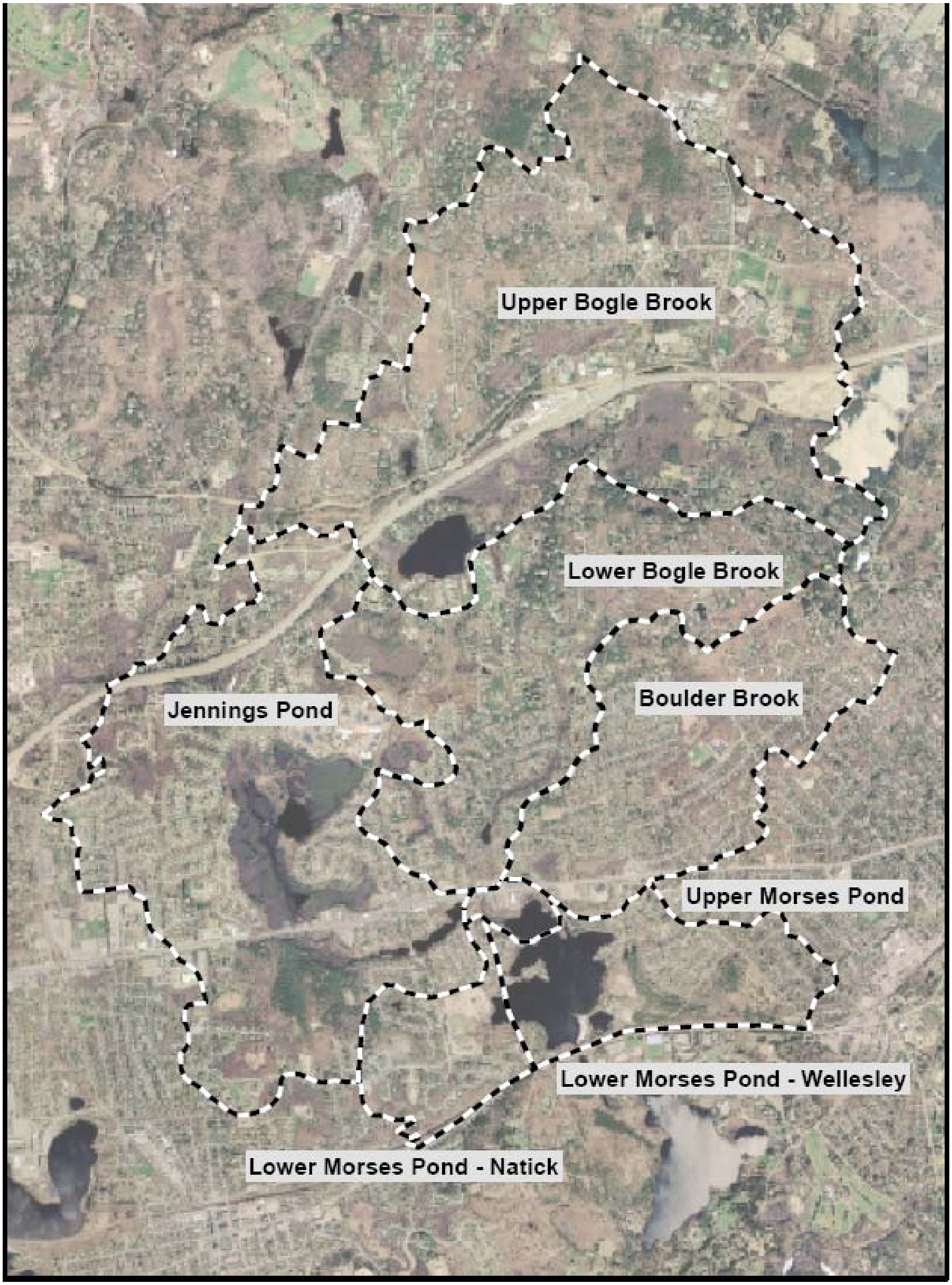


Figure 2. Morses Pond Watershed

Since at least the early 1970s the pond has exhibited symptoms of eutrophication (overfertilization) including recurrent algal blooms, reduced transparency, and dense aquatic vegetation growths that have impaired recreational water uses and important aesthetic and wildlife habitat functions. Blue-green algal blooms required multiple copper treatments in the early 1970s, and the invasive plant Eurasian water milfoil was abundant, along with white and yellow water lilies, in 1973 (Fugro 1994). Other invasive species followed; variable water milfoil became dominant in the 1980s, and a combination of Eurasian water milfoil and fanwort has been dominant since the 1990s. Invasive water chestnut appears almost every year, but is kept from becoming abundant by volunteer hand harvesting.

Because of the importance of Morses Pond as a multiple use resource, the Town, through the dedicated efforts and cooperation of various departments, boards, commissions, and residents, has actively worked towards the management, restoration, and protection of the pond. Since the mid 1960's, various in-lake management efforts including the use of algaecides (copper sulfate), phosphorus inactivation (using aluminum sulfate, a coagulant), weed harvesting, and dredging have been employed to control problems with algae and rooted aquatic plant growth. Monitoring has been performed almost every year since 1981, with sporadic monitoring prior to that date, accumulating a useful database from which management decisions can be made. Management consideration and effort have been fragmented, however, among different groups within the Town, and greater public involvement is desired. Effort has not been consistent over time, and some long-standing recommendations have not been acted upon, mainly as a function of funding needs. The need for a comprehensive plan has been recognized, one which incorporates input from as many parties as possible and examines the complete range of management options for both the short- and long-term.

The 1994 Fugro report summarized management efforts up to that time. Management has included copper, permanganate and alum treatments between 1975 and 1979 over a large portion of the lake to control algae, although lakewide application of chemicals was limited after water supply and flood control were deemed to be the priority uses in 1981. Public interest in recreational uses remained high, however, and localized copper and alum treatments were continued. Such treatments have controlled algae, but only temporarily. Dredging of a reported 54,000 cubic yards of sediment and sewering of most Wellesley residences in the watershed of Morses Pond were conducted by the end of the 1970s. A shift toward green algae from blue-green algae was noted in the 1980s, possibly as a result of these actions, although blue-green blooms still occur in Morses Pond and the importance of watershed runoff as a nutrient source has been recognized since the late 1970s. Harvesting was instituted in the late 1970s and has continued to date, using the same harvester for over 25 years.

Since the 1994 review and planning effort, Reeds Pond on Bogle Brook has been dredged and a circulation system has been installed in the Town swimming area to promote mixing and reduce algae and bacteria accumulations. The Town swimming area has also been hydroraked annually for weed and debris control. Improvements have been made to the outlet to enhance the flood control function of Morses Pond. Copper and occasional alum treatments are conducted only at the southernmost end of the pond, outside of the mapped contributory area to the Town wells (the area referred to in water supply terms as Zone II), and then only in response to water quality and algae monitoring that indicates a distinct benefit from treatment. Mechanical harvesting has become less consistent as a function of breakdowns by old harvesting equipment, but continues as a summer effort. Hand harvesting of water chestnut continues to limit the establishment of that invasive species. Annual water quality, algae, and plant monitoring also continues and supplies valuable information upon which to base management decisions.

Outside of the pond, a number of treatment improvements have been made in association with the Town wells adjacent to Morses Pond to meet Safe Drinking Water Act requirements, but have no direct impact on the pond. Town bylaws relating to water supply protection and discharges to the Town storm water drainage system have been developed, and a plan for storm water management has been prepared under the National Pollutant Discharge Elimination System regulations promulgated under the Federal Clean Water Act. The impact of these management tools on water quality in Morses Pond at this time is unknown, however.

Today Morses Pond is a source of potable water for the Town and is used extensively for recreational purposes, including swimming, boating and fishing. The Morses Pond wellfield is an important component of the Town's water supply system, providing over 40% of total Town supply. The Morses Pond well system is comprised of three gravel packed wells that draw a substantial portion (estimated at 60%) of their water from the adjacent Morses Pond through porous soils. Water quality and quantity are therefore key concerns, even for those who do not actively use the pond. The Town of Wellesley maintains a beach and swimming area near the outlet at the southern end of the pond, and Town residents launch boats without gasoline engines from an adjacent area. Picnicking is also conducted on Town land, and a system of trails is maintained near the pond on Town property. Shoreline residents enjoy passive and some active uses of the pond as conditions and access permits. Eutrophication remains a threat to pond uses.

In 2004 the Town of Wellesley formed the Morses Pond Ad Hoc Committee (MPAHC), comprised of representatives of selected Town boards and civic groups. The Department of Public Works, Natural Resources Commission, and Recreation Commission are the key Town organizations represented on the MPAHC, with additional participation from the Friends of Morses Pond, the Town Advisory Committee, and the Community Preservation Committee. Representatives from other Town boards (e.g., Selectmen) or organizations (e.g., Pesticide Awareness Committee), watershed stakeholders (e.g., Wellesley College), other towns within the watershed (e.g., Natick), and the public at large have attended some MPAHC meetings, all of which are considered open to the public. All interested parties have been encouraged to attend major public forums offered during plan development. The Town solicited proposals and engaged ENSR Corporation for technical assistance with plan development. This document reports on the plan developed as a result of this year-long process.

The process followed during the development of this plan has included regular meetings of the MPAHC and thorough discussion of existing conditions, current uses, condition and use goals, priorities for management, and options for achieving the use goals. In deciding which options were most suitable for managing Morses Pond and its watershed, probability of success, cost and acceptability within the existing regulatory framework were carefully considered. Input from outside parties has been sought at every logical juncture in this process, with plan adjustment as warranted. ENSR has facilitated the technical portion of this process and provided cost estimates and regulatory reviews. The MPAHC has acted as both a barometer of the boards and interest groups represented and as an integrator of general public comment. The MPAHC has educated itself to the degree necessary to critically evaluate lake and watershed management proposals and act on behalf of the Town in crafting a management plan for Morses Pond.

PROBLEM STATEMENT

Since at least the early 1970s, Morses Pond has exhibited symptoms of overfertilization (eutrophication) including recurrent algal blooms, reduced transparency, and dense aquatic vegetation growths that have impaired recreational water uses and important aesthetic and wildlife habitat functions. As an artificially created, shallow waterbody with a large watershed, Morses Pond is predisposed toward certain problems. These include:

1. Low transparency (water clarity) observed on a frequent although not constant basis, attributable to both algae and suspended sediments.
2. Dense rooted plant growths which have changed in composition over a period of decades, with exotic, invading nuisance species having become dominant.
3. Shallow water depth in many areas of the pond, made more problematic by sediment accumulations from both natural and human-induced events over time.

These problems impact habitat, recreational uses of the lake, flood storage potential, and possibly water supply in nearby wells. Based on multiple past investigations of Morses Pond and its watershed, the causes and constraints associated with the above problems have been defined as follows:

- The watershed is about 50 times the area of the pond, predisposing the pond to periodically elevated inputs of sediment and nutrients even without human interactions. Only 21% of the watershed is in Wellesley, creating jurisdictional problems for management. Much of the watershed has been developed for residential use, with landscape management practices fostering high loads of nutrients and other pollutants to waterways and eventually the pond.
- Low transparency is caused by both watershed inputs of solids and algal blooms generated within the pond. Resuspension of particles within the pond is also possible, but seems to be a lesser influence. Algae blooms appear to be a consequence of nutrient inputs from the watershed, triggered by longer summer detention times, warmer temperatures, and phosphorus levels in excess of 20 ppb.
- Algal blooms have included a variety of algae, with blue-green algae (more properly cyanobacteria) causing most of the blooms requiring treatment. Phosphorus and nitrogen may limit algal growth at various times, and each may limit different species at the same time, but other factors such as light and flushing may be important controls on algae in Morses Pond. However, phosphorus is the factor with the greatest potential for control in this system, and could be made to limit algal growth.
- Overall storm-related loading of nutrients and sediment is much larger than dry weather loading, although dry weather loading is not inconsequential. The annual variability in pond conditions appears to be attributable to weather pattern, with wet years causing higher pollutant loading and lower water clarity. However, wet summers often coincide with greater flushing, such that algal blooms may not develop or persist. The combination of a wet spring and dry summer appears to foster the most problematic algae blooms.
- Solids enter the pond in particulate and dissolved forms. Most suspended solids are likely to settle out quickly in the northern portion of the pond, although finer solids will move into the southern basin of Morses Pond. Dissolved solids impart color to the water, giving Morses Pond its characteristically brownish hue. Phosphorus and total solids levels correlate closely, indicating that water clarity impairment from algal growths or non-algal particles can be predicted from phosphorus concentrations.
- Previously constructed hydrologic and phosphorus budgets indicate that the tributaries are the major sources of water and pollutants and that Bogle Brook is the main source within

this group. It does not appear that atmosphere, groundwater, or internal release from sediments contributes significantly to water or nutrient loads. Internal nutrient reserves in the sediments do support rooted plant growths, however.

- Sediment enters from the watershed and is also generated organically within the pond. Sediment accumulations allow many rooted species, native and non-native, to expand coverage and reach nuisance levels. There is enough nutrient-rich sediment in the pond now to support dense rooted plant growths without any future watershed inputs. Light limits plant growth in areas of Morses Pond deeper than about 10 ft, but this leaves about 64 acres of pond area at risk.
- Invasion by non-native species, including two species of milfoil, fanwort, water chestnut, and purple loosestrife has created severe rooted plant problems. Even without considering these invasive species, however, waterlilies, naiad and some native pondweeds sometimes reach nuisance densities in shallow areas. In areas <8 ft deep, rooted plant biomass fills most of the water column by late summer, degrading habitat value for most desirable species and severely impeding recreational uses.

As a result of eutrophication, use of Town facilities at the pond has decreased, boating and fishing activities have declined, and shoreline residents and visitors are dissatisfied with the visual aesthetics of the pond. To meet use goals for Morses Pond, both as determined by a public discernment process and based on the designated uses of the pond under its Massachusetts water quality classification, two distinct goals are set:

1. Improve water clarity by reducing the loading of fine solids and the internal production of algae, especially cyanobacteria. Maintenance of the 4 ft visibility level normally applied to swimming areas in Massachusetts is desired at all times, with clarity averaging around 6 ft preferred.
2. Reduce rooted plant biomass to a level commensurate with optimal overall habitat value and use for swimming and non-motorized boating, with preferred elimination of invasive species. Native plants are not to be eradicated, but rather a native assemblage consistent with desired pond uses is to be encouraged.

Summary

A large watershed area with a substantial portion developed for residential and commercial uses subjects Morses Pond to low water clarity through input of suspended sediment and nutrients that fuel algae growth. The shallow nature of the pond and hospitable soft sediments that have accumulated over many years support dense growths of rooted aquatic plants, with a majority of biomass represented by invasive species. Many uses of the pond are considered to be impaired by these conditions. To meet use goals, water clarity must be increased and rooted plant biomass must be decreased, using methods applied in accordance with a plan developed as part of a public process.

PUBLIC PARTICIPATION

Involving as many parties as possible in the comprehensive planning for the management of Morses Pond was accorded a high priority by the MPAHC. All committee meetings were open to anyone wishing to attend, and multiple meetings were conducted outside of the normal committee meeting times to facilitate involvement by Town boards, commissions, civic organizations and the public at large. It is admittedly difficult to get as large an audience as would be preferred to all meetings and still have meaningful exchanges, but every effort was made in the planning process to solicit input.

The goal and priority setting process included committee discussions, a residential questionnaire survey, discussions with Town boards and commissions, and a public meeting to solicit input. The goals and priorities were revised as warranted and appear in this report as a product of that process.

Review of management options involved many committee meetings, solicited input from Town boards and commissions, and three public meetings to garner input on a wide variety of possible approaches. The fundamental triumvirate of criteria for a management option addresses three basic questions:

- Is it technically feasible with a high probability of success?
- Is it affordable over the short-term and long-term?
- Is it acceptable to the regulatory community and a large majority of interested parties?

Management options for which these questions could not be answered with a “Yes” were either dropped from consideration or where relegated to supplemental status, to be reconsidered if the recommended program did not achieve the desired results.

Evaluation of the draft report encompassed both review of the written report and public meetings to explain the decision process and resulting recommendations, with changes in response to both written and verbal reviews. It is important to note that recommendations represent a protracted effort of analysis and review by many parties representing multiple Town boards and the users of Morses Pond, and may not completely reflect the views or wishes of any one individual or group. However, all comments have been considered and the plan has been subjected to scrutiny and revision as warranted to meet the same key criteria upon which initial screening of management actions was based.

GOALS AND PRIORITIES

While the two general goals of improved water clarity and reduced rooted plant biomass have been apparent to MPAHC members from an early stage of the planning process, a public process of goal development and priority setting was implemented to ensure that as many viewpoints as possible were represented and that important aspects of both the aquatic system and public interest were adequately addressed. The MPAHC therefore discussed the various uses of Morses Pond and their relative priority order in its meetings, solicited input from Town boards and other interest groups, held a public forum for discussion, and collected questionnaires from several hundred residential respondents. The statement of goals and priorities drafted by the MPAHC after its internal deliberations was revised to reflect the input of the larger community, although differences were slight. After a highly public process, the resulting statement (below) provides guidance for considering possible management actions in light of the range of possible impacts (both beneficial and deleterious) on the complete suite of goals, in the priority order gleaned from substantial input.

The Town has managed Morses Pond for water supply (through nearby wells), flood control and recreation (mainly at the Town beach), with consideration for other uses, including habitat for a wide variety of water-dependent species. The Morses Pond Ad Hoc Committee (MPAHC) was formed to advance those management programs that improve and maintain the health of Morses Pond and its environs to serve the public interest. The MPAHC, with input from many groups within Wellesley, has outlined goals for Morses Pond management and has established use priorities for consideration in making management decisions.

It is clear that any in-pond management project must also consider the impact of source water flow from the Morses Pond watershed into the Pond and the outflow from the Pond to Paintshop Pond, Lake Waban, and the Charles River. In addition to the in-pond management goals reflected below, MPAHC will work closely with those towns and neighbors in the watershed that either contribute to or are recipients of pond water flow. The objective of this cooperation will be to deal with those factors that contribute to the degradation of the pond before the arrival of related contaminants in Morses Pond, and to minimize any negative impact of the pond outflow to downstream water bodies.

The following goals and priorities have been established. Explanatory notes relating to how the goal interacts with the potential management of the pond follow each goal.

Top Level Priority

Drinking Water

- Protect the quality of drinking water pumped from the Morses Pond wells – Avoid actions that threaten long-term supply quality, particularly regulated aspects, but consider actions that might improve Morses Pond with only short-term inconvenience or expense to drinking water supply.
- Protect the quantity of water available from the Morses Pond wells – Minimize clogging of the interface between the pond and soil/groundwater and avoid actions that lower the water level in the pond for the long-term, but consider actions that improve Morses Pond with only short-term alteration of water level as long as a temporary alternative supply is available.

Second Level Priorities

Contact Recreation

- Continue Town use of the beach area, promoting water clarity, health standards and aesthetics of the beach area – Promote actions that help meet contact water quality standards (e.g., adequate clarity, low bacteria counts) relating to contact recreation and enhance the safety and enjoyment of the pond for swimmers.
- Minimize remedial actions that interrupt the beach operation – Avoid actions that require beach closures during the swimming season, although consideration may be given to short-term interference with distinct long-term improvement potential.
- Promote overall lake conditions conducive to lakewide contact recreation – Promote actions that improve water quality and maintain open water suitable for contact recreation throughout the pond.

Flood Control

- Maintain current flood control measures – No major increase in flood control is sought, but avoid actions that compromise flood control.
- Establish on-going policy measures to achieve flood control – Seek to control the generation of elevated flows near their source through sound land management practices in the watershed.

Third Level Priorities

Non-motorized Boating

- Enhance canoeing, kayaking, sailing and rowing opportunities – Control plants that impair these uses, especially surface growths that impede all forms of boating, and maintain attractive conditions in the pond.
- Improve and maintain access - Enhance access points for non-motorized boating, facilitating access beyond the beach season and reducing the difficulty of launching boats.

Environment and Wildlife Protection

- Protect wetlands – Recognize the valuable functions of the range of wetland types and minimize impacts on those functions; look to balance open water and emergent wetland functions at Morses Pond; reduce the abundance of invasive species.
- Protect vernal pool habitats – Avoid actions that adversely impact vernal pools or buffer zones surrounding them.
- Protect wildlife habitat (both within the pond and around it) – Avoid actions that damage habitat, although consideration may be given to actions with short-term impacts that generate long-term improvements; reduce the abundance of invasive species.
- Preserve open space within the watershed area and secure conservation restrictions protecting property within the watershed from development – Promote open space preservation for the betterment of downstream water quality as well as local habitat.
- Prevent bank/land erosion and restore where possible – Minimize erosional inputs; recognize the potential for developed land to alter hydrology and seek to mitigate negative consequences.

Fishing

- Enhance fishing opportunities – Promote a balanced and desirable fish community at a naturally sustainable density.

- Enhance and maintain access – Keep access points functional and attractive; balance access with habitat and private property interests; avoid actions that lead to long-term decreased access unless for purposes of habitat protection.

Other Non-contact Uses

- Enhance non-contact recreational opportunities – Support non-contact uses including walking, nature watching, education and general aesthetics; improve the general appearance of the pond as relates to both water quality and plant nuisances.
- Enhance and maintain the trails and related access – Keep the pond accessible for passive uses and facilitate its use as an educational resource.

The interaction between pond uses and key features that affect uses will need to be considered in evaluating management objectives. There are some general conclusions reflected below that can be drawn from the interplay of uses and features in this case:

- Uses are benefited by maximizing lake volume and water level.
- Uses are benefited by maximizing water clarity.
- Uses are benefited by lowering water color, algae, sediment suspension/accumulation, dissolved contaminants, pathogens and invasive species.
- Balanced communities of native rooted plants, invertebrates, fish and waterfowl are beneficial or at least tolerable for stated uses.
- Uses are not benefited by invasive plant species abundance.
- Access for humans facilitates some uses, but may negatively affect others if not limited.
- Watershed features affect the quantity and quality of water entering the pond; improvement in water quality and moderation of water quantity benefits most uses.

Summary

Water supply is the top priority in the management of Morses Pond, with concern for both quantity and quality of water entering the Town wells from the pond. Contact recreation (especially swimming at the Town beach) and flood control are considered to represent equal second level priorities. A third level of priority includes non-motorized boating, environment and wildlife protection (mainly habitat enhancement), fishing, and other non-contact uses such as education and passive enjoyment of the pond. It is desired that all named uses be supported, but actions that positively affect the higher priority uses are likely to have preference, and actions that negatively affect higher priority uses to benefit a lower priority use will be less favored. Maximizing water clarity and eliminating invasive aquatic plant species are viewed as beneficial to all uses.

WATER CLARITY AND PLANT BIOMASS OBJECTIVES TO SUPPORT USE GOALS

Setting actual water quality and plant biomass targets to facilitate achievement of use goals is a complicated and imprecise science. No one number can embody the range of conditions observed over the years in this pond or guarantee that all uses will be completely supported all of the time. Chosen values are like speed limits; exceeding them increases risk, but does not guarantee disaster, while remaining below them does not assure complete safety. We set targets that are predicted to result in desirable conditions, based on known relationships established from data collected in Morses Pond or other comparable aquatic systems. Here we provide a basis for water clarity and plant biomass targets that will become the guiding values for evaluating the potential success of management options.

Water Clarity

Considerable effort has gone into monitoring Morses Pond and its tributaries over a period of almost three decades, and the resultant data have been used to develop guidance for future management in two documents (Fugro 1994 and Wagner 2002). The Fugro (1994) effort concluded that actions aimed at reducing phosphorus input would also tend to reduce sediment loads, and that reduced phosphorus could also lower the sedimentation from internally produced organic matter. The appropriate range for the desired phosphorus loading reduction was set at 27 to 38% on a long-term basis, or about a one third reduction from the current loading level as a general target. Wagner (2002) re-examined these and more recent data, and concluded that the estimate remained appropriate through 1999.

However, it was noted that the range of needed reductions was much wider on an annual basis, ranging from only 10% during a dry year to 57% in a wet year, underscoring the importance of precipitation and runoff in the loading of pollutants to Morses Pond. Therefore, using phosphorus load as a surrogate for all watershed inputs, the load must be reduced by at least 10%, but provisions must be made to reduce it by 57% if loading is to be consistent with water clarity expectations at all times. Additionally, the declining capacity of the northern basin (referred to as Area 1 in this report) was expected to raise the needed level of loading reduction; this area has provided valuable pollutant trapping capacity since it was last dredged in the late 1970s, but has filled in to a point at which more and more phosphorus (and other pollutants) are passing through it and reaching the main body of the pond. Some combination of restored detention capacity in the northern basin and increased pollutant removal in the watershed or in that northern basin (even more dredging or addition of settling agents) are needed to achieve the desired loading reduction.

As a load reduction target, 33% is offered as a general level of reduction from current inputs, based on controlling sources or trapping phosphorus on a regular basis. It may be necessary, however, to do better than this on a seasonal basis, with late spring and early summer inputs especially critical to summer conditions in Morses Pond and impairment of most uses. It may be possible to reduce loading in just that spring-summer period, such that the long-term load reduction is not more than 33%, but the timing of load reduction gives the results that might be expected with a 57% or greater load reduction. This will be a function of the management methods chosen for loading reduction.

Since loading is sporadic and both the amount and timing of loads are important, it is helpful to set a phosphorus control target in terms of the actual concentration in the pond, which tends to be more stable than levels at any inlet. Water is mixed, processed and gradually released from Morses Pond, with a detention time averaging about a month. From simple engineering principles, this suggests that the concentration of phosphorus at the start of summer will have a lot of influence throughout the summer. If the concentration is low at the start of summer, the runoff added during all but the wettest summers will not be enough to raise the phosphorus level to a point where algal blooms will be frequent. Yet during a summer wet enough to raise an initially low phosphorus concentration to a potentially damaging level, flushing may be sufficient to keep algae from building up to bloom proportions. If phosphorus is moderate late in the spring, summer storms may push the pond over the limit, and if phosphorus is high going into the warmer months, blooms may occur without further inputs.

Using the data available for a 20-year period, Wagner (2002) found that the break-point for declining water clarity was about 0.02 mg/L, or 20 ppb, as measured in the southern basin (near the beach). If phosphorus remained below 20 ppb, water clarity was typically above 8 ft. If phosphorus increased to 0.04 mg/L, or 40 ppb, clarity was below the desired 4 ft level in about half the measurements. The range of 20 to 40 ppb was a transition zone. These values are consistent with the findings of an exhaustive review of nutrient data for the New England States (ENSR 2000); lakes with phosphorus levels >24 ppb tend to display the signs of eutrophication, especially algal blooms, while lakes with phosphorus levels <10 ppb rarely exhibit such impairment. A starting summer target for phosphorus of 10 to 15 ppb is suggested, with a late summer phosphorus target of 20 ppb.

To further examine the relationship between loading and phosphorus concentration in the lake, the watershed-water quality model applied in the 1994 analysis was refined and updated, and the more recent data were applied to facilitate a current analysis. The resulting model output (Appendix, Watershed Section) suggests that the average phosphorus concentration in the southern basin of Morses Pond is 29 ppb, a reasonable approximation of what has been observed over the last decade, with variability among wet and dry years. This translates into average water clarity of 5.6 ft with values lower than 4 ft occurring about 10% of the time. From the model, the desirable target for phosphorus to prevent algae blooms and keep clarity consistently above 4 ft is about 20 ppb, consistent with the target established from a review of available data above. Slightly higher values may be tolerable (e.g., the 24 ppb limit from ENSR 2000), but will be difficult to discern within the constraints of measurement accuracy for phosphorus.

Applying loading reductions that represent aggressive but possible management actions to individual sub-watersheds within the overall drainage area of Morses Pond, predicted average phosphorus concentrations in the southern basin of Morses Pond range from 26 to 28 ppb. If action is taken in the Lower Bogle Brook, Boulder Brook and Direct Wellesley drainage basins (all areas within Wellesley), the phosphorus concentration could decline to 24 ppb. If the northern basin (Area 1) is additionally dredged to restore detention capacity, the predicted phosphorus level declines to 21 ppb, very close to the target level. Action throughout the watershed can lower the phosphorus level to <20 ppb, but requires work in Natick and Weston as well as Wellesley. Management effort within Wellesley can address most Weston inputs (via Bogle Brook), but only with creation of large detention areas that may be difficult to site. The 21 ppb prediction probably represents the best that can be expected from structural watershed management and dredging of the northern basin. Additional reductions will depend on source controls.

Plant Biomass

Specific goals for rooted plants depend on the use goal and plant community composition. A dense, low growing, submergent, rooted plant community would not impede most recreation, would provide desirable fish and wildlife habitat, and would not harm water supply. Such a community is therefore targeted. As the current community includes species that literally fill the water column and is dominated by invasive species not native to the area, a major shift in both types and quantity of plants is needed. However, techniques that eliminate plants without consideration for what will grow in place of those that are removed may not benefit all uses. A lack of plants will reduce fish and wildlife habitat and may limit purification potential for water in the pond; this could negatively impact water quality for water supply and contact recreation, uses with the highest priority in this system. The key is to remove invasive species and native species with high nuisance potential while fostering a plant community dominated by native species with desirable traits.

In terms of a plant community composition goal, currently present species that would be considered desirable at higher densities include the pondweeds, submergent arrowhead, coontail and water starwort (Table 1). Species that should be eradicated include the five non-native plants (fanwort, two milfoils, water chestnut and purple loosestrife). Species that should be maintained as part of the plant community but kept under control include the two water lilies, naiad, waterweed, the two bladderworts and smartweed. These latter species have habitat value, but have also achieved nuisance densities in Morses Pond in some locations, and might expand to fill space opened up by removal of the invasive species.

In terms of actual coverage and biovolume goals, all areas of Morses Pond (Figure 3) except the deep part of the southern basin (Area 7) need plant biomass reductions to support use goals. Coverage ratings for the current community outside Area 7 range from 3.6 to 4.9 on a scale of 0 to 5. This means that most of the bottom is covered by plants in the roughly 64 acres included in Areas 1 through 6. Extensive bottom coverage is not inconsistent with use goals, if the growths remain near the bottom, but that is not the case in Morses Pond.

Biovolume ratings for the current plant community outside of Area 7 range from 2.0 to 4.8 (Table 2 and Appendix B) for different areas of the lake (Figure 3), on a scale of 0 to 5, with 0 representing no plants and 5 representing complete filling of the water column and a surface covering of plants. Area 7, the deep portion of the southern basin, has a low value at 0.4, simply as a function of light limitation imposed by depth. The other six areas, covering about 64 acres, have more substantial biovolume values, with Areas 1, 2 and 4 having values >4.0 (very dense biovolume) and Areas 3, 5 and 6 having values between 2.0 and 3.6 (moderate to dense biovolume). A biovolume not less than 1 or greater than 2 would be desirable for most uses of Morses Pond in areas <10 ft deep, although lower biovolume values where lilies or water chestnut was dominant would still negatively impact contact recreation and boating.

Very low biovolume values would support contact recreation and boating uses, but a more moderate amount of plants is generally considered desirable for water supply and fish and wildlife habitat. It would be appropriate to have some areas with more dense plants, providing certain habitat types and filtering capacity for incoming waters, but the overall average should not be high. It would also be appropriate to have some area of very low biovolume, even beyond the deeper open water of Area 7, but complete elimination of plants in shallow water is not desirable either, and is not really practical in Morses Pond from a management perspective. It is possible that management actions will eliminate plants in one part of the pond for some period of time, but as long as other parts of the pond remain vegetated, overall use goals can be met.

Table 1. Vascular Plant Species Found in Morses Pond in 2004

Scientific Name	Common Name	Native	Nuisance Potential	Abbreviation
Cabomba caroliniana	Fanwort	N	High	Ccar
Callitriche sp.	Water starwort	Y	Low	Calli
Ceratophyllum demersum	Coontail	Y	Moderate	Cdem
Decodon verticillatus	Swamp loosestrife	Y	Moderate	Dver
Elodea canadensis	Waterweed	Y	Moderate	Ecan
Lemna minor	Duckweed	Y	Moderate	Lmin
Lythrum salicaria	Purple loosestrife	N	High	Lsal
Myriophyllum heterophyllum	Variable watermilfoil	N	High	Mhet
Myriophyllum spicatum	Eurasian watermilfoil	N	High	Mspic
Najas flexilis	Common naiad	Y	Moderate	Nflex
Nuphar variegatum	Yellow water lily	Y	High	Nvar
Nymphaea odorata	White water lily	Y	High	Nodo
Polygonum amphibium	Water smartweed	Y	High	Poly
Pontederia cordata	Pickerelweed	Y	Low	Pcord
Potamogeton amplifolius	Broadleaf pondweed	Y	Moderate	Pamp
Potamogeton epihydrus	Leafy pondweed	Y	Low	Prob
Potamogeton robbinsii	Robbins pondweed	Y	Low	Ppul
Ranunculus sp.	Water crowfoot	Y	Moderate	Ranu
Sagittaria gramineus	Submerged arrowhead	Y	Low	Sgram
Salix sp.	Willow	Y	Moderate	Salix
Spirodela polyrhiza	Big duckweed	Y	Moderate	Spol
Typha latifolia	Cattail	Y	Moderate	Tlat
Trapa natans	Water chestnut	N	High	Tnat
Utricularia geminiscapa	Bladderwort	Y	Moderate	Ugem
Utricularia gibba	Bladderwort	Y	Moderate	Ugib
Wolffia columbiana	Watermeal	Y	Moderate	Wcol

Table 2. Summary of Plant Cover and Biovolume Plus Sediment Depth and Volume

Area #	Area (ac)	Avg. Actual Water Depth (ft)	High Water Depth (ft)	Actual Water Volume (cy)	High Water Volume (cy)	Avg. Plant Cover	Avg. Plant Biovolume	Avg. Sediment Depth (ft)	Volume of Soft Sediment (cy)
1	15.0	3.8	5.6	92013	136216	4.6	4.3	0.8	18313
2	5.9	4.4	6.3	42156	59596	4.9	4.8	1.9	18051
3	12.7	5.9	7.7	120625	158088	4.3	3.6	2.1	42308
4	9.4	4.7	6.5	71408	99145	4.7	4.2	2.7	41318
5	7.5	4.4	6.3	53637	75706	4.6	2.8	2.5	30723
6	13.0	4.9	6.7	102989	141474	3.6	2.0	2.6	53825
7	42.2	13.5	15.3	918746	1043249	0.6	0.4	NA	NA
Total	105.6			1401574	1713474				204537

Areas refer to Figure 3.
Plant cover and biovolume are based on a 0-5 scale, with 0 representing and moving in 25% increments, with 5 indicating 100% cover or water column filling.
Area 7 was too deep for an accurate estimate of sediment depth.
All values are based on September – October 2004 surveys, with 4 boards out of outlet structure.

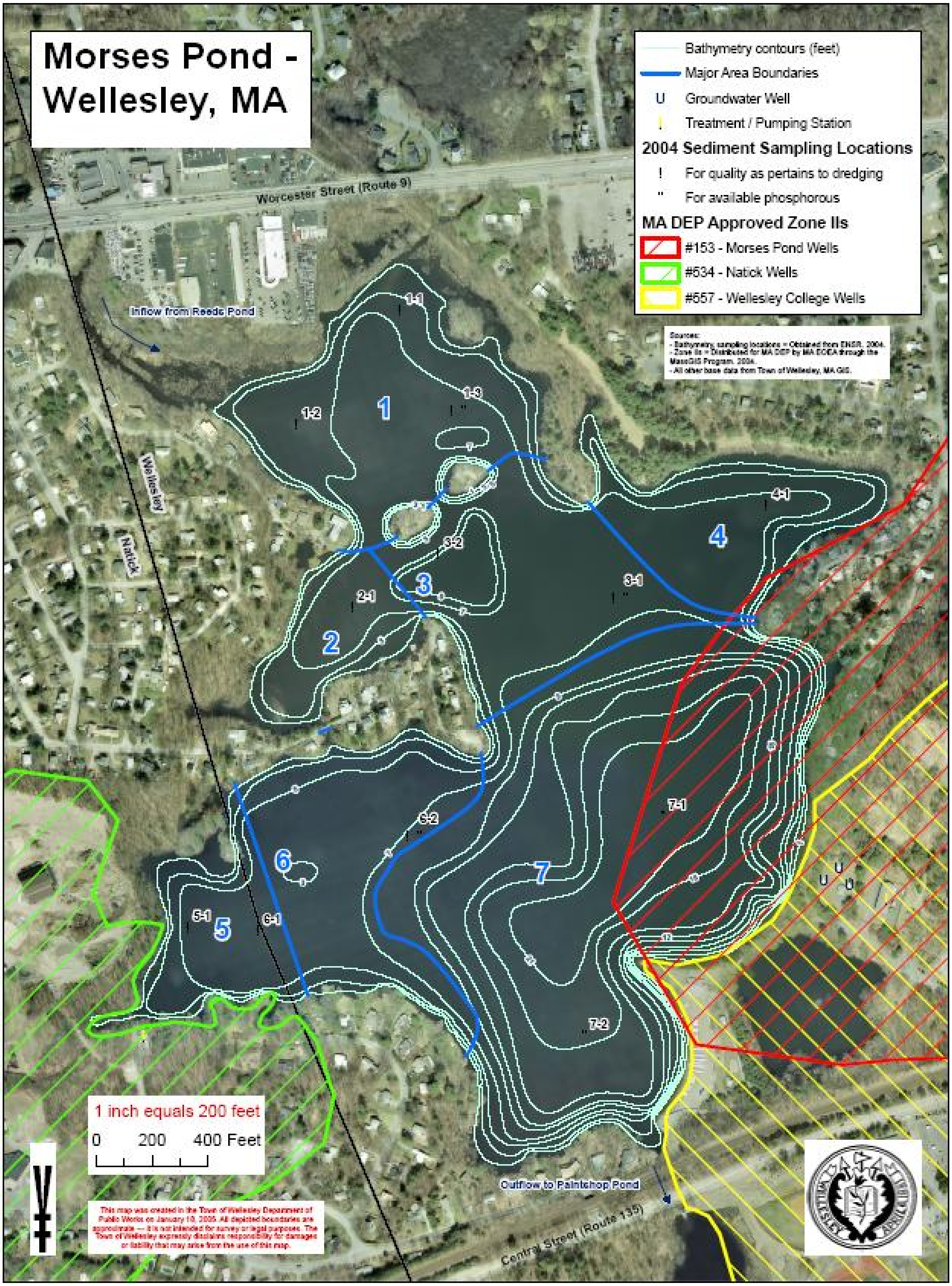


Figure 3. Delineated Management Areas of Morses Pond.

Therefore, plant targets for the purpose of meeting use goals in Morses Pond are set as follows:

- Eliminate invasive plants (introduced species with high nuisance potential) to the extent possible.
- Reduce the abundance of native species currently causing nuisance conditions (most notably naiad and waterlilies).
- Promote greater abundance by native species with high habitat value and lower nuisance potential (for example, the pondweeds).
- Foster moderately dense cover on the pond bottom during summer (cover value target of 3, or 50-75%) with very limited surface cover by plants.
- Manage for a low portion of the water column filled with plants during summer, on average (biovolume value target <2, or <50%), with some areas with higher values and other areas with lower values. Manage for lowest values in areas of highest human access for recreation, and higher value in Area 1, which will augment the role of that area in pollutant removal.

Summary

A review of use goals and supporting conditions for Morses Pond suggests that an average phosphorus loading and concentration reduction of 33% desirable, resulting in an in-lake average phosphorus level of 20 ppb and achievement of 4 ft visibility at all times and >6 ft visibility except in rare cases. Also, elimination of invasive plant species and an overall reduction in plant biomass to 50-75% bottom cover and 25-50% water column filling in areas <10 ft deep are targeted. Phosphorus targets to support use goals are consistent with analyses performed in the past for Morses Pond and more regionally for New England lakes in general. Phosphorus concentrations and loads will vary over time with precipitation and runoff generation, with control of spring and early summer storm water inputs as the most critical need for algae and water clarity control. Summer plant biomass will vary spatially, and can be beneficially high in some areas for habitat (random patches of vegetation away from areas of prime human use) and water quality enhancement (especially in Area 1, to act as a filter for incoming contaminant loads). Most areas should be maintained at a much lower plant biomass, however, for other habitat and human uses, with a near absence of plants in swimming areas and very limited surface cover wherever boating is conducted.

CONSEQUENCES OF THE NO ACTION ALTERNATIVE

From the outset it should be noted that the no action alternative does not mean that there is a complete lack of management of the pond. While many would characterize the activities of the last decade as inadequate to meet use goals, the Town has spent several tens of thousands of dollars annually on monitoring, harvesting, hydroraking, algaecides and alum treatments. Total estimated expenses from 2002 through 2005 average about $25,000, and a few costs (e.g., power for the circulator, gasoline for the harvester, administrative labor) have not been estimated. It might be more appropriate to characterize this option as the “no additional management alternative”. However, considerably more management is needed if goals are to be met.

The no action alternative is usually invoked as a consequence of neglect, lack of funds for desired activities, or inability to get those actions permitted. Funding and permitting have been problems for the management of Morses Pond, with fragmented responsibility and authority in the watershed as additional impediments. Consideration has been given to the management of Morses Pond on multiple occasions in the past, with the 1994 Fugro report representing a detailed review of the situation and options. Over the last decade it has been largely an issue of limited funding and a lack of focused attention on the pond. With the creation of the Morses Pond Ad Hoc Committee, it is expected that a comprehensive plan will be developed which defines and addresses the range of goals and concerns and incorporates input from a wide variety of stakeholders. Funding and fragmented authority will remain as obstacles to management that must be overcome to meet the desired goals most economically over time.

The impact of no additional management on the defined use goals is summarized in the Appendix (No Action Alternative Section). There is considerable uncertainty about the impact on the water supply, although no benefits are expected. The degree of negative impact is unclear as a consequence of the movement of water through considerable soil before it enters the wells, providing substantial purification on the way, and treatment of well water before distribution to consumers. Water withdrawn from the Morses Pond wellfield is treated by filtration, tray aeration, and disinfection with detention. The treatment is identical to that given to water from the other two Town water supplies located elsewhere. Federal regulations for drinking water supplies have caused Wellesley to expend $8 million in capital costs and about $450,000 annually in operational costs to comply with requirements for corrosion control, dissolved mineral removal, and disinfection.

The impact of the no action alternative on water supply should be measurable as increased costs. For comparison, the Rosemary Meadow supply is believed to represent water from a considerably more eutrophic source, and requires additional treatment that includes 35% more hypochlorite and 10% more hydroxide per million gallons than used for Morses Pond wellfield water. The difference in annual cost is about $10,000. If additional treatment was necessitated to remove specific contaminants not currently addressed by the existing treatment system, costs would increase further, but there is no current estimate of what those costs might be. Current treatment has so far been adequate to meet the provisions of the Safe Drinking Water Act.

For other desired uses, the effects of no additional action are clearly negative. More frequent and/or severe algal blooms, continued dense rooted plant growths dominated by invasive species, and periods of turbidity from suspended sediments all act to inhibit contact recreation, diminish flood control capacity by infilling, degrade habitat for many water-dependent forms of wildlife, interfere with boating and fishing, and impair aesthetics. The deterioration over the last 20 years is particularly evident in the northern basin, which has filled in to the point at which emergent vegetation is beginning to appear away from the shoreline. The important detention capacity of this area is estimated to have declined significantly, allowing more pollutants to reach the southern basin where they can impair uses. It appears that the northern basin will have lost most of its value as a detention area in about 20 more years, with a commensurate loss of value expected in the southern basin as more pollutants reach that area.

The economic impact of degraded conditions in Morses Pond has not been precisely calculated, but could be felt in the value of homes (and not just on or near the pond) and on the tax base as a result. Such declines have been measured elsewhere, even within Massachusetts (Jobin 1997). While difficult to quantify, resource economists generally believe that the cost of lake management is less than the potential economic losses within the community and region as a result of deteriorating conditions in a waterbody.

Finally, it should be noted that taking no additional action with regard to Morses Pond will not keep the pond as it is, but will allow further deterioration. Current conditions, while not acceptable for some uses much of the time, do still support many desired uses. The value of Morses Pond to the Town can indeed decline further, and is expected to do so in the absence of additional management actions.

Summary

Taking no additional management actions at Morses Pond means that current approaches will be continued, but that most water use goals would not be met and conditions are likely to further deteriorate. Harvesting would continue to provide some benefits, but the current equipment and manpower allocation is inadequate to maintain desirable conditions in all targeted areas. Annual hydroraking can minimize plant biomass and debris accumulation in the Town swimming area. Treatment with copper and/or aluminum compounds in the southernmost part of the pond can be used to maintain water clarity in the Town swimming area, and the existing circulation system will provide limited but beneficial mixing in that area. Water purification through natural soil filtration and active treatment upon withdrawal from the wells will facilitate a continued supply of safe drinking water, although the cost of water treatment may increase. Overall, however, recreational utility and habitat quality can be expected to decline as the northern basin fills in over the next 20 years and algal blooms become more frequent and possibly more severe in the southern basin. Continued high density of invasive rooted plants will impair swimming and boating uses away from the Town beach and diminish passive enjoyment of Morses Pond.

MANAGEMENT OPTIONS

There are multiple methods for enhancing water clarity and reducing rooted plant growths, each with benefits and disadvantages that must be understood within the context of the target lake. Tables 3 and 4, adapted from the Generic Environmental Impact Report for Eutrophication and Aquatic Plant Management in Massachusetts (Mattson et al. 2004), outline the range of options available for combating the problems facing Morses Pond. These tables, while lengthy, will provide a quick summary of management options and their applicability to Morses Pond. Applicability is defined here as having the potential to meet management goals and be permitted under existing environmental regulations. Cost is not considered, and social acceptability issues are noted but not factored into applicability. For readers with some background in lake management or the specifics of Morses Pond, the field of likely options should be apparent and logical. We attempt here to provide additional background for those less familiar with these options or how they apply to Morses Pond, but readers with limited background are encouraged to consult the GEIR for Lake Management or its condensed version, the Practical Guide to Lake Management in Massachusetts (Wagner 2004). Further discussion is divided among the two primary needs for meeting use goals: improved water clarity and reduced rooted plant biomass.

Management of Water Clarity

Water clarity is a function of both algae growing in the pond and non-living particles suspended in the water. Those non-living particles can originate in the watershed and be carried by runoff to the pond, or they can be generated in the pond, either from dead algae and plant material or from inorganic bottom sediments that can be suspended by wind action in shallow (<10 ft deep) areas. Runoff in the Morses Pond watershed is typically quite turbid and carries enough suspended solids to visually change water clarity during storms. This runoff also carries a substantial phosphorus load, which then fuels algal growth in the pond and can greatly reduce water clarity. Dead algae and externally loaded solids, plus decaying rooted plant matter, can be resuspended by wind. Consequently, control of water clarity involves control of several separate (although linked) processes, with a variety of methods available for management (Table 3).

Watershed management to reduce the input of a variety of pollutants, including sediment and phosphorus, is clearly the preferred approach to enhancing water clarity. While some control of particles already in the pond is likely to be necessary, the frequent input of fine sediment and nutrients from the watershed is the primary driving force behind episodes of low water clarity in Morses Pond. Managing runoff from developed land to limit pollutant loading and erosion from high flows is the most critical step in watershed management, but is difficult to implement as a consequence of physical and jurisdictional limitations.

As a watershed becomes developed, water quality impacts are predictable, with impervious surface area >10% usually causing detectable effects and impervious cover >25% almost always causing measurable negative impacts (CWP 2003). Only about one third of the land in the Morses Pond watershed could be considered to be in a natural state, and impervious surface area is estimated at about 32%. Management actions are necessary to control pollutant loading under these conditions, and would likely involve some combination of source controls (limiting the generation of pollutant loads) and pollutant trapping (capturing or converting contaminants before they reach the lake). However, over three quarters of the watershed is outside Wellesley, and even that part within Wellesley is not subject to regulation at a level that easily facilitates runoff management.

Table 3. Options for Improving Water Clarity, with Applicability Based on Technical and Permitting Issues

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
WATERSHED CONTROLS				
1) Management for nutrient input reduction	♦ Includes wide range of watershed and lake edge activities intended to eliminate nutrient sources or reduce delivery to lake ♦ Essential component of algal control strategy where internal recycling is not the dominant nutrient source, and desired even where internal recycling is important	♦ Acts against the original source of algal nutrition ♦ Creates sustainable limitation on algal growth ♦ May control delivery of other unwanted pollutants to lake ♦ Facilitates ecosystem management approach which considers more than just algal control	♦ May involve considerable lag time before improvement observed ♦ May not be sufficient to achieve goals without some form of in-lake management ♦ Reduction of overall system fertility may impact fisheries ♦ May cause shift in nutrient ratios which favor less desirable algae	♦ High ♦ Need source controls and pollutant trapping throughout watershed
1a) Point source controls	♦ More stringent discharge requirements ♦ May involve diversion ♦ May involve technological or operational adjustments ♦ May involve pollution prevention plans	♦ Often provides major input reduction ♦ Highly efficient approach in most cases ♦ Success easily monitored	♦ May be very expensive in terms of capital and operational costs ♦ May transfer problems to another watershed ♦ Variability in results may be high in some cases	♦ Moderate ♦ No discharges other than storm water, but storm water is regulated in this area under NPDES Storm Water Phase II. ♦ Need to work with Towns in watershed to craft appropriate management plans

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
1b) Non-point source controls	♦ Reduction of sources of nutrients ♦ May involve elimination of land uses or activities that release nutrients ♦ May involve alternative product use, as with no phosphate fertilizer	♦ Removes source ♦ Limited or no ongoing costs	♦ May require purchase of land or activity ♦ May be viewed as limitation of “quality of life” ♦ Usually requires education and gradual implementation	♦ High ♦ Storm water, whether regulated as point sources or not, requires source management
1c) Non-point source pollutant trapping	♦ Capture of pollutants between source and lake ♦ May involve drainage system alteration ♦ Often involves wetland treatments (det./infiltration) ♦ May involve storm water collection and treatment as with point sources	♦ Minimizes interference with land uses and activities ♦ Allows diffuse and phased implementation throughout watershed ♦ Highly flexible approach ♦ Tends to address wide range of pollutant loads	♦ Does not address actual sources ♦ May be expensive on necessary scale ♦ May require substantial maintenance	♦ High ♦ Source control will not be sufficient by itself ♦ Need increased detention in watershed plus restored capacity in northern basin of pond ♦ Detention can be through larger basins associated with tributaries or smaller systems linked to many specific sites

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
IN-LAKE PHYSICAL CONTROLS				
2) Circulation and destratification	♦ Use of water or air to keep water in motion ♦ Intended to prevent or break stratification ♦ Generally driven by mechanical or pneumatic force	♦ Reduces surface build-up of algal scums ♦ May disrupt growth of blue-green algae ♦ Counteraction of anoxia improves habitat for fish/invertebrates ♦ Can eliminate localized problems without obvious impact on whole lake	♦ May spread localized impacts ♦ May lower oxygen levels in shallow water ♦ May promote downstream impacts	♦ Moderate ♦ Used now in Town swimming area ♦ Could be expanded to greater area ♦ Not likely to counteract all loading impacts
3) Dilution and flushing	♦ Addition of water of better quality can dilute nutrients ♦ Addition of water of similar or poorer quality flushes system to minimize algal build-up ♦ May have continuous or periodic additions	♦ Dilution reduces nutrient concentrations without altering load ♦ Flushing minimizes detention; response to pollutants may be reduced	♦ Diverts water from other uses ♦ Flushing may wash desirable zooplankton from lake ♦ Use of poorer quality water increases loads ♦ Possible downstream impacts	♦ Low ♦ No ready source of water at key time (summer)

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
4) Drawdown	♦ Lowering of water over autumn period allows oxidation, desiccation and compaction of sediments ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Algae are affected mainly by reduction in available nutrients.	♦ May reduce available nutrients or nutrient ratios, affecting algal biomass and composition ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ May provide rooted plant control as well	♦ Possible impacts on non-target resources ♦ Possible impairment of water supply ♦ Alteration of downstream flows and winter water level ♦ May result in greater nutrient availability if flushing inadequate	♦ Low ♦ Has benefits, but impact on water supply is too great
5) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Nutrient reserves are removed and algal growth can be limited by nutrient availability	♦ Can control algae if internal recycling is main nutrient source ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging	♦ High ♦ Restoring detention capacity of northern basin has high priority ♦ Removing accumulated sediment from other areas of the pond <10 ft deep would be beneficial, but of lesser priority for water clarity control ♦ Must avoid loss of soil filtering capacity, but not a significant issue in northern basin

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
5a) “Dry” excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment	♦ Eliminates most aquatic biota unless a portion left undrained ♦ Eliminates lake use during dredging	♦ Moderate ♦ Necessary drawdown impacts water supply, unless areas are sequestered and pumped
5b) “Wet” excavation	♦ Lake level may be lowered, but sediments not substantially exposed ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve aquatic biota	♦ Usually creates extreme turbidity ♦ Normally requires intermediate containment area to dry sediments prior to hauling ♦ May disrupt ecological function ♦ Use disruption	♦ Low ♦ Creates too much turbidity, possible impacts in other areas of pond and downstream
5c) Hydraulic removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle coarse or debris-laden materials ♦ Requires sophisticated and more expensive containment area	♦ High ♦ Minimizes impacts to water supply and downstream ♦ Allows pumping of sediment slurry to location off pond ♦ Requires substantial engineering and disposal arrangement

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
6) Light-limiting dyes and surface covers	♦ Creates light limitation	♦ Creates light limit on algal growth without high turbidity or great depth ♦ May achieve some control of rooted plants as well	♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water	♦ Low ♦ Natural water color already provides this function
6.a) Dyes	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting algal growth ♦ Dyes remain in solution until washed out of system.	♦ Produces appealing color ♦ Creates illusion of greater depth	♦ May not control surface bloom-forming species ♦ May not control growth of shallow water algal mats ♦ Altered thermal regime	♦ Low
6.b) Surface covers	♦ Opaque sheet material applied to water surface	♦ Minimizes atmospheric and wildlife pollutant inputs	♦ Minimizes atmospheric gas exchange ♦ Limits recreation	♦ Low
7) Mechanical removal	♦ Filtering of pumped water for water supply purposes ♦ Collection of floating scums or mats with booms, nets, or other devices ♦ Continuous or multiple applications per year usually needed	♦ Algae and associated nutrients can be removed from system ♦ Surface collection can be applied as needed ♦ May remove floating debris ♦ Collected algae dry to minimal volume	♦ Filtration requires high backwash and sludge handling capability ♦ Labor and/or capital intensive ♦ Variable collection efficiency ♦ Possible impacts on non-target aquatic life	♦ Low ♦ Filtering arrangement would have to be large, expensive, and space intensive

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
8) Selective withdrawal	♦ Discharge of bottom water which may contain (or be susceptible to) low oxygen and higher nutrient levels ♦ May be pumped or utilize passive head differential	♦ Removes targeted water from lake efficiently ♦ Complements other techniques such as drawdown or aeration ♦ May prevent anoxia and phosphorus build up in bottom water ♦ May remove initial phase of algal blooms which start in deep water ♦ May create coldwater conditions downstream	♦ Possible downstream impacts of poor water quality ♦ May eliminate colder thermal layer that supports certain fish ♦ May promote mixing of remaining poor quality bottom water with surface waters ♦ May cause unintended drawdown if inflows do not match withdrawal	♦ Low ♦ No selective withdrawal capacity; requires major outlet overhaul
9) Sonication	♦ Sound waves disrupt algal cells	♦ Supposedly affects only algae (new technique) ♦ Applicable in localized areas	♦ Unknown effects on non-target organisms ♦ May release cellular toxins or other undesirable contents into water column	♦ Low ♦ May have some use in swimming area, but requires live electric line, possible safety hazard
IN-LAKE CHEMICAL CONTROLS				
10) Hypolimnetic aeration or oxygenation	♦ Addition of air or oxygen provides oxic conditions ♦ Maintains stratification ♦ Can also withdraw water, oxygenate, then replace	♦ Oxic conditions reduce P availability ♦ Oxygen improves habitat for fish/invertebrates ♦ Oxygen reduces build-up of ammonium, sulfides	♦ May disrupt thermal layers important to fish community ♦ Theoretically promotes supersaturation with gases harmful to fish	♦ Low ♦ Hypolimnion is small ♦ Internal P load is low compared to external sources

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
11) Algaecides	♦ Liquid or pelletized algaecides applied to target area ♦ Algae killed by direct toxicity or metabolic interference ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid elimination of algae from water column , normally with increased water clarity ♦ May result in net movement of nutrients to bottom of lake	♦ Possible toxicity to non-target species ♦ Restrictions on water use for varying time after treatment ♦ Increased oxygen demand and possible toxicity ♦ Possible recycling of nutrients	♦ High ♦ Not the preferred approach, but helps maintain clarity as interim measure
11a) Forms of copper	♦ Cellular toxicant, disruption of membrane transport ♦ Applied as wide variety of liquid or granular formulations	♦ Effective and rapid control of many algae species ♦ Approved for use in most water supplies	♦ Possible toxicity to aquatic fauna ♦ Accumulation of copper in system ♦ Resistence by certain green and blue-green nuisance species ♦ Lysing of cells releases nutrients and toxins	♦ High ♦ Current algaecide used when needed
11b) Peroxides	♦ Disrupts most cellular functions, tends to attack membranes ♦ Applied as a liquid or solid. ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid action ♦ Oxidizes cell contents, may limit oxygen demand and toxicity	♦ Much more expensive than copper ♦ Limited track record ♦ Possible recycling of nutrients	♦ High ♦ Less potential negative impact than copper, but more expensive

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
11c) Synthetic organic algaecides	♦ Absorbed or membrane-active chemicals which disrupt metabolism ♦ Causes structural deterioration	♦ Used where copper is ineffective ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on water use	♦ Low ♦ Perceived risk to water supply and contact recreation
12) Phosphorus inactivation	♦ Typically salts of aluminum, iron or calcium are added to the lake, as liquid or powder ♦ Phosphorus in the treated water column is complexed and settled to the bottom of the lake ♦ Phosphorus in upper sediment layer is complexed, reducing release from sediment ♦ Permanence of binding varies by binder in relation to redox potential and pH	♦ Can provide rapid, major decrease in phosphorus concentration in water column ♦ Can minimize release of phosphorus from sediment ♦ May remove other nutrients and contaminants as well as phosphorus ♦ Flexible with regard to depth of application and speed of improvement	♦ Possible toxicity to fish and invertebrates, especially by aluminum at low pH ♦ Possible release of phosphorus under anoxia or extreme pH ♦ May cause fluctuations in water chemistry, especially pH, during treatment ♦ Possible resuspension of floc in shallow areas ♦ Adds to bottom sediment, but typically an insignificant amount	♦ High ♦ Has been used with varied success in the past ♦ Results in water column can be dramatically positive, but do not last with continued loading ♦ Can offset loading very quickly; interim and back-up for watershed management ♦ Less applicable for sediment P inactivation ♦ Must maintain pH between 6 and 8 SU

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
13) Sediment oxidation	♦ Addition of oxidants, binders and pH adjustors to oxidize sediment ♦ Binding of phosphorus is enhanced ♦ Denitrification is stimulated	♦ Can reduce phosphorus supply to algae ♦ Can alter N:P ratios in water column ♦ May decrease sediment oxygen demand	♦ Possible impacts on benthic biota ♦ Longevity of effects not well known ♦ Possible source of nitrogen for blue-green algae	♦ Low ♦ Limited internal P load or oxygen demand
14) Settling agents	♦ Closely aligned with phosphorus inactivation, but can be used to reduce algae directly too ♦ Lime, alum or polymers applied, usually as a liquid or slurry ♦ Creates a floc with algae and other suspended particles ♦ Floc settles to bottom of lake ♦ Re-application typically necessary at least once/yr	♦ Removes algae and increases water clarity without lysing most cells ♦ Reduces nutrient recycling if floc sufficient ♦ Removes non-algal particles as well as algae ♦ May reduce dissolved phosphorus levels at the same time	♦ Possible impacts on aquatic fauna ♦ Possible fluctuations in water chemistry during treatment ♦ Resuspension of floc possible in shallow, well-mixed waters ♦ Promotes increased sediment accumulation	♦ High ♦ Aluminum use for P inactivation also fills this function ♦ Alternative coagulants exist, but may not inactivate P to desired extent

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
15) Selective nutrient addition	♦ Ratio of nutrients changed by additions of selected nutrients ♦ Addition of non-limiting nutrients can change composition of algal community ♦ Processes such as settling and grazing can then reduce algal biomass (productivity can actually increase, but standing crop can decline)	♦ Can reduce algal levels where control of limiting nutrient not feasible ♦ Can promote non-nuisance forms of algae ♦ Can improve productivity of system without increased standing crop of algae	♦ May result in greater algal abundance through uncertain biological response ♦ May require frequent application to maintain desired ratios ♦ Possible downstream effects	♦ Low ♦ Detention time too short to allow reliable manipulation
IN-LAKE BIOLOGICAL CONTROLS				
16) Enhanced grazing	♦ Manipulation of biological components of system to achieve grazing control over algae ♦ Typically involves alteration of fish community to promote growth of large herbivorous zooplankton, or stocking with phytophagous fish	♦ May increase water clarity by changes in algal biomass or cell size distribution without reduction of nutrient levels ♦ Can convert unwanted biomass into desirable form (fish) ♦ Harnesses natural processes to produce desired conditions	♦ May involve introduction of exotic species ♦ Effects may not be controllable or lasting ♦ May foster shifts in algal composition to even less desirable forms	♦ High, with native species ♦ Low for introduced species, due to regulatory restrictions ♦ Reliability over time tends to be low, however; biological controls are not static

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
16.a) Herbivorous fish	♦ Stocking of fish that eat algae	♦ Converts algae directly into potentially harvestable fish ♦ Grazing pressure can be adjusted through stocking rate	♦ Typically requires introduction of non-native species ♦ Difficult to control over long term ♦ Smaller algal forms may be benefited and bloom	♦ Low ♦ Non-native species introductions generally inappropriate ♦ Possible permitting issues
16.b) Herbivorous zooplankton	♦ Reduction in planktivorous fish to promote grazing pressure by zooplankton ♦ May involve stocking piscivores or removing planktivores ♦ May also involve stocking zooplankton or establishing refugia	♦ Converts algae indirectly into harvestable fish ♦ Zooplankton response to increasing algae can be rapid ♦ May be accomplished without introduction of non-native species ♦ Generally compatible with most fishery management goals	♦ Highly variable response expected; temporal and spatial variability may be high ♦ Requires careful monitoring and management action on 1-5 yr basis ♦ Larger or toxic algal forms may be benefitted and bloom	♦ High ♦ More large zooplankton would suppress algae ♦ Limited by dense rooted plants; may occur naturally if plants controlled ♦ Limited by fish community composition; may adjust naturally after plant control

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
17) Bottom-feeding fish removal	♦ Removes fish that browse among bottom deposits, releasing nutrients to the water column by physical agitation and excretion	♦ Reduces turbidity and nutrient additions from this source ♦ May restructure fish community in more desirable manner	♦ Targeted fish species are difficult to control ♦ Reduction in fish populations valued by some lake users (human/non-human)	♦ Low ♦ Not a know problem at this time
18) Pathogens	♦ Addition of inoculum to initiate attack on algal cells ♦ May involve fungi, bacteria or viruses	♦ May create lakewide “epidemic” and reduction of algal biomass ♦ May provide sustained control through cycles ♦ Can be highly specific to algal group or genera	♦ Largely experimental approach at this time ♦ May promote resistant nuisance forms ♦ May cause high oxygen demand or release of toxins by lysed algal cells ♦ Effects on non-target organisms uncertain	♦ Low ♦ No commercially available forms
19) Competition and allelopathy	♦ Plants may tie up sufficient nutrients to limit algal growth ♦ Plants may create a light limitation on algal growth ♦ Chemical inhibition of algae may occur through substances released by other organisms	♦ Harnesses power of natural biological interactions ♦ May provide responsive and prolonged control	♦ Some algal forms appear resistant ♦ Use of plants may lead to problems with vascular plants ♦ Use of plant material may cause depression of oxygen levels	♦ Low ♦ Already have overly dense rooted plant community

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
19a) Plantings for nutrient control	♦ Plant growths of sufficient density may limit algal access to nutrients ♦ Plants can exude allelopathic substances which inhibit algal growth ♦ Portable plant "pods" , floating islands, or other structures can be installed	♦ Productivity and associated habitat value can remain high without algal blooms ♦ Can be managed to limit interference with recreation and provide habitat ♦ Wetland cells in or adjacent to the lake can minimize nutrient inputs	♦ Vascular plants may achieve nuisance densities ♦ Vascular plant senescence may release nutrients and cause algal blooms ♦ The switch from algae to vascular plant domination of a lake may cause unexpected or undesirable changes	♦ Low ♦ Already have very dense plant community
19b) Plantings for light control	♦ Plant species with floating leaves can shade out many algal growths at elevated densities	♦ Vascular plants can be more easily harvested than most algae ♦ Many floating species provide waterfowl food	♦ Floating plants can be a recreational nuisance ♦ Low surface mixing and atmospheric contact promote anoxia	♦ Low ♦ Already have very dense plant community
19c) Addition of barley straw	♦ Input of barley straw can set off a series of chemical reactions which limit algal growth ♦ Release of allelopathic chemicals can kill algae ♦ Release of humic substances can bind phosphorus	♦ Materials and application are relatively inexpensive ♦ Decline in algal abundance is more gradual than with algaecides, limiting oxygen demand and the release of cell contents	♦ Success appears linked to uncertain and potentially uncontrollable water chemistry factors ♦ Depression of oxygen levels may result ♦ Water chemistry may be altered in other ways unsuitable for non-target organisms	♦ Low ♦ Not registered as an algaecide ♦ Unreliable results in other systems ♦ Low detention time will limit results

Table 4. Options for Control of Rooted Plants, with Applicability Based on Technical and Permitting Issues

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
Physical Controls				
1) Benthic barriers	♦ Mat of variable composition laid on bottom of target area, preventing growth ♦ Can cover area for as little as several months or permanently ♦ Maintenance improves effectiveness	♦ Highly flexible control ♦ Reduces turbidity from soft bottoms ♦ Can cover undesirable substrate ♦ Can improve fish habitat by creating edge effects	♦ May cause anoxia at sediment-water interface ♦ May limit benthic invertebrates ♦ Non-selective interference with plants in target area ♦ May inhibit spawning/feeding by some fish species	♦ High ♦ Localized control can be achieved and maintained ♦ Not typically used on larger areas (>2 acres)
1.a) Porous or loose-weave synthetic materials	♦ Laid on bottom and usually anchored by weights or stakes ♦ Removed and cleaned or flipped and repositioned at least once per year for maximum effect	♦ Allows some escape of gases which may build up underneath ♦ Panels may be flipped in place or removed for relatively easy cleaning or repositioning	♦ Allows some growth through pores ♦ Gas may still build up underneath in some cases, lifting barrier from bottom	♦ High ♦ Easy to apply and maintain ♦ Must maintain, however, to keep effective
1.b) Non-porous or sheet synthetic materials	♦ Laid on bottom and anchored by many stakes, anchors or weights, or by layer of sand ♦ Not typically removed, but may be swept or “blown” clean periodically	♦ Prevents all plant growth until buried by sediment ♦ Minimizes interaction of sediment and water column	♦ Gas build up may cause barrier to float upwards ♦ Strong anchoring makes removal difficult and can hinder maintenance	♦ Moderate ♦ More effort to install than porous forms, must vent trapped gases ♦ Less maintenance needed, but must avoid sediment accumulation on top

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
1.c) Sediments of a desirable composition	♦ Sediments may be added on top of existing sediments or plants. ♦ Use of sand or clay can limit plant growths and alter sediment-water interactions. ♦ Sediments can be applied from the surface or suction dredged from below muck layer (reverse layering technique)	♦ Plant biomass buried ♦ Seed banks can be buried deeper ♦ Sediment can be made less hospitable to plant growths ♦ Nutrient release from sediments may be reduced ♦ Surface sediment can be made more appealing to humans ♦ Reverse layering requires no addition or removal of sediment	♦ Sediments may sink into or mix with underlying muck ♦ Permitting for added sediment difficult ♦ Addition of sediment may cause initial turbidity increase ♦ New sediment may contain nutrients or other contaminants ♦ Generally too expensive for large scale application	♦ Low ♦ Regulatory restrictions on adding fill
2) Dredging	♦ Physical sediment removal, with deposition in a containment area ♦ Can be applied on a limited basis, but is most often a major restructuring of an impacted system ♦ Plants and seed beds are removed and re-growth can be limited by light and/or substrate limitation	♦ Plant removal with some flexibility ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ Threat to fish ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging ♦ Usually expensive	♦ High ♦ Provides additional benefits of added depth and changing substrate ♦ Will not prevent regrowth; must apply additional maintenance techniques

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
2.c) Hydraulic (or pneumatic) removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and limits impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle extremely coarse or debris-laden materials ♦ Requires advanced and more expensive containment area ♦ Requires overflow discharge from containment area	♦ High ♦ Minimizes impacts to water supply and downstream ♦ Allows pumping of sediment slurry to location off pond ♦ Requires substantial engineering and disposal arrangement
3) Dyes and surface covers	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting plant growth ♦ Dyes remain in solution until washed out of system. ♦ Opaque sheet material applied to water surface	♦ Light limit on plant growth without high turbidity or great depth ♦ May achieve some control of algae as well ♦ May achieve some selectivity for species tolerant of low light ♦	♦ May not control peripheral or shallow water rooted plants ♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water ♦ Covers inhibit gas exchange with atmosphere	♦ Low ♦ Natural water color already provides this function

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
4) Mechanical removal (“harvesting”)	♦ Plants reduced by mechanical means, possibly with disturbance of soils ♦ Collected plants may be placed on shore for composting or other disposal ♦ Wide range of techniques employed, from manual to highly mechanized ♦ Application once or twice per year usually needed	♦ Highly flexible control ♦ May remove other debris ♦ Can balance habitat and recreational needs	♦ Possible impacts on aquatic fauna ♦ Non-selective removal of plants in treated area ♦ Possible spread of undesirable species by fragmentation ♦ Possible generation of turbidity	♦ High ♦ Will not prevent regrowth, but can maintain desired biomass level
4.a) Hand pulling	♦ Plants uprooted by hand (“weeding”) and preferably removed	♦ Highly selective technique	♦ Labor intensive ♦ Difficult to perform in dense stands	♦ High ♦ Localized technique for low density growths
4.b) Cutting (without collection)	♦ Plants cut in place above roots without being harvested	♦ Generally efficient and less expensive than complete harvesting	♦ Leaves root systems and part of plant for re-growth ♦ Leaves cut vegetation to decay or to re-root ♦ Not selective within applied area	♦ Low ♦ Water quality impacts of large quantities of plant biomass too great

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
4.c) Harvesting (with collection)	♦ Plants cut at depth of 2-10 ft and collected for removal from lake	♦ Allows plant removal on greater scale	♦ Limited depth of operation ♦ Usually leaves fragments which may re-root ♦ May impact fauna ♦ Not selective within applied area ♦ More expensive than cutting	♦ High ♦ With adequate equipment, can maintain biomass consistent with use goals
4.d) Rotovation	♦ Plants, root systems, and surrounding sediment disturbed with mechanical blades	♦ Can thoroughly disrupt entire plant	♦ Usually leaves fragments which may re-root ♦ May impact fauna ♦ Not selective within applied area ♦ Creates l turbidity ♦ More expensive than harvesting	♦ Low ♦ Turbidity impacts too high
4.e) Hydroraking	♦ Plants, root systems and surrounding sediment and debris disturbed with mechanical rake, material usually collected and removed	♦ Can thoroughly disrupt entire plant ♦ Also allows removal of stumps or other obstructions	♦ Usually leaves fragments which may re-root ♦ May impact fauna ♦ Not selective within applied area ♦ Creates turbidity ♦ More expensive than harvesting	♦ Moderate ♦ Applicable on very small scale, as with annual use in Town swimming area ♦ Creates high turbidity

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
5.a) Drawdown	♦ Lowering of water over winter period allows desiccation, freezing, and physical disruption ♦ Exposure and dewatering are critical aspects ♦ Variable species tolerance to drawdown ♦ Most effective on annual to once/3 yr. basis	♦ Control with some flexibility ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ Impacts vegetative propagation species with limited impact to seed producing populations	♦ Possible impacts on linked wetlands ♦ Possible effects on reptiles/amphibians ♦ Reduction in potential water supply and fire fighting capacity ♦ Alteration of downstream flows ♦ May result in greater nutrient availability for algae	♦ Low ♦ Drawdown to effective level will severely impair water supply from nearby Town wells
5.b) Flooding	♦ Higher water level in the spring can inhibit seed germination and plant growth ♦ Higher flows which are normally associated with elevated water levels can flush seed and plant fragments from system	♦ Where water is available, this can be an inexpensive technique ♦ Plant growth need not be eliminated, merely retarded or delayed ♦ Timing of water level control can selectively favor certain desirable species	♦ Water for raising the level may not be available ♦ Potential peripheral flooding ♦ Possible downstream impacts ♦ Many species may not be affected, and some may be benefitted ♦ Algal nuisances may increase where nutrients are available	♦ Low ♦ Water level rise causes flooding of property, possible downstream impacts

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
6) Herbicides	♦ Liquid or pelletized herbicides applied to target area or to plants directly ♦ Contact or systemic poisons kill plants or limit growth ♦ Typically requires application every 1-5 yrs	♦ Wide range of control is possible ♦ May be able to selectively eliminate species ♦ May achieve some algae control as well	♦ Possible toxicity to non-target species ♦ Possible downstream impacts ♦ Restrictions of water use for varying time after treatment ♦ Increased oxygen demand from decaying vegetation ♦ Possible recycling of nutrients to allow other growths	♦ Moderate ♦ Only a few herbicides can be used in water supplies ♦ Will not prevent eventual regrowth, but can be used to reset plant community ♦ Social acceptability issues exist ♦ NRC policy prohibits use of herbicides at this time
6.a) Forms of copper	♦ Contact herbicide ♦ Cellular toxicant, suspected membrane transport disruption ♦ Applied as wide variety of liquid or granular formulations, often in conjunction with polymers or other herbicides	♦ Moderately effective control of some submersed plant species ♦ More often an algal control agent	♦ Toxic to aquatic fauna as a function of concentration, formulation, and ambient water chemistry ♦ Ineffective at colder temperatures ♦ Copper ion persistent; accumulates in sediments or moves downstream	♦ Moderate ♦ Used for algae, however, not rooted plants in most cases

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
6.b) Forms of diquat (6,7-dihydropyrido [1,2-2’,1’-c] pyrazinediium dibromide)	♦ Contact herbicide ♦ Absorbed by foliage but not roots ♦ Strong oxidant; disrupts most cellular functions ♦ Applied as a liquid, sometimes in conjunction with copper	♦ Moderate control of some emersed plant species, moderately to highly effective control of floating or submersed species ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to zooplankton at recommended dosage ♦ Inactivated by suspended particles; ineffective in muddy waters ♦ Time delays on use for water supply, agriculture and recreation	♦ Low ♦ Restriction on use in drinking water supply ♦ NRC policy prohibits use of herbicides at this time
6.c) Forms of glyphosate (N-[phosphonomethyl glycine)	♦ Contact herbicide ♦ Absorbed through foliage, disrupts enzyme formation and function in uncertain manner ♦ Applied as liquid spray	♦ Moderately to highly effective control of emersed and floating plant species ♦ Can be used selectively, based on application to individual plants ♦ Rapid action ♦ Low toxicity to aquatic fauna at recommended dosages ♦ No time delays for use of treated water	♦ Non-selective in treated area ♦ Inactivation by suspended particles; ineffective in muddy waters ♦ Not for use within 0.5 miles of potable water intakes ♦ Highly corrosive; storage precautions necessary	♦ Moderate ♦ Appropriate for use on purple loosestrife and water lilies ♦ Limited application area based on water supply wells ♦ NRC policy prohibits use of herbicides at this time

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
6.d) Forms of fluridone (1-methyl-3-phenyl-5-[-3-{trifluoromethyl} phenyl]-4[IH]-pyridinone)	♦ Systemic herbicide ♦ Inhibits carotenoid pigment synthesis and impacts photosynthesis ♦ Best applied as liquid or granules during early growth phase of plants	♦ Can be used selectively, based on concentration ♦ Gradual deterioration of affected plants limits impact on oxygen level (BOD) ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna	♦ Impacts on non-target plant species possible at higher doses ♦ Extremely soluble and mixable; difficult to perform partial lake treatments ♦ Requires extended contact time	♦ High ♦ Effective on most problematic submergent species ♦ Can be applied in isolated area ♦ May not be applicable for whole pond ♦ Social acceptability issues exist ♦ NRC policy prohibits use of herbicides at this time
6.e) Amine salt of triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid)	♦ Systemic herbicide, registered for aquatic use by USEPA and in MA in 2004 ♦ Readily absorbed by foliage, translocated throughout plant ♦ Disrupts enzyme systems specific to plants ♦ Applied as liquid spray or subsurface injected liquid	♦ Effectively controls many floating and submersed plant species ♦ Can be used selectively, more effective against dicot plant species, including many nuisance species ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna ♦ Fast action	♦ Impacts on non-target plant species possible at higher doses ♦ Current time delay of 30 days on consumption of fish from treated areas	♦ Moderate ♦ Limited experience, but effective on many problem species ♦ Social acceptability issues exist ♦ NRC policy prohibits use of herbicides at this time

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
Biological Controls				
7) Biological introductions	♦ Fish, insects or pathogens which feed on or parasitize plants are added to system to affect control ♦ The most commonly used organism is the grass carp, but the larvae of several insects have been used more recently, and viruses are being tested	♦ Provides potentially continuing control with one treatment ♦ Harnesses biological interactions to produce desired conditions ♦ May produce potentially useful fish biomass as an end product	♦ Typically involves introduction of non-native species ♦ Effects may not be controllable ♦ Plant selectivity may not match desired target species ♦ May adversely affect indigenous species	♦ Low ♦ Legality and effectiveness issues exist
7.a) Herbivorous fish	♦ Sterile juveniles stocked at density which allows control over multiple years ♦ Growth of individuals offsets losses or may increase herbivorous pressure	♦ May greatly reduce plant biomass in single season ♦ May provide multiple years of control from single stocking ♦ Sterility intended to prevent population perpetuation and allow later adjustments	♦ May eliminate all plant biomass, or impact non-target species ♦ Funnels energy into algae ♦ Alters habitat ♦ May escape upstream or downstream ♦ Population control issues	♦ Low ♦ Grass carp are not legal in MA

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO MORSES POND
7.b) Fungal/bacterial/ viral pathogens	♦ Inoculum used to seed lake or target plant patch ♦ Growth of pathogen population expected to achieve control over target species	♦ May be highly species specific ♦ May provide substantial control after minimal inoculation effort	♦ Effectiveness and longevity of control not well known ♦ Infection ecology suggests incomplete control likely	♦ Low ♦ No commercially available forms
7.c) Selective plantings	♦ Establishment of plant assemblage resistant to undesirable species ♦ Plants introduced as seeds, cuttings or whole plants	♦ Can restore native assemblage ♦ Can encourage assemblage most suitable to lake uses ♦ Supplements targeted species removal effort	♦ Largely experimental ♦ May not prevent nuisance species from returning ♦ Introduced species may become nuisances	♦ High ♦ Not sufficient by itself, but supplements control techniques that reset the plant community, if natural colonization is inadequate

Source Controls

Source controls would include education for watershed residents about their role in maximizing water quality in Morses Pond and land use regulations that restrict activities that generate pollutants of concern. Education is an important step in any source control, as land use regulations are often received as an infringement of personal rights. Education may change attitudes and practices voluntarily, but may be even more important in fostering support for bylaws and other more formal controls. Education must be an ongoing process, with interaction with as much of the watershed population as possible on a repeated basis. There will always be new people to educate, and some may need to hear the message multiple times to accept the cultural shift being requested. Patient, well substantiated persuasion is needed, supported by as much positive reinforcement as possible.

With specific regard to phosphorus control, preservation of open space or buffer zones without actual purchase of the land, prohibition or less severe limitation of fertilizer use, requirements for yard waste disposal, and restrictions on maintenance activities like vehicle washing or driveway deicing are all desirable activities that require much education and community cooperation to successfully implement. Voluntary programs have generally not produced spectacular results, making some form of enforcement or incentives necessary in most cases. However, where such controls are successfully applied, the potential for loading declines, as the pollutants are simply not generated on the target sites. While source controls are not likely to be sufficient by themselves to achieve the desired phosphorus loading reduction, they represent a valuable approach to reducing loading that represents little cost to the Town and moves the public toward more ecologically friendly living. What is needed is a review of Town bylaws to determine where improvements are needed and what opportunities are available for source control.

Pollutant Trapping

Developed areas will generate pollutants to a greater degree than more natural areas, simply as a function of greater impervious surface area and the generation of runoff that is not processed the way it would be in a forest or wetland before it enters a tributary or the pond directly. Some form of pollutant trapping is therefore usually necessary to control loading in urbanized areas. There are many possible methods, often used in conjunction with each other, as some are more effective under certain circumstances or in relation to different pollutants. Ideally, pollutant should be trapped as close to the source as possible, as this minimizes the amount of runoff that must be handled in each case and the variability associated with runoff quantity and quality. In other words, a series of small detention basins, each near a targeted source, will usually be more effective than a single, larger basin further downstream that must handle those sources plus other non-target areas in between. Fluctuations in flow, loads and treatment efficiency are likely to be wider for the larger basin, necessitating more area and/or volume to accomplish treatment goals. Yet sometimes it is easier to acquire the land and build a larger facility than it is to place many smaller ones, and management of one larger facility may be easier than that for multiple smaller ones, where active management is required.

As a rough rule, the storm water management area will need to be between 2 and 7% of the area it serves, depending upon land uses, slopes, drainage pattern, area, and treatment design. The area of Morses Pond is 2% of the area of its watershed, suggesting that it is at the low end of the scale for effective storm water treatment to protect downstream resources (Waban Reservoir and the Charles River). There are other detention areas in the watershed (e.g., Nonesuch Pond on Bogle Brook in Weston, the smaller Reeds Pond on Bogle Brook in Wellesley, and the large wetland parcel along Jennings Brook in Natick), increasing the area involved in storm water treatment in the Morses Pond system to at least 5%, and in fact the quality of water leaving Morses Pond is generally acceptable for downstream uses. Yet if we want to improve the condition of Morses Pond, we must relocate its function as a detention basin to points upstream in its watershed. A combination of larger detention systems and smaller, site-specific runoff control methods are likely to be needed, as space for larger systems is in short supply and the ability to implement site-specific controls on a watershed-wide basis is limited.

Among the approaches to storm water management, infiltration and chemical coagulant addition provide the best phosphorus and fine sediment control, but the availability of storage space for water awaiting infiltration and current Commonwealth policies regarding discharges of storm water into groundwater will limit application of infiltration. If chemical additions (typically aluminum compounds) are acceptable, such treatment in smaller detention areas can be very effective. Ideally, these treatment areas would be "off-line", out of the direct path of storm water and stream flow, usually in a basin into which storm water can be directed for active treatment. However, addition of aluminum directly to streams or the pond is possible and has been tested in the past in this system. On a larger scale, it may be possible to divert some of the storm water entering Morses Pond from Bogle and Boulder Brooks, using the Cochituate Aquaduct or the land corridor it creates. This storm water would then be treated in an off-line facility before discharge back to the pond or into the ground, probably on Town property associated with the public wellfield east of the lake.

Simple detention can also be effective if the area is properly sized, and off-line systems are also preferable here, especially if the first flush of storm water (which typically contains the bulk of the pollutant load) can be isolated. This is more feasible for smaller detention areas in smaller drainage areas near sources; the first flush concept is less applicable for larger drainage areas. Temporary detention areas, where storm water is impounded during the storm and for a short time thereafter and then released gradually into the stream system or pond, are likely to be most applicable to the Morses Pond system. These temporary pool systems can be applied "in-line" as well, but some downstream movement of trapped pollutant is to be expected. If the pollutant is converted to a less deleterious form (e.g., dissolved phosphorus converting to particulate phosphorus) this approach can still be effective. These could consist of semi-permeable weirs, like rock-filled baskets crossing a drainage path in an area where impounded water during a storm does not represent a threat to public safety or private property. Such areas are not likely to be large in this watershed, so many would be needed.

What is needed is an analysis of land areas within the watershed that could be adapted as detention systems, with an assessment of what level of improvement could be expected if this was done. As a follow-up, a conceptual program should be outlined for managing residential areas to maximize pollutant trapping on a very localized basis. Low impact development (LID) principles and street-level trapping devices should be considered, incorporated as warranted, and assessed for potential benefit to the pond as part of a watershed-wide or at least Wellesley-wide program. Additionally, the possibility of storm water diversion and treatment should be examined carefully.

In-lake Options

Phosphorus and sediment can be inactivated by chemical coagulation in the lake. Aluminum sulfate has been used over a substantial part of the lake well in the past (1970s, see Fugro 1994 summary of past management) and more recently in the southern end of the southern basin in response to algal blooms or high particle concentrations. Treating incoming storm water in the northern basin represents one way to inactivate phosphorus and reduce suspended solids loading before the water reaches the more actively used parts of the pond. Tests were run in 1997 using this approach, with limited success, but newer technology and expansion to a bigger portion of the northern basin are expected to enhance performance. It is an approach worth testing further.

Dredging can remove accumulated nutrient reserves, limit wind mixing effects and create capacity to hold more settled solids. The available data suggest that sediment on the pond bottom is not a major source of nutrients for algae (although it is for rooted plants). Wind mixing may be an important influence, but is overshadowed by watershed inputs during larger storms. Restoring the capacity to hold settled solids is very important, however, particularly in the northern basin of the pond, which has filled in since the last dredging in the late 1970s. While settled sediment may not be a major source of nutrients, getting dissolved nutrients converted to settleable solids and having a place for them to settle is a critical function of a detention area. The northern basin is an important detention area for the rest of the pond, and maximization of the capacity of that area to settle and hold solids is accorded a high priority in management.

As a supplement to dredging, creation of wetland “baffles” or “cells” could increase the detention time and maximize treatment functions in the northern basin. Some dredging would still be necessary, but rather than removing all sediment, areas would be filled to direct the incoming water along a sinuous path in the northern basin. Given the detention time provided in the northern basin, wetland creation offers about a 25% increase in removal efficiency under average conditions, but may not perform as well as a larger detention area (without the loss of filled areas), especially during larger storms. Additionally, permitting for filling operations is more complicated and may not be granted without compensatory actions that increase cost and technical difficulty. The wetland option is worth considering, but is not a clearly advantageous approach.

Other available methods generally treat the symptoms of excessive nutrient or solids loading, and are therefore maintenance measures that will have to be repeated over and over, possibly multiple times within the summer season or continuously. Mixing and aeration strategies limit phosphorus availability and can directly disrupt the life cycle of some algae, but the expected loads from the watershed will overpower any system envisioned for Morses Pond. The Town swimming area applies an air-driven mixing system which enhances water quality in that area, but it has no discernible impact on the rest of the pond and is not sufficient to counteract major inputs of sediment or long-dry spells that promote algal growth. Larger units may improve effectiveness, but would still not provide major benefits throughout the pond. Application of algaecides (mainly copper products) near the swimming area is practiced in accordance with the most appropriate protocols (monitoring algae and treating before severe blooms form), but is not sufficient to prevent blooms that originate elsewhere in the lake and has no effect on non-algal turbidity.

Techniques not actively applied to Morses Pond include dilution and flushing, light-limiting dyes, sonication, enhanced grazing by zooplankton, and use of rooted plants to inhibit algal growths. There is no obvious, inexpensive source of water for dilution or flushing. The amount of water needed would be on the order of 140 million gallons every two weeks (15.5 cfs), to cut current detention time roughly in half. The most likely source would be the Cochituate Aqueduct, and the water would be least available when it was most needed (in summer). The water of Morses Pond is already highly colored, providing natural dye and negating most benefits expected from adding an artificial dye. Sonication might be tried near the swimming area, and can minimize algal growths on structures and perhaps in the water column, but it would have to be run continuously and involves running a power supply into the water near the swimming area; the safety hazard this presents may be unacceptable for a maintenance activity. Enhanced grazing by zooplankton is highly desirable and could improve water clarity while providing more food for fish, but artificially raising zooplankton levels is very difficult to do. Increased grazing is more often the result of fish manipulations that would be nearly impossible without a change in the rooted plant community, in which case the situation might rectify itself without human intervention. There are already too many rooted plants in Morses Pond, and algal blooms have not been prevented; increasing plant coverage to control algae does not appear applicable in this case.

Based on this review, chemical phosphorus inactivation and dredging with or without wetland creation warrant further and detailed evaluation. Improvements of the algaecide and circulation programs might be considered as in-lake water clarity management methods.

Management of Rooted Aquatic Plants

Management options for rooted plant control (Table 4) encompass physical, chemical and biological methods. The choice of method is largely related to the species or assemblage being targeted, potentially sensitive non-target species present in the pond, and the extent of application required. It is not reasonable to expect that hand harvesting, one of the least intrusive and most selective methods, will be applicable to dense growths covering multiple areas. Application of herbicides results in use restrictions in many cases that may not be tolerable. Bio-control agents are typically species specific, except in the case of grass carp, which are not legal for use in Massachusetts. When contemplating plant management, it is therefore important to consider the target plants, the desired plant community, other biological components of the pond, all uses of the waterbody, and the degree of rehabilitation that is needed to meet use goals.

Morses Pond has about 64 acres of area that is overgrown with aquatic vegetation, much of it invasive forms that have been introduced to the pond over the last few decades. Some have blamed past management efforts for opening areas to colonization by these species, and there may be some truth to such allegations, as invasive species tend to be opportunistic and readily colonize areas opened by disturbance, human-induced or natural. Yet invasive species have been gaining dominance even in lakes with no management and a healthy native plant community, and management of aquatic plants is necessary to maintain desired conditions in most urban/suburban lakes.

Removal of unwanted plants has been practiced for over 50 years in the United States, and for at least 30 years in Morses Pond. As plants will grow where light penetrates to a suitable substrate, growth of plants in shallow areas of Morses Pond is inevitable. Plant management programs have often failed to consider what will grow after controls are implemented, or what type of plant community is desired, given the likelihood of plant regrowth. More enlightened recent efforts have considered the target plant assemblage, applying techniques with the intent of fostering a desirable assemblage. What is needed in a case like Morses Pond, where undesirable plants are dominant and abundant (Appendix, Herbicide Section), is one or more methods to reset the plant community, eliminating or greatly reducing unwanted species. At that point, the undesirable plants should be kept under control until more desirable species grow in naturally, or those desirable species can be actively planted. More than one method is probably necessary to maintain control, as different plants have different growth and reproduction strategies. A less selective technique may be adequate to keep plant biomass suitably low, but may not foster the desired native assemblage (e.g., harvesting, bottom barriers).

Of the plant control techniques in Table 4, only a few can provide the needed community reset function on a lakewide basis; dredging, herbicides and drawdown are the primary choices. Harvesting has some potential to alter the community over multiple years of intensive use, but not at the rate or with the certainty of the other techniques. Grass carp might also reset the plant community over a period of several years, but are not legal for use in Massachusetts. Dredging is applicable to all target areas of the pond (Figure 3, Areas 1-6), and the sediments in these areas are "clean" in comparison with Massachusetts standards (Appendix, Dredging Section), but this is an expensive technique and is unlikely to achieve either a depth or substrate limitation on future plant growth. In other words, dredging will reset the plant community (and provide a number of other benefits relating to nutrient reserves, sediment resuspension, and water depth), but will not maintain those desirable conditions without application of other follow-up techniques.

Of the available herbicides, none is ideal; not all target plants will be affected, and not all non-target plants will be unaffected. However, fluridone is effective against most of the problem aquatic species in Morses Pond and is a systemic herbicide; it can kill the entire plant, facilitating the highest possible level of control. It is not effective on water chestnut, which is kept in check by annual manual harvesting, and has variable effectiveness on variable milfoil, which is currently less abundant than most other invasive species. At low doses (<10 ppb) it has limited effects on most non-target species, such that recovery is possible within a year or two. Fluridone is also approved for use in drinking water supplies at concentrations <20 ppb. No other herbicide offers this combination of effectiveness and regulatory acceptability (Appendix, Herbicide Section). The Natural Resources Commission's Integrated Pest Management Policy prohibits the use of herbicides on Town property without a public or environmental health emergency and where viable alternatives are unavailable; this will limit the applicability of any herbicide treatment in this case.

The greatest technical drawback to fluridone use is the need for extended exposure; at least 90 days at low dose are needed to kill the target species. Flushing must therefore be minimized. Control of inflow is not realistically feasible for Morses Pond, so target areas would have to be sequestered during treatment with aquatic curtains, a technique which is becoming more popular since the first successful such treatment in 2000. Triclopyr was recently approved for use in Massachusetts and may offer some benefits for spot treatments where flushing is an issue, but there is a very limited track record for that herbicide and its effectiveness is not greater than that of fluridone.

Drawdown is effective against species that overwinter in a vegetative form, which includes the milfoils, fanwort and waterlilies, but would not be effective against water chestnut or the native naiad, which produce highly viable seeds. Additionally, drawdown would necessitate lowering the water level by at least 4 ft and preferably 8 ft to have a measurable impact, and that range of drawdown is expected to impair water supply in the adjacent wellfield (Appendix, Drawdown Section). Although alternative water sources may be available, the high priority accorded to maintaining the water supply linked to Morses Pond minimizes the potential to apply drawdown, which would need to be almost an annual occurrence for many years to be successful.

The experience with harvesting at Morses Pond has been mixed and not overly positive in recent years, but the available harvester is old and too small for the area it must manage (Appendix, Harvesting Section). Harvesting is often equated with mowing the lawn, and that can be a valid analogy. Only if the mower can be operated to cover the target area in the time it takes for excessive growth to occur can growths be successfully controlled. However, with adequate equipment and a trained operator, the harvester can also be used to shape the aquatic plant community over multiple years, favoring desired species. It is not realistic to expect that at some point harvesting will be unnecessary, but the level of effort may indeed decline with intense and educated use.

Stocked at a high enough density, grass carp will virtually eliminate submergent vegetation from a pond. Assuming that sterile grass carp are stocked, these fish will die off over a roughly 6 year period, releasing the pressure on the plant community. What will grow at that time is a function of colonization forces unless an active planting program is conducted. However, consumed plants come out the other end of the grass carp as available nutrients, so many lakes with grass carp become light limited as a consequence of algal blooms, and few plants grow. While this might suit some users of Morses Pond, the algal blooms would be in direct contradiction of the other primary goal of management, improved water clarity, and would also be ecologically deleterious to many water-dependent species using the pond. As grass carp are illegal in Massachusetts, these considerations are largely moot, but it should be noted that this approach would have drawbacks even if legal.

Remaining techniques are either inapplicable to Morses Pond or are appropriate mainly on a localized basis. Hand harvesting can be very selective and can rid a small area of pioneer infestations by invasive or other problem species, although the effort can be extreme and this tends to be a repetitive approach akin to weeding a garden. On a localized basis, it is a workable method. Once plants become denser than about one stem per 10 square feet or the area becomes larger than about 5 to 10 acres, hand harvesting becomes much less practical. For dense growths, hand harvesting presents a distinct risk of spreading plants that can reproduce from vegetative fragments, like milfoils.

Benthic barriers are non-selective, killing virtually all plants covered by the range of materials available. It is most suited to patches of unwanted vegetation, usually in swimming areas or around boat docks, and can be applied to create lanes through dense weeds to allow boat access to open water or fishing access to weed beds. On a small scale, impacts are not considered to represent a major impact to the aquatic system, and the MA DEP encourages use of benthic barriers (and hand harvesting) on early growths of invasive species, often without a permit. However, this technique is not suited to large scale application, for reasons of both impact and cost. Application to more than 10% of a waterbody is usually discouraged, and most installations involve no more than a few acres of material in the entire lake.

Hydroraking is sometimes applied in the Town swimming area for control of plants and debris, but the turbidity generation makes widespread use inconsistent with water clarity goals elsewhere in the pond. Use in small shoreline areas would be tolerable, but this technique is not suitable for lakewide control of rooted plants in Morses Pond.

Techniques with little apparent applicability to Morses Pond include dyes, flooding, other harvesting techniques, and herbivorous insects. Natural water color already provides the function of any dye that might be added. Raising the water level is contrary to a second level priority of flood control. Rotovation creates excessive turbidity and does not provide lasting results, necessitating re-application on a probable annual basis. The milfoil weevil has some potential to control Eurasian watermilfoil, but not any of the other problem species, and success with even Eurasian watermilfoil has been limited.

Selective planting is listed in Table 4 and is mentioned above in conjunction with resetting the plant community. This is not an adequate control technique by itself, but is a viable means of achieving a desirable plant assemblage when invasive species have become so dominant that recovery of a native community is jeopardized. There is not yet enough experience with this approach to know how essential it is to holistic plant management or how successful it will be; many systems will recover on their own if the nuisance species are controlled, and planting additional species does not guarantee success. Selective planting is most often used as a contingency plan if recovery is not as rapid as desired. Given the long dominance of invasive species in Morses Pond, however, selective planting is worth consideration in the management plan.

Finally, purple loosestrife is not addressed in this section, which focuses on submergent or floating aquatic plants. Purple loosestrife is an invasive species with minimal habitat value and the propensity to take over shoreline vegetation communities. As such, it is to be removed whenever possible, but it is not a major threat to the use goals of Morses Pond established in this report. Harvesting with ground based equipment, hand pulling, treatment with the herbicide glyphosate and/or biocontrol with the beetle *Galarucella* are the primary means of control, all of which could be appropriate at Morses Pond.

Summary

A wide variety of techniques for managing algae/water clarity and rooted plant composition/biomass have been reviewed and applicability to Morses Pond has been evaluated. Controlling algae and other suspended solids that affect water clarity is most effectively accomplished by watershed management, with both pollutant source control and trapping as viable approaches from a technical perspective. The focus would be on storm water inputs in this watershed. In-lake methods will constitute maintenance in this case, with repeated application necessary. However, as watershed management is typically a protracted effort (a decade or more), the use of aluminum compounds to inactivate phosphorus and settle out suspended solids in the northern basin (Area 1) has distinct merit as an interim approach with a high probability of success. Additionally, dredging the northern basin would restore detention capacity that could protect the remainder of the pond from elevated loadings much of the time. Hydraulic dredging would be the most likely method applied to remove sediment from Morses Pond. Use of algaecides remains as a back-up option as warranted, but will not control other suspended solids and should be minimized by proper watershed management, aluminum treatments and/or dredging. Circulation and enhanced grazing by zooplankton have merit as algae controls but are not primary control options in this system.

The plant community could be restructured on a lakewide basis by herbicide treatment, dredging, or possibly mechanical harvesting. The herbicide fluridone is most applicable to Morses Pond, given the mix of species and its role as an indirect drinking water supply via nearby wells, but technical and regulatory issues limit immediate applicability. Dredging would remove plants and their root systems, seed beds and accumulated sediment, effectively setting the pond back in time, but at great cost and with limited control over later regrowth, which is likely to be substantial and could involve invasive species without continued management by other techniques. Harvesting could provide the desired level of control, and might shift the community toward a more desirable mix of species over time if conducted carefully over multiple years with equipment capable of addressing all target areas in an appropriately rapid amount of time, but would be an ongoing management effort. More localized control of rooted plants can be realized through hand harvesting, benthic barriers or hydroraking, each of which has merit for certain species and areas of the pond, but none of which is applicable over the entire area in need of plant management. The use of biocontrol agents is really only applicable to the emergent invasive purple loosestrife, which is considered peripheral to this management plan.

POTENTIAL FOR WATERSHED MANAGEMENT THROUGH LARGER DETENTION SYSTEMS

The primary goal of watershed management detention system(s) for Morses Pond is to reduce the phosphorus loading in the stream systems which flow into Morses Pond. The watershed area of Morses Pond is approximately 5300 acres. Using the storm water management requirement of between 2 and 7 percent of the watershed area, a minimum of 106 acres would be required for effective treatment. That happens to be the approximate area of Morses Pond; we are basically seeking to transfer the function of Morses Pond to upstream areas. The addition of some larger detention systems upstream of Morses Pond would therefore be helpful in reducing the level of pollutants flowing into the pond (pollutant trapping).

Nonesuch Pond in Weston appears to provide adequate detention for upper Bogle Brook; additional detention may provide additional loading reductions, but the priority for working in the upper watershed of Bogle Brook does not seem as great as that for lower Bogle Brook, with limited detention area and many sources of pollutants. Likewise, wetlands and Jennings Pond in Natick provide substantial detention for the Jennings Brook system. In comparison, Boulder Brook has minimal detention and potentially large inputs. Most of the lower Bogle Brook and Boulder Brook watersheds are in Wellesley, although added detention for any of the tributaries in Weston and Natick would be welcome. The availability of open space in Wellesley is limited, however, so several smaller detention systems would have to be used in parallel to provide a sufficient amount of detention.

An analysis of land areas within the watershed that could be adapted as detention systems was performed. Only locations within the Town of Wellesley were considered. Locations suitable for storm water detention and treatment have the following characteristics: sites adjacent to major tributaries with significant upstream watershed, sites with flat slopes, non-wetland sites, and sites containing soils conducive to infiltration. After considerable investigation and discussion with knowledgeable parties in Wellesley, only three sites within the Wellesley portion of the watershed were chosen for further investigation and evaluation (Figure 4):

1. Open space area in Lower Bogle Brook, upstream of Reed’s Pond (12 acres).
2. Open space area in Boulder Brook containing Kelly Park (12 acres).
3. Cochituate Aqueduct, located in the Lower Basin of Morses Pond (23 acres, but this would be a conduit to another site, not an actual detention area).

The first management option would be to place pervious weirs in the channel upstream of Reeds Pond in the Bogle Brook Reservation (Figure 5). While providing valuable detention in aggregate with other ponds, the area of Reeds Pond itself is too small to provide effective storm water treatment for the upper and lower Bogle Brook watersheds. An additional detention system in this area would improve the water quality flowing downstream into Morses Pond. Weirs would be designed to divert water into an offline storage (detention or infiltration basin) area which would hold water for an interval of time allowing for natural purification of storm water, especially during small- to medium-sized storms. Approximately 1 acre-foot of temporary storage would be provided along Bogle Brook. The placement of weirs in conjunction with a storage area in this channel would assist with phosphorus removal from both the upper and lower Bogle Brook watersheds. This would provide a phosphorus load reduction to Morses Pond of 1-2 ppb as predicted by the model. Given a current average phosphorus level in the pond of about 29 ppb and a target of about 20 ppb, it represents a valuable addition, but is not

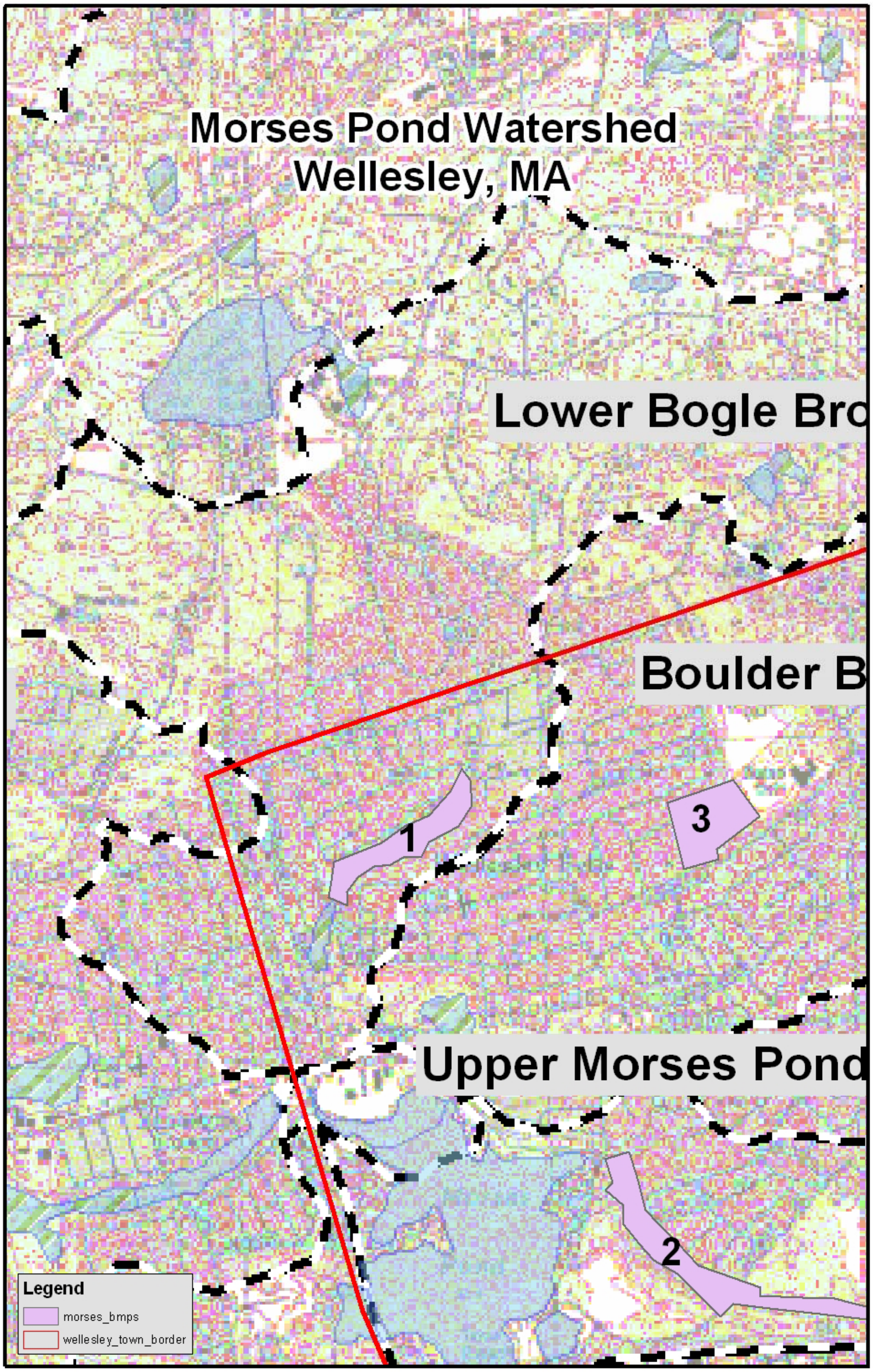


Figure 4. Possible Detention Areas in the Wellesley Portion of the Morses Pond Watershed

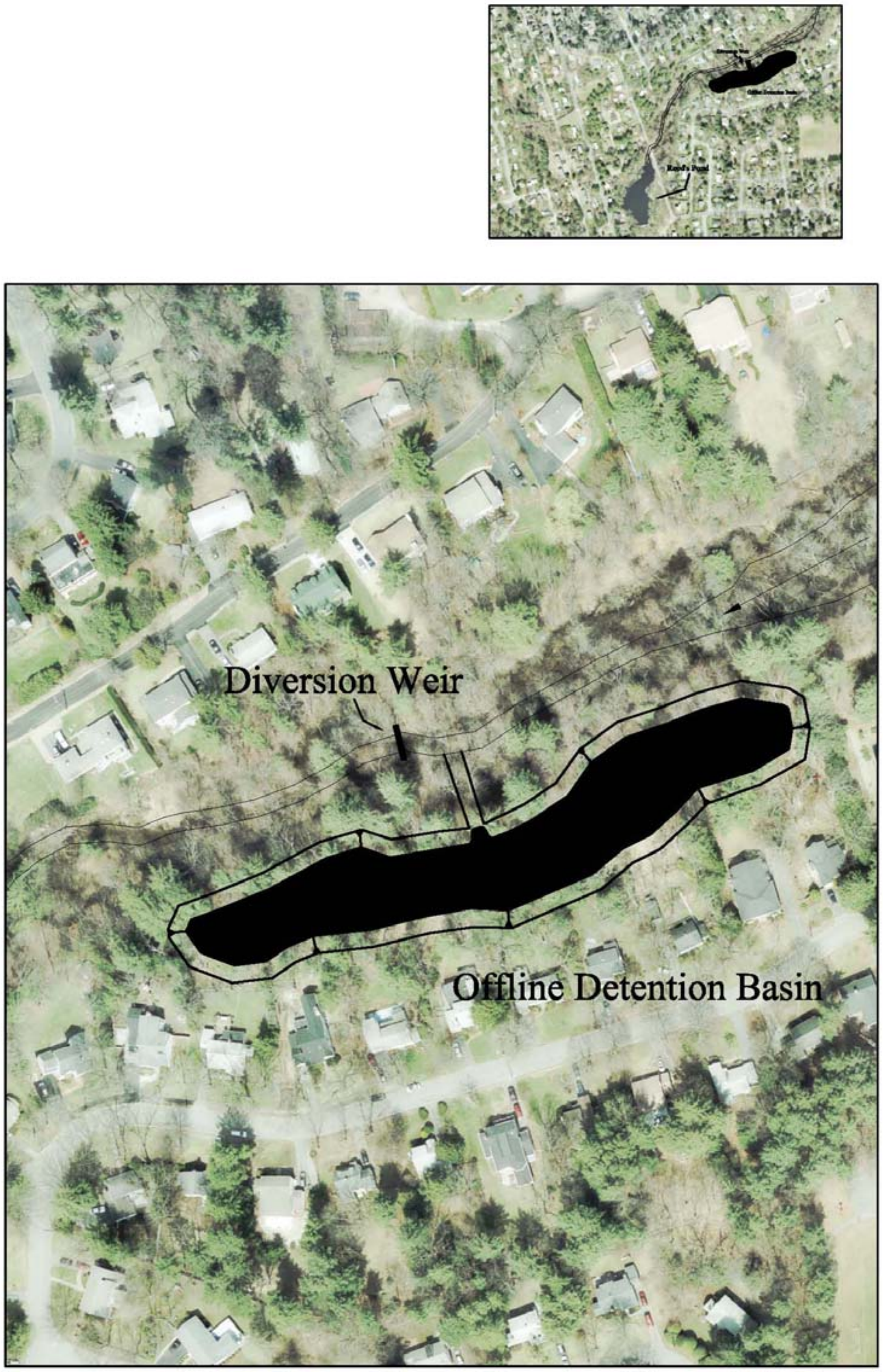


Figure 5. General Layout of a Detention System for the Area Upstream of Reeds Pond.

sufficient by itself to meet the goal. The cost of this option would be approximately $500,000, based on the cost of design, permitting, excavation and the building of the required structures.

A second alternative would be to create a detention pond in Kelly Park within the Boulder Brook Reservation. The addition of a pond in the Boulder Brook Reservation could provide 1-2 acre-feet of storage, and reduce the phosphorus loading to the pond by as much as 1 ppb. Care must be taken to avoid flooding in this area, but such a detention area would provide valuable detention capacity in area which has very little now. A conservation restriction on the Kelly Park parcel currently precludes excavation, however, and would greatly increase the difficulty of providing meaningful detention in this area. A change in the conservation restriction would be necessary to maximize the benefits of detention at this site.

A third option would be to use the Cochituate Aqueduct, or at least the right of way it represents, to redirect water currently flowing directly into Morses Pond from Boulder Brook and possible Bogle Brook as well. Storm flows could be routed through the aqueduct or a pipe to an offline detention area for treatment. The storm water could then be discharged back into the pond or into the ground. Routing the storm induced flows from just Boulder Brook into a detention system served by the Cochituate Aqueduct is predicted to reduce the phosphorus loading to Morses Pond by an additional 2 ppb. If a substantial portion of the Bogle Brook flow could be handled this way, a much larger reduction in phosphorus concentration could be achieved (up to 6 ppb). If routed to an off-line detention area, the potential also exists to apply alum for further water quality improvement. This option is discussed further under a separate section (Potential for Storm Water Treatment), and requires further investigation to determine feasibility, acceptability and cost.

Model simulations show the current average phosphorus loading to Morses Pond is approximately 29 ppb. This simulation was based on an analysis of storm water runoff under existing land use conditions. A summary of the model input and output parameters can be found in the Appendix (Watershed Section). A target phosphorus concentration of 20 ppb would provide water clarity of between 4 and 6 feet on a continuous basis. Meeting this target through storm water management is unrealistic with just the two itemized areas above (upstream of Reeds Pond and at Kelly Park), and the Kelly Park option is currently limited by a conservation restriction. Redirecting storm water for detention and/or treatment is an admirable approach, but has major logistic problems in addition to limited land availability. Unless more land area can be made available for detention and treatment, it seems likely that smaller scale methods, applied on individual lots or at the subdivision level, will be necessary to meet the targeted load reduction and phosphorus concentration.

Summary

Larger, upstream detention systems would relocate the detention functions now served by Morses Pond for its watershed to points upstream and would enhance overall removal of contaminants prior to entry of storm water to Morses Pond. This option is limited, however, by the availability of land on which such detention systems could be constructed. An analysis of properties currently controlled by the Town of Wellesley indicates that only two useful locations are currently available, each of which offers valuable but small detention capacity, and one of which may have regulatory constraints that negate its meaningful use. It may be possible to divert a substantial amount of storm water along the Cochituate Aquaduct right of way to a detention site to be constructed on Town land, but further feasibility investigation is needed and this option is addressed in a separate section of this report (Potential for Storm Water Treatment).

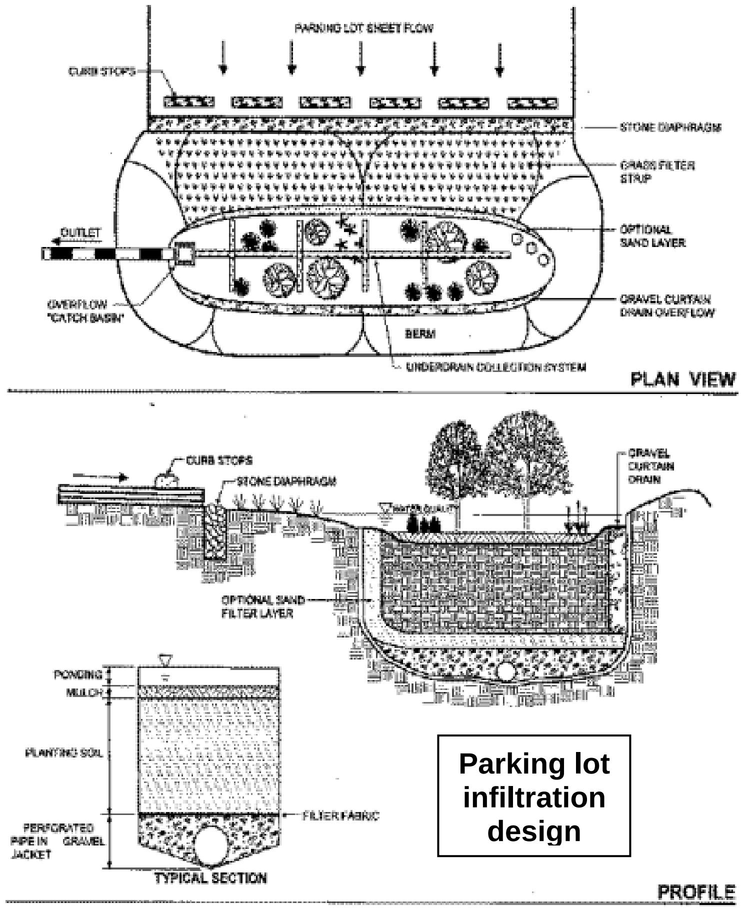
POTENTIAL FOR WATERSHED MANAGEMENT THROUGH SMALLER, SITE-SPECIFIC CONTROLS

The addition of smaller site-specific controls for storm water management will also help to reduce the concentration of pollutants flowing into Morses Pond, and may be essential in light of limited land availability for larger detention systems. The following techniques could be used, some of which are illustrated in Figure 6:

1. Source controls
   - Limit or eliminate fertilizer use, or use only low or no phosphorus fertilizers
   - Compost or dispose of lawn wastes in a manner that does not expose them to runoff
   - Collect and dispose of pet wastes in a way that avoids contact with runoff
   - Do not wash vehicles on impervious surfaces, like roads or driveways
   - Use low or no phosphorus deicers
   - Dump no wastes into storm drainage systems or onto ground or paved surfaces
2. Runoff controls
   - Minimize areas of disturbed soils
   - Minimize impervious surfaces that generate runoff more easily
   - Disconnect existing impervious surfaces to avoid additive effects
   - Capture runoff in bioretention areas (landscape features that also trap pollutants)
   - Install rain barrels that provide irrigation water during dry weather
   - Install rain gardens that hold and process runoff
   - Install other detention or infiltration facilities size to be appropriate for parcel
   - Lengthen the path runoff must take before it leaves the property
   - Maximize sheet flow and associated evaporation/infiltration
   - Establish green roofs, with vegetation that limits runoff
   - Alter soils to enhance infiltration
   - Preserve or enhance vegetation for pollutant trapping and evapotranspiration
3. Drainage system maintenance
   - Clean catch basins more frequently (twice per year is optimal, spring and fall)
   - Sweep streets regularly (seasonally is reasonable but difficult)
   - Be certain there are no illicit connections (non-permitted discharges)

The Fugro (1994) report presents the potential reduction in phosphorus loading to Morses Pond from the Wellesley portion of the watershed using several site-specific watershed management controls (Table 5). Lawn fertilizer represents a more major source than suggested here, but past fertilization will cause future inputs for many years after controls are implemented; the estimate considers new phosphorus inputs as a portion of the total. Additionally, there may be some overlap between sources; fertilizers contribute to the street load, which contributes to the catch basin load, and so on. The table simply provides an estimate of what could be expected from independent actions directed as specified sources, and then only within Wellesley.

Application of watershed management at the most local scale (the residential lot or subdivision), while clearly the “right” thing to do, will yield only very small increments of improvement per lot or parcel managed. It is only through widespread participation that a measurable impact can be made. Effort within the Town of Wellesley is entirely appropriate in this regard, but as less than a quarter of the watershed is within Wellesley, cooperation in Natick and Weston must be sought for this approach to allow water quality goals to be met.

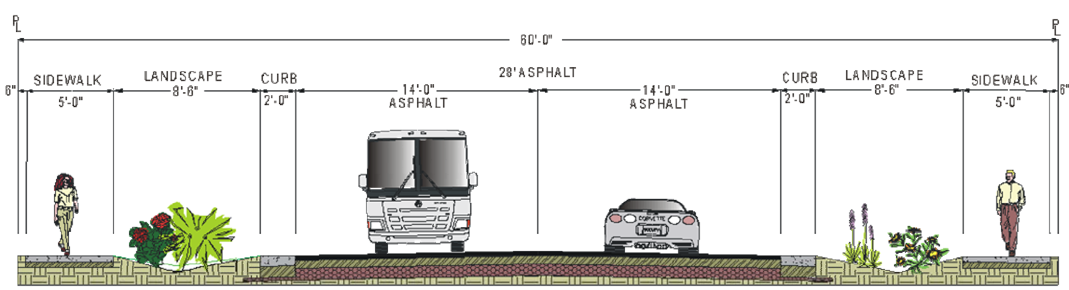


Parking lot infiltration design

Rain Barrel Irrigation System

Landscaped Swale

NEW 60' RIGHT-OF-WAY
SERVICE 26 TO 75 RESIDENCES

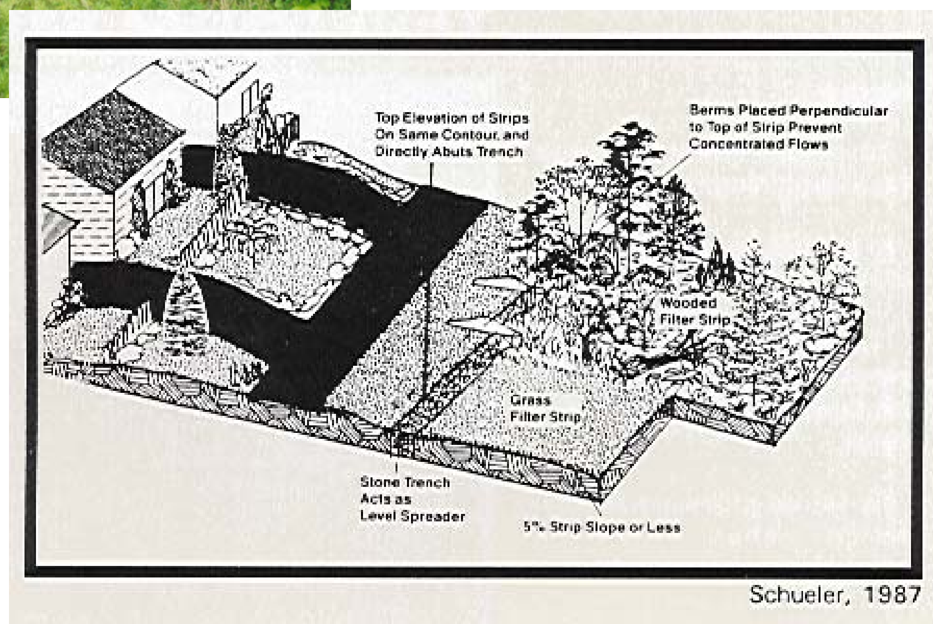


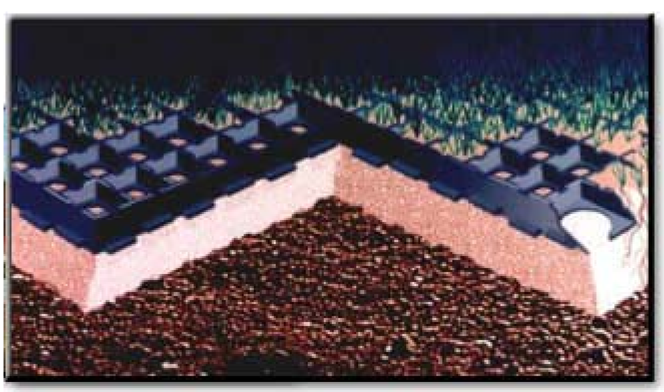
Re-designed roadway to minimize impervious surface and increase infiltration of runoff

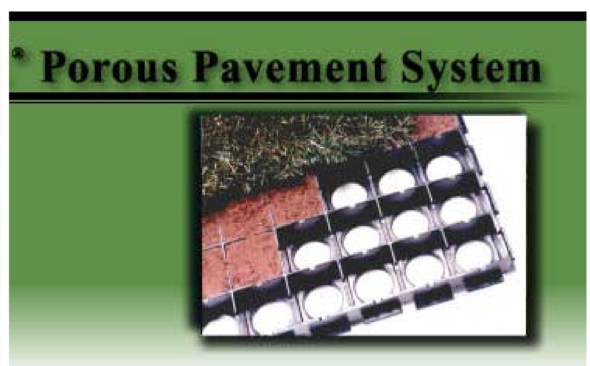
LOW IMPACT RESULTS
- 28% LESS ASPHALT SURFACE
- 10-14% STORM WATER RUNOFF REDUCTION
- 125% INCREASE IN GREEN SPACE

Figure 6a. Low Impact Development Techniques.

Buffer strips – natural or engineered vegetated zones to slow, filter and infiltrate runoff







Porous pavement – blocks, sheets, or other materials laid down to support traffic while allowing infiltration of runoff

Figure 6b. Low Impact Development Techniques.

Table 5. Expected Phosphorus Loading Reduction in Wellesley from Selected Watershed Management Actions

Management Option	Current Phosphorus Contribution, % of Total	Expected % of Reduction	Expected phosphorus load reduction to Morses Pond, % of Total
Limit lawn fertilization	2.9 – 4.4	50	1.5 – 2.2
Clean catch basins twice more per year	14.7	10.5 – 34.5	1.5 – 5.1
Sweep streets once per month	10.5 – 14.7	20	2.1 – 2.9

Many of the above techniques are grouped in what is termed Low Impact Development (LID). LID is a storm water management approach which involves managing runoff at the source. The goal of LID is to retain the predevelopment hydrology of a site by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Comprehensive LID site design maintains the integrity of each watershed by maintaining the natural, pre-developed hydrology on each development site. Site hydrology is the relationship between rainfall, runoff, plant uptake, evaporation and infiltration. LID design creates a functional hydrologic landscape by maintaining natural drainages, like streams, and by using small-scale storm water controls distributed evenly throughout the site. By doing this on individual sites, the overall watershed can be better protected. LID is a blend of measures that include conservation, minimization of impacts, maintaining historic, pre-developed runoff rates, integrated management practices, and pollution prevention techniques. Together, these form a holistic approach to site design and storm water management.

Landscaping features at the individual lot level (rooftops, parking lots, sidewalks, medians) are adapted to address storm water. These techniques can be applied to new or existing development, although retrofitting presents cultural and technical challenges. LID could be an effective storm water management option for the Morses Pond watershed, but would require a sustained educational program and probably some incentives over a period of at least a decade to produce measurable results. In many cases lot owners can realize savings by participating, especially where potential runoff can be held and used to irrigate the landscape during dry weather. Additional details of specific LID practices include:

Bioretention

Bioretention is a practice to manage and treat storm water runoff by using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The bioretention concept was originally developed by the Prince George's County, Maryland, Department of Environmental Resources in the early 1990s as an alternative to traditional BMP structures. The method combines physical filtering and adsorption with biological processes. The system can include the following components, a pretreatment filter strip of grass channel inlet area, a shallow surface water ponding area, a bioretention planting area, a soil zone, an underdrain system, and an overflow outlet structure (MD DER, 1999).

Disconnecting Impervious Area

One of the most effective retrofit LIDS is to "disconnect" impervious areas. Impervious areas that drain directly to closed drainage systems produce runoff in all but the smallest of rain events. If runoff from paved surfaces is allowed to flow over pervious/vegetated surfaces before entering a drainage collection system, some or all of the runoff from small storm events will be intercepted and percolated into the ground. Disconnecting impervious areas from storm sewer systems can have significant benefits for small storm events, which make up the majority of all storm events. Methods of disconnecting impervious areas include (MD DER, 1999):

- Removing curbs on roads and parking lots
- Locating catch basins in pervious areas adjacent to parking lots, not in the paved portion Disconnecting roof drains and directing flows to vegetated areas.
- Directing flows from paved areas such as driveways to stabilized vegetated areas.
- Breaking up flow directions from large paved surfaces.
- Encouraging sheet flow through vegetated areas.
- Carefully locating impervious areas so that they drain to natural systems, vegetated buffers, natural resource areas, or infiltratable zones/soils.

Flow Path Practices

Typical development practices significantly decrease a watershed's time of concentration (Tc) by concentrating flows and efficiently conveying them to the outlet. The time of concentration (Tc), in conjunction with the hydrologic site conditions, determines the peak discharge rate for a storm event. Shorter Tc values result in higher peak discharge rates. Site and infrastructure components that affect the time of concentration include travel distance (flow path), slope of the ground surface and/or water surface, surface roughness, and channel shape, pattern, and material components. Several techniques may be employed to manage flow and conveyance systems within the development to mimic predevelopment Tc, including:

- Maximize overland sheet flow.
- Increase and lengthen flow paths.
- Lengthen and flatten site and lot slopes.
- Maximize use of open swale systems.
- Increase and augment site and lot vegetation.

An additional benefit of these flow path practices is an increased opportunity for infiltration of runoff, thereby reducing runoff volume in addition to runoff peak rates (MD DER, 1999).

Green Roofs

Green roofs, also known as vegetated roof covers, eco-roofs or nature roofs, are multi-beneficial structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall. They are constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. The soil is planted with a specialized mix of plants that can thrive in the harsh, dry, high temperature conditions of the roof and tolerate short periods of inundation from storm events. Green roofs provide storm water management benefits by:

- Utilizing the biological, physical, and chemical processes found in the plant and soil complex to prevent airborne pollutants from entering the storm drain system.
- Reducing the runoff volume and peak discharge rate by holding back and slowing down the water that would otherwise flow quickly into the storm drain system.

Other benefits include energy savings and lengthened life of the roof, improved air quality, and cooler air temperatures (www.lowimpactdevelopment.org).

Minimizing Disturbance Area

Conserving natural drainages, trees and other vegetation, and soils is the first step in low impact development. Trees and natural forest cover are terrific "sponges" for storing and slowly releasing storm water. Comprehensive land use planning, watershed or basin planning, habitat conservation plans, and stream and wetland buffers are good tools to identify and set aside natural areas within a community and on an individual site. Once conservation areas are established for each site, the designer can then work within the developable area envelope and evaluate the effects of design options on these areas. A significant portion of trees and other vegetation should be left in a natural state and not developed.

Minimizing Site Imperviousness

Reducing the amount of imperviousness on the site will have a significant impact on the amount of other storm water management practices required for mitigating development impacts. The following practices may be employed to help minimize site imperviousness (MD DER, 1999):

- Evaluate alternative roadway layouts to minimize total road length
- Use Reduced road width sections
- Limit sidewalks to one side of primary roads
- Use vertical construction to reduce rooftop footprints
- Use shared driveways whenever possible
- Limit driveway width to 9 feet
- Minimize building setbacks to reduce driveway length
- Use pervious/porous pavement

Porous Pavement

Porous pavement is a special type of pavement that allows rain and snowmelt to pass through it, thereby reducing the runoff from a site and surrounding areas. The two primary types of porous pavement include porous asphalt and pervious concrete. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of liquids through the pavement. The porous pavement surface is typically placed over a highly permeable layer of open-graded gravel and crushed stone. The void spaces in the aggregate layers act as a storage reservoir for runoff. Two common modifications made in designing porous pavement systems are (1) varying the amount of storage in the stone reservoir beneath the pavement and (2) adding perforated pipes near the top of the reservoir to discharge excess storm water after the reservoir has been filled. Porous pavement may substitute for conventional pavement on parking areas, areas with light traffic, and the shoulders of airport taxiways and runways, provided that the grades, subsoils, drainage characteristics, and groundwater conditions are suitable. Slopes should be flat or very gentle (EPA 1999).

Preservation of Infiltratable Soils

This practice includes site planning techniques such as minimizing disturbance of soils, particularly vegetated areas, with high infiltration rates (sandy and loamy soils), and placement of infrastructure and impervious areas such as houses, roads, and buildings on more impermeable soils (silty and clayey soils) (MD DER 1999).

Preserve Natural Depression Areas

This practice involves preserving existing topographic depressions during the planning process, which serve to naturally reduce runoff volume via percolation and evaporation.

Rain Barrels/Cisterns

Rain barrels are low-cost, effective, and easily maintainable retention devices applicable to both residential and commercial/industrial LID sites. Rain barrels operate by retaining a predetermined volume of rooftop runoff. An overflow pipe also provides some detention beyond the retention capacity of the rain barrel. Rain barrels are typically used to store runoff for later reuse in lawn and garden watering. Storm water runoff cisterns are roof runoff management devices that provide retention storage volume in underground storage tanks for re-use for irrigation or other uses. On-lot storage with later reuse of storm water also provides an opportunity for water conservation and the possibility of reducing water utility costs (MD DER, 1999).

Rain Gardens

A simple, yet effective method to control storm water is through the use of rain gardens. Also known as bioretention areas, rain gardens are small vegetated depressions that collect, store, and infiltrate storm water runoff. They contain various soil types from clays to sands and size varies depending on area drained and available space. The design of a rain garden involves the hydrologic cycle, non-point pollutant treatment, resource conservation, habitat creation, nutrient cycles, soil chemistry, horticulture, landscape architecture, and ecology. Beyond its use for storm water control, the rain garden provides aesthetically pleasing landscaping and a natural habitat for birds and butterflies. Finally, rain gardens promote sustainable design practices while encouraging environmental stewardship and community pride (www.lowimpactdevelopment.org).

Soil Amendment

The aeration and addition of compost amendments to disturbed soils is extremely effective at restoring the hydrologic functions of soils and reducing runoff. Soil amendments increase the spacing between soil particles so that the soil can absorb and hold more moisture. Compared to compacted, unamended soils, amended soils provide greater infiltration and subsurface storage and thereby help to reduce a site's overall runoff volume, helping to maintain the predevelopment peak discharge rate and timing. Soil amendments help to provide water quality and quantity benefits, not only by increasing the infiltration capacity of the soil, but also by:

- Filtering and breaking down potential pollutants.
- Immobilizing and degrading pollutants by holding potential pollutants in place so that soil microbes can decompose them.
- Reducing the need for fertilizers, pesticides and irrigation by supplying more nutrients and a slow-release of them to plants.
- Holding more rainwater on-site, decreasing runoff, and providing increased soil moisture and infiltration capacity.
- Increasing soil stability, leading to less potential erosion.
- Providing added protection to groundwater resources, especially from heavy metal contamination.
- Reducing thermal pollution by maintaining runoff in the soil and on-site longer.
- Providing increased groundwater recharge through better infiltration and by maintaining the water on-site longer.

- Improving soil structure and stability, while increasing infiltration capacity and available storage within the soil.
- Increasing soil stability, leading to less runoff and erosion through improved cover conditions

Vegetation Preservation

Woods and other vegetated areas provide many opportunities for storage and infiltration of runoff. By maintaining the surface coverage to the greatest extent possible, the requirement for other storm water management practices is reduced. Vegetated areas can also be used to provide surface roughness, thereby increasing the time of concentration. In addition, vegetated areas filter out many particulate pollutants.

LID is entirely consistent with the NPDES Phase II Storm Water Regulations. These regulations are part of the Federal Clean Water Act and apply to storm water discharged by pipes or ditches in areas having some minimum population. Virtually all of the communities in the greater Boston area are subject to these regulations, and towns such as Wellesley have developed plans for meeting them. These plans tend to be fairly rudimentary in nature, however, and do not typically target phosphorus loading reductions as aggressively as what is needed to meet the goals for Morses Pond. A more active approach to storm water management will be needed before LID becomes truly commonplace.

In addition to resources cited above, two manuals developed by the staff of Prince George's County, MD and published by the USEPA in 2000 (PGC 2000a, 2000b) lay out the process and hydrologic details of applying LID. An educational program for Wellesley (and possibly Natick and Weston too) could be structured around the content of these user friendly manuals, encouraging homeowners to apply these techniques. An incentive of free technical and planning assistance from the Town, presumably through a consultant or after appropriate training of designated personnel, might make application more attractive. An allocation of $100,000 for training and technical assistance is suggested to support this effort over several years, with $25,000 devoted to demonstration projects on Town land and about $50,000 devoted to monitoring results at individual properties. Actual costs for site work can vary tremendously, but do not need to be more than hundreds or a few thousand dollars per site. Ultimately, in excess of $1,000,000 is likely to be expended by private citizens on their collective properties if this approach is to be successful, but the Town commitment for LID promotion would be more modest.

Summary

Localized, site specific controls for minimizing runoff and enhancing the quality of that runoff are highly desirable throughout the watershed and places the burden of pollution control as close to the source as possible. Such efforts tend to be most effective and least capital cost intensive, and may even result in a cost savings to property owners in the long-term, but widespread participation is essential for the overall load to Morses Pond to be lowered substantially. Key elements include limitation of practices that lower runoff quality (e.g., fertilizer application, car washing, pet and yard waste disposal), site construction or alteration to infiltrate as much runoff as possible into the ground, and small scale detention for water that can't be infiltrated. The Town should conduct demonstration projects and fund technical assistance and monitoring support for a wider set of Low Impact Development efforts, but the bulk of the cost (estimated at >$1 million) would be expended by private parties. Expansion to sites in Weston and Natick is also highly desirable.

POTENTIAL FOR STORM WATER TREATMENT

The simplest approach to treating storm water to enhance water clarity in Morses Pond is to dose it with aluminum sulfate, possible with a buffer if the pH is <6 or >8 standard pH units. This is an approach with over 15 years of experience now (Harper et al. 1999), and one for which some experimentation has been performed in Morses Pond already (Fugro 1994, ENSR 1997). Results have not been lasting, which is not surprising in light of continued loading from the watershed, but the ability of alum to inactivate phosphorus and settle solids is not in question; properly dosed and buffered, alum can lower the phosphorus level to below the target of 20 ppb and will result in both dramatic increases in incoming water clarity and lowered fertility of the water in the pond. Dosing at the Bogle Brook inlet encountered problems of highly variable water quality, but by the end of the experimental period a 40 to 50% reduction in phosphorus level in that tributary was achieved.

Greater efficiency and effectiveness can be achieved if the storm water can be treated in a basin where detention time is greater and mixing can be encouraged, as opposed to a linear flow channel. Application of alum to the northern basin could potentially meet this need; commercial application systems with aeration lines to foster mixing have now been available for over five years. While site specific planning and adjustment are needed, several successful installations have been reported (F. Lubnow, pers. comm.). Application in the northern basin would address inputs from Bogle Brook, Jennings Brook and Boulder Brook, the three main tributaries, and could potentially decrease phosphorus and suspended solids (turbidity) levels by 75 to 90% over current levels. With no other watershed management, water clarity goals could be met by such a system, if effective. If only 50% of the phosphorus passing through the northern basin was inactivated, the current load to the southern portion of the lake would be reduced by 43%, more than the targeted phosphorus load reduction of 33%. Inactivation at the 90% level would reduce phosphorus loading by 77%.

The downside to treating the storm water in the northern basin is that the alum sludge will accumulate there. While the amount of sludge is not extreme, it will gradually accumulate and represents a rate of infilling greater than that experienced now (which has resulted in a need for dredging after about 25 years). The settled material, or “floc”, is not toxic or mobile after the aluminum has reacted, and holds the contaminants very well, but it is likely to smother aquatic invertebrates and may affect plant growths over an extended period of time. For reasons such as this, regulatory agencies prefer that the settling occur “off-line” (in a basin outside the lake), but as an indefinite term interim measure before watershed management has progressed to a sufficient degree, it has definite merit. Such storm water treatment could be tested before any dredging was done in the northern basin, allowing an assessment of floc accumulation before this area is restored.

The alternative is to divert some portion of the storm water entering the pond to an off-line detention area where treatment can be applied, with discharge of treated water to the pond or injected near the pond. The treatment aspect is relatively straightforward, and is done routinely in many storm water collection basins. It is the collection and routing of storm water that presents a challenge. With the Cochituate Aqueduct running across the Bogle Brook and Boulder Brook inlets, the potential exists to use the aqueduct or just the right of way created by its existence to route storm water to a point on Town land near Morses Pond on the southeast side, near the current water supply operation.

Treatment could occur in a sealed basin, with overflow directly to the lake. The level of a variety of contaminants and specifically aluminum would be checked in the discharge, as the proximity of the discharge to the wells will be closer than where contaminants would otherwise enter the pond. If clean enough, discharge to the ground through the isolated wetland known as ice house cove might be possible, but the location of this feature in the Zone I (immediate contributory) area of the Town wells limits this option. For any planning purposes, discharge back to Morses Pond should be assumed, but that discharge may be near the outlet instead of near the inlets. The level of load reduction should be very high for the treated water (>90% for phosphorus and solids), but the impact on total loading will depend on how much storm water can be diverted and treated. If half of the storm water from Bogle and Boulder Brooks was treated, that would lower the phosphorus load to Morses Pond by as much as 31%, very close to the targeted reduction to support desired uses.

Treatment in the Northern Basin

To treat incoming storm water in the northern basin, a dosing station would need to be established somewhere on shore, with a delivery system in the northern basin. The keys to effective treatment include proper dosing, pH control, high mixing, and provision of a quiescent settling area. Background data from the 1997 experimental treatments suggests that aluminum compounds would indeed be the best choice, and that the concentration of aluminum will have to be in excess of 5 ppm, probably closer to 10 ppm. Treatment would not have to occur in all storms; mid-spring through early summer is the critical period for Morses Pond, with possible treatment through August in wetter years.

The dosing station could go anywhere convenient for access; the site must have power and aluminum compounds in liquid form must be delivered. The logical location would be near the current pump station along the aqueduct, just off Route 9. Sites along the northern or western sides of the northern basin could be used as well, if available, but the pump station site appears nearly ideal. The necessary building for the dosing station would be about 100 to 150 square feet, containing the controls, pumps and a compressor to run a diffuser system for mixing in the lake. A larger building could also house the storage vats for aluminum compounds, but those do not need to be inside.

The dose of aluminum needed to inactivate phosphorus and settle incoming suspended solids can vary considerably among storms and over time within a storm. This was one of the problems faced in the 1997 experimental treatments, which were conducted in the Bogle Brook channel where water quality changed by the minute. By locating the treatment area in the northern basin, only the largest storms would provide enough flow to potentially cause such wide fluctuations. Under “normal” conditions, storm water accumulates and mixes in the northern basin, creating more uniform (although not desirable) water quality.

The most successful 1997 treatments applied close to 10 ppm of aluminum, and experience elsewhere suggests that this is typical. In some cases aluminum doses as low as 1 ppm have provided the desired coagulation and settling, but more often a much higher dose is needed (Harper et al. 1999). Some experimentation would be needed to determine the optimal dose for Morses Pond, and it is likely that no one dosing level will be perfect, but a value between 5 and 10 ppm is expected to provide the best results.

It is essential that a pH between 6 and 8 standard pH units be maintained, both for ecological and water supply considerations. Experience over the last seven years indicates that the best pH balance comes from a mixture of aluminum sulfate (acidic) and sodium aluminate (basic) at a 2:1 (alum to aluminate) ratio by volume (Mattson et al. 2004). Aluminum sulfate provides 0.49 pounds of aluminum per gallon of liquid, while liquid sodium aluminate contains 1.23 pounds of aluminum per gallon. The amount of storm water being treated will vary and is not a constant by any means, but the annual inflow from Bogle, Jennings and Boulder Brooks is 11,386,000 cubic meters, or 3 billion gallons. Only about half of this is storm water. We do not have detailed inflow records by month, but storm water inflow in May, June and July would be expected to involve no more than 375 million gallons of storm water, and could include as little as about 200 million gallons. The volume of the northern basin is about 19 million gallons, so it is flushed at least 10 times during the May-July interval, and possibly as much as 20 times.

At 10 ppm, the total aluminum input would be 17,000 to 31,000 pounds. At only 5 ppm, the aluminum need would be half that at 8,500 to 15,500 pounds. Dividing the mass of aluminum into alum and aluminate at a 2:1 volumetric ratio (recalling that the aluminum content of alum is much less than that of aluminate), the dose would equate to almost 8000 gallons of alum and 4000 gallons of aluminate for the lowest dose and quantity of storm water discussed here (200 million gallons at 5 ppm). For the maximum amount of storm water and dose (375 million gallons at 10 ppm), 28,000 gallons of alum and 14,000 gallons of aluminate would be needed.

The cost would be roughly proportional to the planned dose. Storage volumes would be dependent on how much chemical was to be used, but a majority of the cost over a 10 to 20 year period would be related to the chemicals themselves. Alum costs about $0.90/gallon and aluminate costs roughly $2.60/gallon. Assuming that these values remained appropriate, the low end of the projected chemical cost for the targeted period within a year is $17,600, while the high end is $61,600. The annual budget for managing water clarity in association with the Town swimming area is closer to the low end of this cost range.

Maximum efficiency of aluminum dosing is achieved with high mixing. In a shallow lake environment, such mixing can be provided by a simple bubble aeration system. More sophisticated versions have been developed with alum treatment in mind, but basic air diffusion systems seem to work reasonably well. It does seem preferable to use aeration lines in conjunction with chemical feed lines, matching the release nozzles for each to maximize mixing over a substantial area, rather than point diffusers (single stones or rings as used in the Town swimming area) that focus mixing on a smaller area. For this type of system, a 30 hp compressor is recommended, supplying up to 125 cubic feet of air per minute. This would serve the two four-acre areas targeted (near the Bogle/Jennings and Boulder inlets, Figure 7). The compressor would be housed in the building with the chemical dosing pumps and controls. Three lines would be run together into each of the target areas, one bearing the aluminum sulfate, one carrying the sodium aluminate (these cannot be mixed prior to delivery) and the last one transferring the air.

The operation of the system could be flexible. Dosing could be flow activated, based on increasing flows in response to precipitation in Boulder or Bogle Brook. It could also be manually operated, turned on in response to storms (later the same day or the next day, except for larger storms that flush the northern basin). Given the uncertainty of climatic patterns each spring, it will take several years to develop a track record for best operational procedures. Cost of chemicals will be a concern, so the procedure that results in acceptable clarity with the least cost is likely to be preferred. As a start, it is suggested that the system be run manually in response to storms, beginning in May and continuing until at least the end of June, with operation in July or even August as warranted by water clarity. A large storm could overrun the capacity of this system to manage water clarity throughout the lake under such an operational

Figure 7. Aluminum Injection System for the Northern Basin of Morses Pond.

scenario, but under most circumstances this system should suffice. It is also true that in a "good" year very little if any dosing would be necessary, greatly reducing long-term costs.

Based on an ENSR review of system needs, the cost of the envisioned dosing system would include the following:

A protective building with power	$40,000
Two or three chemical storage tanks	$15,000
Two chemical feed pumps	$5,000
One compressor	$20,000
Air and chemical feed lines	$8,000
Controls and related accessories	$15,000
Design and permitting	$20,000
Installation (labor and supervision)	$30,000
Total	$153,000

Based on discussion with reputable vendors for this equipment, a capital cost on the order of $103,000 was derived. Some installation supervision by the manufacturer's representative is included, but adding in the $20,000 from above for design and permitting and installation labor at $30,000, a total cost of $153,000 appears to be an appropriate estimate. The annual operating cost is mostly linked to chemical costs which have been placed at a minimum of $17,600 and could be as high as $61,000. It is suggested that an annual budget of $25,000 be established for this element of the plan and adjusted for inflation.

Summary

Storm water can be effectively treated with aluminum compounds, reducing phosphorus and suspended solids content by 75-90+%. It would be ideal to intercept storm flows in Bogle and Boulder Brooks, divert them to a detention basin, and treat them with aluminum compounds there, with release back to the pond. However, this is a technically difficult and expensive approach in this case. A simpler and potentially more effective approach involves delivering aluminum compounds at a ratio that minimizes pH change to the northern basin (Area 1) through a diffuser system, using air to mix the chemicals and water in response to storm events in spring and early summer. This process would increase the effectiveness of Area 1 as a detention area and could reduce the available phosphorus concentration in Morses Pond to the targeted level of <20 ppb during summer. As an interim measure to be performed until watershed controls can be implemented, in-lake phosphorus inactivation with aluminum has a high potential to provide the desired control of algae and suspended sediments, improving water clarity to meet use goals at an operational cost similar to what is spent on water quality management at the Town beach now.

POTENTIAL FOR WATERSHED MANAGEMENT THROUGH ORDINANCES AND PROCEDURAL METHODS

Although some structural support techniques are usually essential for urbanizing watersheds, improved watershed management can be achieved with non-structural approaches. Indeed, non-structural methods, such as education and ordinances, tend to target actual generation of pollutants and release to the environment, and therefore form the backbone of source control. Education is a critical component in any non-structural approach. While complete cooperation is not expected, an expectation of any cooperation is predicated upon an understanding by watershed residents of their role in determining downstream water quality. Participation in procedural changes, such as creation of less impervious surface, alteration of fertilizer use, or improved waste disposal, is enhanced by education. Additionally, support for ordinances that govern management practices is increased. As ordinances must go through a rigorous development and review process, often with some form of democratic vote at the end, a clear understanding of management needs and consequences is essential to success.

Application of existing regulations to their fullest extent is a logical first step toward managing pollutant sources in the Morses Pond watershed. Over three quarters of that watershed is not in Wellesley, but application of Wellesley's rules to its portion of the watershed is an appropriate start. There are one federal and three state level statutes that are highly relevant to the management of Morses Pond. Additionally, Wellesley has four ordinances with distinct implications for watershed management.

NPDES Phase II Storm Water Regulations

Wellesley has a storm water management plan prepared pursuant to the NPDES Phase II Storm Water Regulations, which govern municipal runoff controls in metropolitan areas, including all of the greater Boston area. This is a relatively new requirement (plans were developed to meet a 2003 deadline), and plans may need adjustments over time to make a real difference in nutrient loading. Controls are typically applied only when an acre or more of land is disturbed, exempting most single family home sites, but some general provisions of the plan may affect smaller parcels.

The Wellesley plan includes provisions for public outreach, education and participation, illicit connection detection and elimination, control of runoff from construction sites, management of post-construction runoff from developed sites, and pollution prevention for municipal operations. Each element includes goals, a timeline, and measures of success. The Municipal Stormwater Drainage System Rules and Regulations (see below) were developed as a consequence of the NPDES Phase II process. Reversing eutrophication in Town ponds and meeting use goals are included in the NPDES Phase II plan; this comprehensive plan for the management of Morses Pond is therefore a logical extension of the NPDES process.

Massachusetts Wetlands Protection Act

Promulgated to protect wetland resources from a variety of impacting activities and made effective in April of 1983, the Wetlands Protection Act (MGL 131 Section 40 and associated regulations in 310 CMR 10.00) establishes eight interests associated with wetlands to be protected by a set of performance standards applied in an approval process governed by local conservation commissions with oversight from MA DEP. All eight interests are relevant to the management of Morses Pond, although protecting all interests may not always be consistent with use goals for the pond. For example, protecting the habitat of one species may interfere with flood control or habitat for other species. Additionally, recreation is not recognized as an interest of the Act, and improving the pond for recreation can sometimes conflict with water supply or habitat interests. A clause in the Act allows for Limited Project status, which recognizes the value of control of eutrophication and nuisance aquatic plants and acknowledges that not all performance standards can be met when conducting lake management projects. Watershed management consistent with the Act is expected to be beneficial for all use goals for Morses Pond, but the application of the Act is limited to areas within 100 ft of identified wetland resources, unless an impact can be demonstrated by activities further away. Water quality aspects of the Act are much less rigorously applied than those pertaining to emergent wetland vegetation and related visually apparent features, mostly as a consequence of limited monitoring data.

Massachusetts Rivers Protection Act

Passed in 1996 with associated regulations developed in late 1997, the River Protection Act (Chapter 258 of the Acts of 1996) is an extension of the Wetlands Protection Act and is intended to protect continually flowing rivers and streams from impacts of development. The Rivers Protection Act establishes a “no build” zone within 100 ft of constantly flowing waters and an additional protected zone between 100 and 200 ft from those waters. This legislation is not applicable to lakes or intermittent streams, but would be relevant to new development activities within 200 ft of streams like Bogle Brook, Boulder Brook and Jennings Brook. It is meant to operate cooperatively with the Wetlands Protection Act, with its regulations incorporated into 310 CMR 10.00, and establishes protective provisions for applicable parcels that would serve to minimize contaminant inputs to the subject streams and eventually to Morses Pond.

Massachusetts Storm Water Policy

Applied in 1997 as an extension of the Wetlands Protection Act to govern new development and re-development activities with regard to resulting hydrology, the Commonwealth of Massachusetts Storm Water Policy is particularly relevant to controlling inputs to Morses Pond delivered by storm water. The focus of the Storm Water Policy is on maintaining or restoring pre-development hydrology. For residential and commercial areas, this translates into lowered runoff allowance and promotes detention, treatment and infiltration schemes. Designs are to incorporate management practices expected to remove 80% of the post-development solids load. Low Impact Development programs are highly applicable in meeting the goal of a more natural hydrology and lower loading rates to receiving waters. Unfortunately, the policy does not apply only to single family house projects or residential subdivisions with four or fewer lots unless a critical area may be impacted. Application on the scale of individual parcels, some as small as one quarter acre, is needed to really make a difference in urbanized watersheds. Additionally, a large portion of the nutrient and other contaminant loads may be associated with the smallest 20% of particles, those that may not be removed by designs intended to meet the 80% solids removal target. Some consideration of dissolved and fine particulate loads is needed to minimize development impacts.

Wellesley Wetlands Bylaw

This local bylaw (Article 44 of Town Bylaws), which supplements the state version but is separate from it, establishes an approval process for activities that could impact wetlands. The Wellesley bylaw adds recreation and sedimentation/erosion control to the interests protected under the Commonwealth’s Wetlands Protection Act, and lumps shellfisheries with other fisheries. Each of the environmental interests of the bylaw is directly applicable to use goals for

Morses Pond, with protection of ground water supply, flood control, sedimentation/erosion control and recreation having especially strong relevance. The approval process is applied to land located within 100 ft of a proposed activity, and allows control if activities further from the wetland result in a measurable impact. Greater application to storm water impacts is needed. As with the state level version, the inability to require water quality controls on land >100 ft from an identified wetland until an impact is demonstrated is a major shortcoming, as water quality monitoring is usually minimal and once a parcel has been developed, it is rarely if ever undeveloped.

Wellesley Municipal Stormwater Drainage System Rules and Regulations

The drainage system rules and regulations (Article 3100) establish a permit system for discharging to the storm water drainage system within Wellesley, governing such activities as piped connections from private property, disposal of construction runoff and general discharge of water into public streets. Infiltration of untreated storm water also requires a permit. Discharge of a wide variety of contaminants is expressly prohibited, including wastewater, yard and pet wastes, detergents, automotive products, and sediment. However, irrigation is allowed without apparent regulation except during drought. It is not clear how pet and yard wastes will be kept out of the drainage system with unregulated irrigation. Vehicle washing is also allowed, without specification for placing vehicles on permeable surfaces. It is not clear how detergents and automotive products will be prevented from entering the drainage system as a result of vehicle washing.

Wellesley Flood Plain or Watershed Protection District Zoning Bylaw

This bylaw prohibits further building and filling within flood plains and restricts non-building activities within the area that may be subject to flooding. Repair or improvement of existing dwellings can be permitted, with the intent of reducing potential flood damage. To the extent that this bylaw minimizes accumulation of materials that may be carried by flood waters to Morses Pond, it is beneficial, but it does not provide for eventual “undevelopment” within flood-prone areas or create buffer zones where they do not already exist. It allows for possible use of flood plain for parks and golf courses, each of which may receive fertilizers, and does not control the discharge of storm water from areas outside the flood plain to or through the flood plain.

Wellesley Water Supply Protection District Zoning Bylaw

This bylaw restricts land uses within the watershed of a water supply, which would apply to the entire Morses Pond watershed within the Town of Wellesley. Specific activities involving hazardous wastes are prohibited, and a permit is required to conduct certain activities, including construction projects involving more than 10,000 square feet of impervious surface. It calls for recharge of all storm water generated on sites within the district, although this does not appear to apply to existing development. It also provides a provision for monitoring to be required if the Town perceives a risk of contamination from a site or activity. This bylaw has the potential to control activities such as lawn fertilization on residential property in a manner beneficial to Morses Pond, but does not appear to be applied beyond activities involving clearly hazardous substances such as gasoline or organic solvents.

Relation to Needed Loading Reduction

If the watershed was in its natural state, defining natural in this case as an absence of human influence, one might expect an average annual phosphorus load of about 122 kg/yr (all land use set to forest and wetland), compared to a corresponding current load of 403 kg/yr (current land uses, all other model assumptions held constant). This suggests that about 281 kg/yr of phosphorus is attributable to human activities, or 70% of the total. To get the desired 33% reduction in loading, the human contribution needs to be reduced by about 52%.

Efforts to get volunteer compliance with desirable residential land management practices rarely yield more than a 20% reduction and usually not much more than a 10% reduction, so if a larger loading reduction is needed, more than voluntary compliance will be needed. Structural methods of phosphorus control tend to achieve 40-60% reductions, and the LID practices discussed previously could produce this level of control if practiced on a widespread basis. While a more detailed review of bylaw content and application in Wellesley is needed, it appears that some strengthening of existing bylaws and possible crafting of new rules to govern runoff management on individual parcels as small as one quarter acre would be beneficial.

Recent experience in Minnesota (from presentations at the 2005 NALMS conference) indicate that control of lawn fertilizers has yielded significant reductions in the phosphorus content of runoff. The change was substantial enough to cause the Minnesota legislature to enact a law governing phosphate fertilizer application, finding this to be the most cost effective strategy to meet newly established phosphorus standards for lakes in that state. Similar criteria have been established in Massachusetts by EPA Region I action (regional nutrient criteria), but there is no similar fertilizer control statute in the Commonwealth. It is therefore left to Towns to address nutrient problems on their own, with ordinances aimed at fertilizer management looking very attractive from a cost-benefit perspective.

Actually passing more stringent bylaws is a challenge in our democratic society, and will require considerable education and illustration of the potential gains to be had. Bylaw adjustments or additions therefore go hand in hand with both a strong education program and LID demonstration projects sponsored by the Town.

Summary

Activities in the watershed of Morses Pond are governed by at least one federal, three state and four town level regulatory statutes, each of which represents a useful tool in controlling the quantity or quality of storm water runoff entering the pond. Strengths include emphasis on watershed resident education and participation, minimization of runoff discharges in favor of infiltration, and a permit system that could allow tracking of progress. Weaknesses include thresholds on applicability that allow existing sites or smaller new sites to contribute phosphorus and some other contaminants without regulation, limited control in areas away from watercourses but tributary to them, and lack of control in watershed areas outside of Wellesley. The cumulative regulations applicable to the Morses Pond watershed within Wellesley should prevent significantly worsened conditions in the pond as a consequence of actions on land within Wellesley, but are unlikely to improve conditions without application to existing development and extension to the entire watershed. Strengthening of existing bylaws and possible development of new ones focused on runoff management may be necessary to achieve targeted loading reductions.

POTENTIAL FOR WATER CLARITY IMPROVEMENT THROUGH IN-LAKE MEASURES

The use of alum in the northern basin to inactivate phosphorus and settle suspended sediment entering with storm water has been discussed in a previous section of this report (Potential for Storm Water Treatment). Remaining in-lake approaches of potential applicability in Morses Pond include periodic alum treatments in areas of the pond outside the northern basin, mixing, algaecides, biomanipulation (enhanced grazing on algae), dredging and wetlands creation. All of these methods have merit, yet all but dredging may be unnecessary if alum treatment in the northern basin is successful. Dredging of at least the northern basin remains a major need, both to restore the detention capacity of that area and to support the alum treatment over an extended period of years. Many of these useful techniques are illustrated in Figure 8.

Lakewide Alum Treatment

Additional alum treatment could be applied to other areas of the lake to clear the water in those areas. This has been practiced several times in the southern portion of the southern basin to maintain sufficient water clarity to keep the swimming area open. This alternative to algaecides has been implemented when the algae causing decreased water clarity are forms with possible resistance to copper or when non-algal particles are a major component of the observed turbidity. This approach is far more expensive than copper per unit of area treated and will only last until the nutrients and solids are replaced by the movement of water from upstream. Treatments over a large portion of the lake in the 1970s appear to have been fairly effective for the whole summer season, but the combination of expense and repetitive need on at least an annual basis eventually resulted in abandonment of this approach. With concern over longer term impact of alum sludge deposition, and noting the entry of most nutrients and solids into the northern basin, it makes more sense to apply the alum in the northern basin than elsewhere.

Mixing

Mixing is currently used to improve circulation in the swimming area, adding oxygen and encouraging dilution that will minimize the build-up of pollutants that could affect use of the swimming area. As long as soft bottom sediments are not resuspended, this approach can be an effective method for preventing bacterial exceedences and keeping surface scums from forming. Mixing as currently practiced in the swimming area of Morses Pond has limited potential for expanded benefit by mixing more of the pond, as contact recreation is much less intense in other areas. Additionally, a lakewide system would require a lot of equipment and piping that could interfere with other uses. A larger aeration system in the swimming area might be more effective in that area, and a solar powered system might be more economical in the long run, but the current system does not require any major change at this time.

Algaecides

Algaecides are used only when clarity declines to a point that threatens safe use of the swimming area, and in recent years the algae have been tracked on a weekly basis to ensure that the timing of treatment is appropriate. One goal of a comprehensive water clarity program would be to minimize the need to use algaecides, but as currently applied, this is a valuable back-up technique. The use of copper is problematic in that it can release odor compounds and toxins from some algae, builds up in the sediments over many years, and can drive the algal assemblage toward copper resistant forms, many of which are major nuisance species. Use of

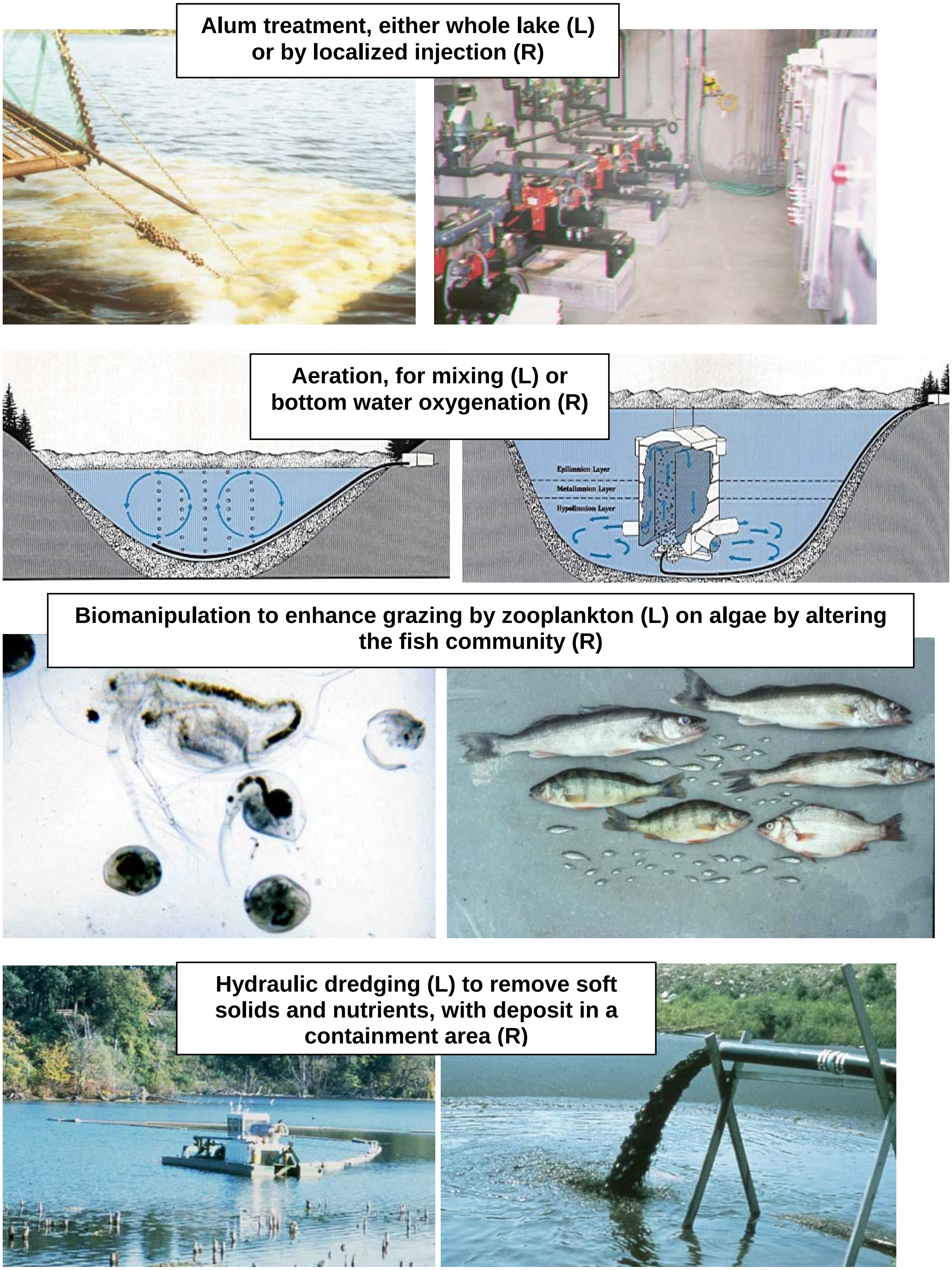


Figure 8. In-Lake Methods for Enhancing Water Clarity.

more recently developed peroxides is viewed as more environmentally friendly based on the mode of action (Appendix, Algaecide Section), but is more expensive than copper. There is no evidence that copper has caused any negative impacts in Morses Pond at this time, but it would be appropriate to experiment with a peroxide algaecide, and, if successful, alternate its use with copper treatments to minimize adverse copper impacts. Again, a successful water clarity management program will minimize the use of algaecides such that this alternating approach may be of no real consequence.

Biological Controls

Biomanipulation is the alteration of biological features to generate a desired effect in a lake. In terms of water clarity control, the most common approach involves altering the panfish community to reduce predation pressure on large-bodied zooplankton, thereby maximizing grazing on phytoplankton (algae in the water column) and minimizing algae biomass. For a given level of fertility in a lake, it does appear that enhanced grazing pressure will provide the greatest clarity possible (Mattson et al. 2004). However, improving the grazer population will not override the effects of excessive nutrient loading on a continual basis; eutrophic lakes have algae blooms, with or without large populations of grazing zooplankton.

Additionally, it is very difficult to alter the panfish population when rooted plant assemblages are dense and extensive, which is the case in Morses Pond. Enhancing grazing pressure on phytoplankton is not a realistic possibility until the rooted plant community has been managed. If such management occurs, such that open water dominates in Morses Pond, the panfish population may be naturally controlled by predation by gamefish in the absence of the cover provided by dense rooted plants. If additional panfish controls are needed, either netting operations or stocking of more gamefish would be the logical approaches. Either method is likely to require about five years of sustained effort to make a measurable difference.

Dredging

Dredging has two purposes with regard to water clarity management in Morses Pond: 1) restore detention capacity (especially in the northern basin) to limit movement of phosphorus and solids into the main body of the southern basin, and 2) remove shallow deposits of soft sediments that may release nutrients or become resuspended and create turbidity. As water depth in all areas except the northern basin is adequate to support the desired uses, it is difficult to justify dredging outside the northern basin on the basis of water clarity alone. Yet when the impact of dredging on rooted plants and the physical desirability of having less muck in areas where people may swim or boat are considered, dredging becomes more attractive although still very expensive. Dredging of Area 1, the northern basin, appears essential to water quality management in Morses Pond.

Dredging the northern basin of Morses Pond is viewed as the one in-lake water clarity management action that is essential to long-term management. Storm water treatment within the northern basin is also a viable in-lake action, and may be the most efficient way to control phosphorus and solids inputs, but this function could be filled outside the pond. Additional dredging of other areas of Morses Pond would provide distinct benefits for altering sediment characteristics and rooted plant growths, but increased detention in other areas does not offer the same level of water quality benefit (the three main tributaries and the bulk of the nutrient and solids loads enter via the northern basin). If affordable, dredging all areas of the pond <10 ft deep could reset the plant community and set the stage for efficient ongoing rooted plant management. It would also limit wind-induced resuspension of fine sediments and enhance the nature of the bottom sediments with regard to human contact recreation (less loose muck), and would improve the overall function of Morses Pond as a detention area for downstream resources (e.g., Waban Lake, Charles River). Dredging of all identified management areas with an average depth <10 ft in the Town of Wellesley is therefore considered here. A review of dredging considerations is provided in the Appendix (Dredging Section), with key aspects revisited and expanded here.

Perhaps the most critical aspect of planning for a dredging project is testing the sediment quality. Contaminant levels will strictly govern how the sediment must be handled and what disposal options are available, largely determining the feasibility of a project before the many other aspects of a dredging project that must be addressed are even considered. Fortunately, the sediments in Areas 1-6 of Morses Pond are considered clean by all Massachusetts standards (Appendix, Dredging Section), maintaining all disposal options and decreasing cost in that regard.

The quantity of sediment is the second most important factor to consider, and the soft sediment accumulations in Morses Pond have been divided among the six delineated areas of the pond considered for dredging (Appendix, Dredging Section). Area 1, the northern basin and area of greatest dredging need, contains about 18,300 cubic yards (cy) of soft sediment, and more sediment could be removed if so desired, as this area is underlain by what appear to be clays and peats. Area 2, the small cove southwest of the islands (Figure 3), has a similar amount of sediment. Areas 3 and 4, south and east of the islands, contain between 41,000 and 43,000 cy of soft sediment each. Area 5 is the Natick portion of the pond and contains almost 31,000 cy. Area 6, the portion of the southwest basin in Wellesley, contains almost 54,000 cy. All totaled, the six potential target areas contain almost 206,000 cy of soft sediment. Removal of all this sediment represents a very large expense, on the order of $5 million. Just the sediment in Area 1 represents an investment in dredging of over $500,000.

Once quality and quantity of sediment have been considered, temporary and ultimate disposal arrangements must be addressed. Because the sediments do not exceed any contaminant levels regulated in Massachusetts, a range of disposal options remain open and an active search for the most advantageous approach should be conducted when a commitment is made to dredge any portion of Morses Pond. Recent discussion about filling a gravel pit in Natick for use as possible ballfields provides an example of beneficial use suited to the material in the pond, but the timing was wrong for that particular need, which was more immediate. Other filling opportunities are likely to arise in the greater Boston area, however, and the material would be suitable for a variety of uses. It has only a moderate organic content and fairly high sand content (particles >2 mm), and should dry faster than a lot of more organic, fine grained pond sediments often encountered. Some blending with more sand may be necessary to improve stability upon drying, but the material may indeed have value in filling operations ranging from gravel pit reclamation to topsoil creation. It would also be suitable for use as landfill cover.

Dredging methods include wet and dry state technologies, but the most appropriate method of removal in Morses Pond would appear to be hydraulic dredging, whereby a cutterhead attached to a barge mixes sediment and water at a solids percentage of about 10 to 20%, sucking that slurry into a pipeline through which it is pumped to a containment area for drying. Hydraulic dredging is conducted under full lake conditions, precluding the need for drawdown and limiting related impacts on water supply. Even without potential water supply effects, maintaining dry conditions for conventional equipment in Morses Pond represents a formidable challenge, given the large watershed and utility of the pond in flood control.

The difficult aspect of hydraulic dredging is providing a containment area where sediments can dry to the extent necessary for final disposal. Direct placement onto land to be reclaimed (e.g., old gravel pits) is a great option if available, but often more desirable land must be used and the material must be removed after it has dried. One approach that has improved in technology and applicability in recent years is the use of coagulants on the dredged slurry in mixing tanks, followed by belt pressing to reduce the water content. Material goes from the pond into the tanks and onto the belts, usually then being transferred directly to dump trucks for hauling to the site of designated use. This process adds considerably to the cost per cubic yard, but eliminates the need for a large containment area, which represents a major cost savings. The rate of dredging is often slowed by this process, as there is no substantial storage area and all parts of the process must operate at once to move material. Establishing one or more larger storage tanks can help, but requires space, is considered unsightly in most neighborhoods, and adds cost.

Despite cost and storage issues, the coagulation and belt pressing operation is suggested as the most advantageous method for dredging Morses Pond, and has been applied successfully to Hardy Pond in nearby Waltham. A temporary dewatering area near the beach could be set up after Labor Day and the dredging could run from September to about Thanksgiving in any given year. A spring dredging season of mid-April to mid-June is also possible. A well run program could dredge Over 20,000 cy in a 12 week period, suggesting that Area 1 could be dredged in one fall season. Area 2 would also be amenable to a short season of dredging, but the other areas would require two or more years of activity to be completed. If all target areas were dredged in this manner, using only the fall period, it would require ten years of effort. Adding in a spring dredging season would cut the time to about seven years. Either way, the dredging program would be quite protracted, although this would also spread out costs.

Given known quantities of clean sediment and a process that could produce a desirable if not salable material, the Town should consider costs and seek possible disposal arrangements. It should not be assumed that money will be made from the material unless a contract is in place, but it may be possible to get it hauled away for much less than usually assumed in dredging projects. Disposal costs represent a major and highly variable component of the dredging program, and effort spent researching options in the region can pay huge dividends.

The cost of dredging the targeted areas of Morses Pond were derived (Appendix, Dredging Section) from general guidelines for key elements of dredging, and assumed an aggregate cost of $30/cy. This results in a total cost of $6,325,000 if all soft sediment in Areas 1-6 was removed, and about $550,000 if just Area 1 is dredged. This is helpful for general planning purposes, but is not nearly site-specific enough to use in soliciting or evaluating bids. Key factors in getting a more accurate cost include determining how much sediment will be removed over what period of time and selecting the intermediate and final disposal locations. Additional considerations for possible bidders will include access and security for equipment, allowable hours and days of operation, ownership of the material, and any equipment specifications made to either improve the process or protect natural resources. All of these issues can be addressed in a supplemental dredging planning phase that would result in a conceptual plan or even bid documents. Making logical assumptions about the proposed dredging of Area 1, a total, all-inclusive cost of $650,000 was derived (see Recommendations section).

Wetlands Creation

Wetland creation is viewed here as a supplement to dredging. It provides a place to dispose of some of the dredged material and could result in a flow path that would maximize treatment for typical smaller to medium sized storms. Larger storms might receive less treatment, as some portion of the potential detention capacity would be lost to the created wetlands. Analysis of engineering models of treatment under the range of scenarios suggests no clear advantage to the wetland approach with a basin the size of Area 1 and the inputs from the very large Morses Pond watershed. Engineering analysis of flood impacts also suggests no negative impacts of wetland construction in accordance with any of the scenarios outlined in the Appendix (Wetlands Section).

The islands create a largely natural barrier that accomplished much of what constructed wetlands would do in terms of flow path, and it does not appear that the wetlands could be large enough to have major direct water quality benefits by treatment in addition to that offered by detention. Because there could be some cost savings relating to dredged material disposal, creating wetlands in association with a dredging project in the northern basin does not represent a major increase in cost, but it would not provide a cost reduction in the overall management program. If the alum addition to the northern basin is implemented as recommended, it will provide more water quality benefit than constructed wetlands and it will be more important to provide the maximum amount of detention for settled solids. Consequently, constructing wetlands in the northern basin is not recommended at this time, but could be considered if alum treatment is not pursued.

Summary

In-lake techniques that could help control algae and suspended solids and maximize water clarity include periodic alum treatments beyond just the northern basin, mixing, algaecides, biological controls (enhanced grazing on algae), dredging and wetlands creation. All of these methods have merit, yet all but dredging may be unnecessary if alum treatment in the northern basin is successful. Dredging of at least the northern basin remains a major need, both to restore the detention capacity of that area and to support the alum treatment over an extended period of years. There does not appear to be any major advantage to creating wetlands in association with proposed dredging of the northern basin, and given the expected accumulation of solids associated with alum treatment, maximizing detention volume by a thorough dredging is preferred in that area. Hydraulic dredging appears most appropriate, with coagulation and belt pressing of dredged material to limit containment space needs. The sediments are clean by Massachusetts standards, so a variety of disposal options are possible. Additional dredging beyond the northern basin could also be beneficial, but the high cost is not justified solely for improved detention in Morses Pond.

POTENTIAL FOR ROOTED PLANT CONTROL

From the previous discussion of rooted plant management options, there are two viable methods for potentially resetting the plant community on a lakewide basis (dredging and the herbicide fluridone) and two highly applicable methods for controlling rooted plants on a localized basis (hand harvesting and benthic barriers). Additionally, mechanical harvesting represents a general purpose method with a high degree of flexibility but limitations on the speed and area of coverage. Mechanical harvesting with a machine that cuts and collects vegetation has been practiced for over two decades in Morses Pond, but the process could be improved considerably. Hydroraking is a form of mechanical harvesting with potential on a localized basis in this system; it carries a higher cost per unit area over time but also removes debris from target areas, a perceived benefit for swimming areas. Each applicable method has a potentially beneficial role, and every method has limitations that make it less than ideal for Morses Pond. Additionally, planting areas where problem species have been removed with more desirable species represents a follow-up technique that may accelerate or direct recovery in a positive manner, but may not be necessary if natural recolonization proceeds favorably.

Other possible plant control techniques have been reviewed and considered inappropriate for Morses Pond for reasons of technical applicability, undesirable impacts, or regulatory prohibition. For example, drawdown to an effective depth is not possible with the current outlet configuration and would adversely affect water supply. Grass carp tend to promote algal blooms and cannot be legally stocked in Massachusetts waters. Insect herbivores do not attack the majority of problem species in the lake. The options discussed below are considered to be the best available methods for addressing rooted plant problems in Morses Pond.

Dredging

The technical aspects of dredging have been addressed under the previous section of this report. As a plant control technique, it has great potential to allow a fresh start in any area <10 ft deep in Morses Pond, but is not expected to minimize future plant growths by itself. The organic sediment layer in Morses Pond is underlain by fine grained materials that will still support plant growth, albeit at a reduced density for some period of years. Except in a few areas, a depth limitation on plant growth will not be established, so dredging will essentially clear an area of plants, roots, seeds and some of the richest substrate, opening area for new growths. While some species would not be expected to return for a long time as a function of substrate changes (e.g., water lilies, which prefer loose organic material), any of the invasive species could colonize these areas, although probably at a lower density.

Using dredging to give the plant community of Morses Pond a fresh start is conceptually very appealing. It would provide corollary benefits in terms of increased depth and removal of soft organic sediments, setting the pond back in time. In reality, however, dredging would not be applied on a lakewide basis over a period of time that would be short enough to reset the plant community over that whole area. Dredging, if extended beyond Area 1 where restoration of detention capacity is needed, is envisioned as a minimum four year project (five years including Area 1). As the lake would not be drained for the dredging period, problem plants from areas not scheduled to be treated until late in the program could contribute to recolonization of areas dredged earlier in the program. Additional control methods would be required to achieve desired conditions, so dredging alone does not represent a complete plant management program. The expense of dredging all target areas of the pond is also very high; it is not clear that enough public benefit would accrue to justify this level of expense.

An active planting plan, focusing on low growing native species that might form a dense carpet and minimize invasions, might be an important supplement to dredging to control nuisance plants. Such planting efforts are relatively new in lake management and reliable approaches are still under development. Additional techniques should be available, however, to combat new growths. Hand harvesting and benthic barriers would be appropriate over the potential dredging area on a spot basis (small scale application in response to regrowth), but will require vigilance (annual monitoring) and rapid application to maintain the desired conditions.

Fluridone

The use of fluridone is inconsistent with the current policy of the Natural Resources Commission regarding the use of pesticides (which includes herbicides) on Town property. The Integrated Pest Management (IPM) policy states that pesticide use is only acceptable where there is a public or environmental health emergency and viable alternatives are unavailable. The Natural Resources Commission voted in June of 2005 to uphold that policy with regard to any test treatment in Morses Pond with fluridone. As a result, fluridone can not be used unless the IPM policy conditions are met in the future or the NRC grants a policy exemption for the use of fluridone.

Nevertheless, fluridone is evaluated here as the only herbicide considered potentially appropriate for use in Morses Pond at this time. Fluridone should not be confused with any other herbicide in discussions of effectiveness and non-target impacts. To properly evaluate the use of this herbicide, a common understanding of what the technique can and cannot do is essential. With this in mind, the following information is offered.

Fluridone acts against vascular plants by inhibiting the synthesis of pigments essential to protecting the photosynthetic process. It is not the photosynthetic pigment chlorophyll that is attacked, but rather auxiliary carotenoid pigments that protect the chlorophyll from strong sunlight. Some plants depend on these auxiliary pigments more than others, or have their production interrupted at different doses of fluridone, so there is variable susceptibility to fluridone. Fluridone is absorbed into plant tissues and moved around within the plant, potentially affecting all parts of the plant except already formed seeds or turions that are not connected by a circulation system; such chemicals are called “systemic” herbicides. Fluridone is effective at much lower doses than other systemic herbicides, with recent treatments at levels typically below 15 ppb (ug/L).

At a dose of >20 ppb for an extended period of time (>40 days), most submergent and floating aquatic plants will be killed. At a dose of <8 ppb for a more extended time (>60 and preferably >90 days), many nuisance forms are killed but many non-target species are not. It is not an either-or phenomenon, however, but rather a probability distribution; a complex gradient of susceptibility exists based on the plant in question, the dose, and the duration of exposure. At intermediate doses (8-20 ppb), there is a gradient of susceptibility that is highly dependent on exposure time. If we want to be sure to kill a target species such as Eurasian watermilfoil or fanwort, a dose in excess of 8 ppb should be used for as much of the growing season as possible. Such a dose will kill some but not all non-target plants. There are lab tests that can be run to get an idea of what a given dose will do to a selected plant community, but when dealing with biology, substantial variability is to be expected.

As the goal in Morses Pond is to eliminate or reduce invasive plant species in favor of a native assemblage with more desirable characteristics, and knowing that continued invasion by unwanted species is more or less inevitable, a treatment that kills a majority of the native plants appears unwarranted. The use of fluridone in a test treatment at an initial dose of 10 ppb has been considered, with a “boost” treatment whenever the concentration drops below 6 ppb for a period of 90 days. At an initial dose of 10 ppb and a typical rate of uptake and photodegradation, the concentration will have to be boosted roughly monthly. This treatment will kill most but not all of the problem species, most notably the Eurasian watermilfoil. Some fanwort and variable milfoil survival is expected at this dose, despite the prolonged exposure. Broadleaf pondweed, naiad, and waterweed will also be affected, possibly severely, although the pondweed and naiad are seed producers that tend to recover over two to four years after treatment. Naiad is currently too dense in Morses Pond, so this would be a beneficial effect. The intent would be to get the susceptible problem species under control to the point where other techniques (e.g., hand harvesting, benthic barriers) can be used to further or maintain control. Such control is by no means guaranteed, but as a test case in one area, this is a logical approach.

Fluridone is highly diffusive, so keeping it in a target area usually involves surrounding that area with a curtain to keep the water in place to the maximum extent possible (Figure 9). The best candidate area for a fluridone test treatment is Area 2, the six acre cove west of the islands. This cove can be sequestered with a curtain that will limit movement of fluridone out of the cove, although some movement with wave action and possible curtain distortion in the wind is to be expected. However, if a dose of 10 ppb in Area 2 was completely and instantaneously released, the dilution before it could reach the swimming area or wells would be so extreme that it would be undetectable and several orders of magnitude below any effect level ever derived. Curtains have proven effective at keeping enough herbicide in the target area to get the desired effect.

Nevertheless, fluridone is an herbicide and as a chemical intended to kill select biological components of the aquatic system, it is quite rational that some will feel that the risk to system ecology or human health is too great for the benefits that might be accrued. It is not possible to prove that fluridone has no potentially negative health impacts, only that no such impacts have been found to date. In over two decades of testing, much of it quite rigorous to gain federal registration of fluridone under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), no impacts have ever been observed to any animal at doses that could be encountered in any treatment in accordance with the label restrictions. The mode of action of fluridone appears to have no unintended interactions with animal life, and emergent plants are generally unaffected as well. Some turf grasses and ornamentals are impacted, so irrigation use is not recommended. Direct contact with full strength fluridone poses some health risk, but it comes as an easy to handle liquid, so inhalation and ingestion modes are highly unlikely. Skin contact is the only significant risk, and then really only for applicators, as fluridone is mixed with pond water in a vat on the treatment vessel before application. This may not make everyone comfortable with application of an herbicide, but the level of risk to anything but submergent and floating plants is undeniably low.

Fluridone at the suggested dose may cause some decrease in water lily abundance, but it is likely to be temporary. Likewise, some other target plants are likely to survive, and the potential for re-infestation by nuisance species is high without supplemental techniques such as hand harvesting or benthic barriers. In many lakes, fluridone is simply applied again after target species regain dominance, typically between two and five years after the previous treatment. This is not the intended approach at Morses Pond; fluridone application has been evaluated as a means to reset the plant community and attempt to re-establish a more desirable assemblage of native species. Where substantial areas are opened up (devoid of plants), consideration would be given to planting desirable species. If treatment was needed after anything less than

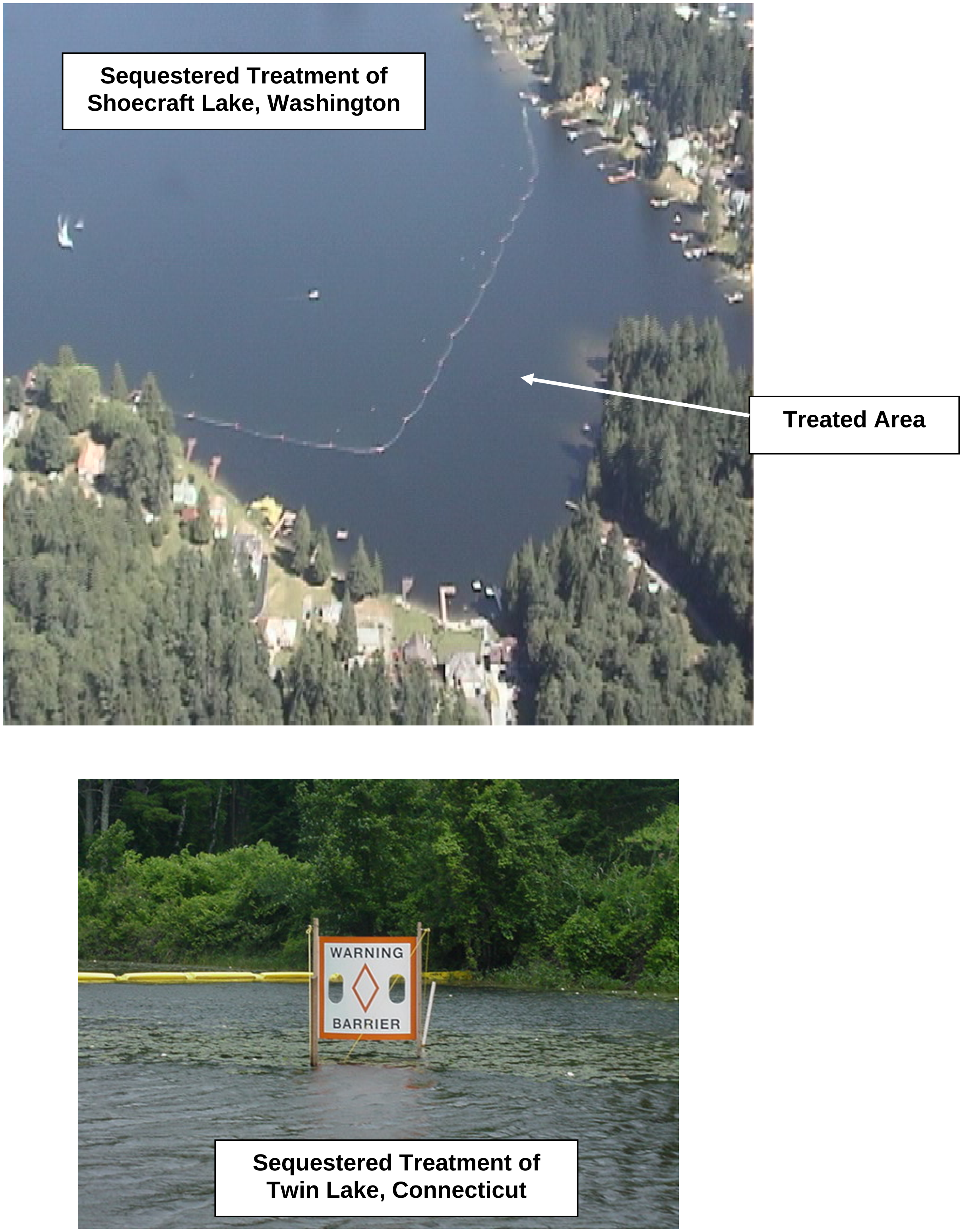


Figure 9. Sequestered Fluridone Treatments for Rooted Plant Control.

five years, and preferably closer to ten years with supplemental management, the use of fluridone in Morses Pond would be considered inappropriate.

As any test case would likely be followed by at least two years of evaluation, use of fluridone would not be rapidly adopted on a lakewide basis. Also, it is uncertain how all areas of Morses Pond could eventually be treated, since the Town wells on the east side of the pond draw considerable water from the adjacent part of the pond. An evaluation of dilution potential would be needed. During the time it took to evaluate fluridone for use in multiple areas of Morses Pond, untreated areas could supply more nuisance plants to colonize treated areas, creating a clear need for additional management during this period. Consequently, this approach cannot be portrayed as a rapid or complete plant management program. However, where applied, fluridone represents the least expensive means to gain control over at least some nuisance species so that other less controversial techniques can be used to maintain desired conditions.

Should the IPM policy be changed, the treatment of Area 2 is expected to cost about $5000 per acre, or $30,000 for Area 2. The typical cost for a sequential bump treatment with sequestration is closer to $2500 per acre for a situation like Area 2 in Morses Pond, but an increased level of permitting and monitoring is expected, all of which would be done by professional contractors separate from the herbicide applicator. The cost for Area 4 would be similar per unit area, suggesting an independent treatment cost for Area 4 of about $47,000. However, done sequentially, the same curtain used to sequester Area 2 could be applied, with a slight extension, reducing costs to around $41,000. Treating Area 3 is somewhat more difficult, as most inflows must pass through Area 3, requiring additional sequestration. Such a treatment could require splitting Area 3 into two separate areas for sequential treatment, involving as much as 2000 ft of additional curtain and $1000 more per acre. This suggests a treatment cost for Area 3 of approximately $76,000. Area 5 is in Natick, but would logically be treated along with Area 6 in Wellesley. Treated independently from the other areas (no assumption of curtain re-use), the cost to treat Areas 5 and 6 would be about $100,000. However, with re-use of curtains from the other areas, the cost could be reduced to about $80,000. Any reduction of monitoring based on experience with the first treated area or two could reduce costs, such that treatment of all likely target areas could be on the order of $170,000 to $200,000, rather than the simple sum of area costs noted above ($227,000). No treatment of Areas 1 or 7 would be expected.

Hand Harvesting

Highly selective removal of target species by hand is the most desirable plant removal technique in terms of focusing on target species and potentially leaving desirable species intact. However, this approach does not work when the assemblage is so dense that separate plants cannot be readily discerned. As a general guideline, hand harvesting is appropriate when the target species is present at a density of no more than 1 plant per 10 square feet, or <500 target plants per acre. Certainly slightly more dense growths can be hand harvested in some cases in small areas, but where density is much greater over an area of multiple acres, there is little documentation of cases of successful control by hand harvesting (Mattson et al. 2004).

Where applied as an invasion prevention technique, hand harvesting can be very effective. Densities are initially low and plants can be singled out and removed by hand. This approach has been a tremendous aid to maintaining control over water chestnut, which repeatedly invades Morses Pond, presumably by seeds carried into the pond by birds. Several canoes full of water chestnut are hand pulled by volunteers each summer. Effort should be focused on the first half of summer, before seeds can be generated and deposited. Some observers may dismiss preventive actions as having no visible impact, but there is little question that pond conditions have greatly benefited from this effort. Systems in which water chestnut was not aggressively managed from the start have spent huge sums of money on mechanical harvesting to gain control. For example, the former Metropolitan District Commission spent over $150,000 in three successive years to reduce water chestnut densities in the lake district of the Charles River after about a decade of neglect (Mattson et al. 2004), and the currently responsible agency, the Department of Conservation and Recreation, continues to battle this plant.

Hand harvesting may also have merit as a maintenance technique after another technique is applied to remove problem species on a larger scale (the “resetting” of the community). Colonization of newly opened areas may very well be by invasive species unless there is a viable seed bed of native species present and conditions are right to get those seeds to germinate and form plants that will lay down more seeds before the end of the growing season. Hand harvesting might be applied to newly opened areas, providing control on a localized scale.

However, given the high density of most nuisance species in Morses Pond, hand harvesting has limited applicability at this point in time beyond maintaining control over water chestnut and any other species that might show up now for the first time. It may also be a useful technique on very localized areas not accessible by a harvester, such as right at the shoreline or around docks of shoreline property owners. Hand harvesting cannot be used to restructure the plant community on a lakewide basis in this case.

The cost of the water chestnut harvesting effort is internalized by a group of volunteers. Estimates from other programs, most notably Lake George, NY, which has hand harvested new growths of Eurasian watermilfoil for over 15 years, range from $200 to $500 per acre for low density infestations. Yet this cost estimate cannot be applied to current densities of milfoil, fanwort, naiad, waterlilies, or any other problem species in Morses Pond, where the technique is essentially inapplicable. If another method can be used to gain control over those problem species, hand harvesting efforts over the 64 acres of area potentially in need of such management would cost on the order of $13,000 to $32,000 per year in labor alone if performed professionally. This approach continues to have great merit for water chestnut, but will not be applicable to other species on more than a very localized basis until a more aggressive method is applied to reduce nuisance plant densities.

Benthic Barriers

Benthic barriers are mats that can be used to cover areas of unwanted plants (Figure 10). They can be porous or impermeable, but are expected to remain in place for at least a month and will kill virtually all plants under the barrier for that time. Further detail on this approach is included in the Appendix (Benthic Barrier Section), but the key elements to be understood are that it is an effective technique where applied, but application on a large scale is almost never attempted because of logistic difficulties, potential impacts, and cost. The largest installations in Massachusetts have been on the order of two acres, and application over an area more than about 10% of the area of the lake that supports plants is generally considered to present the potential for unreasonable impacts on benthic aquatic life other than the target species (Mattson et al. 2004).

Benthic barriers are therefore applied on a smaller scale, to dense growths of unwanted plants, and are an ideal complement to hand harvesting of low density nuisance plants. Monitoring to detect areas of target species growth with removal of low density growths by hand harvesting will yield information on the distribution of beds or other dense assemblages of nuisance

Figure 10. Benthic Barrier Installation for Rooted Plant Control.

species. For small (<1 acre) areas with dense infestations of an undesirable species, benthic barriers can gain the level of control that allows hand harvesting to be effective thereafter. If solid sheet materials are used they must typically be vented to allow gas to escape, otherwise they may become buoyant. However, plant regrowth will be negligible until sediment accumulates on the barrier, necessitating possible maintenance. If porous screen materials are applied, gases tend to be released but regrowth of some nuisance species is likely over time, necessitating annual maintenance actions. If the barriers are removed after killing the plants they cover, colonization may involve nuisance species and is likely to require some follow up control, like hand harvesting.

Benthic barriers are ideal for swimming areas and boat docking locations where low densities of aquatic plants are essential. It is also possible to create lanes through dense plant assemblages to facilitate boat access to open water or to create edge effect valued by fishermen. On a lakewide basis, the impact of large scale benthic barrier application on system ecology is unlikely to be acceptable under the Wetlands Protection Act, and would probably be cost prohibitive anyway.

Most benthic barrier would be applied by homeowners or the Town in widely spaced areas of the pond, making detailed quantity and cost estimation difficult. If we assumed that no more than 10% of the potential plant growth area was covered, that would be approximately 6 acres at a cost of around $40,000 per acre for materials and about $5000 per acre for labor to lay it out and remove any panels in swimming areas before or after the contact recreation season, or a total cost of $270,000 in the initial year. Only the labor cost would apply in subsequent years, with the more durable materials lasting at least a decade.

Mechanical Harvesting

Mechanical harvesting has several forms, all involving some power-driven apparatus that cuts unwanted plants. Rotovation is similar to rototilling a garden, and is intended to disturb the root systems as well as the visible parts of the target plants. A year or more of reduced rooted plant biomass is often achieved. It does not collect the disturbed material and creates very high turbidity, however, so rotovation is not applied on a large scale where uses such as contact recreation have priority. Similarly, hydroraking uses a York rake to rip up plants and root systems, and also creates considerable turbidity. Hydroraking is applied at the Town beach as needed but not more frequently than annually, before the swimming season. The cost of either rotovation or hydroraking is on the order of $6000 per acre, making it very expensive and rarely applied on a large scale. Neither rotovation nor hydroraking is likely to have a substantial role in meeting the lakewide goal for rooted plant biomass control in Morses Pond, but hydroraking is addressed separately as a possible smaller scale technique.

Mechanical cutting systems that do not collect the cut plants will have no place in Morses Pond, given the ability of many problem species to re-root from fragments, and the potential impacts on water quality. Mechanical harvesting that collects plants for disposal outside the pond is appropriate and has been practiced for over two decades at Morses Pond (Figure 11). Results have not generally been satisfactory, however, and an evaluation was performed as part of this plan development process to determine why harvesting had not yielded acceptable results and how the process could be improved (Appendix, Harvesting Section).

The conclusion drawn from evaluation of the existing harvesting approach is that the available equipment is simply not sufficient to handle the area of plants which it must address. The rate of harvesting was estimated at about 0.15 acres per hour, with about half the time consumed by

Current Wellesley Harvesting Equipment, in Operation since 1979

Newer Model Harvester, with Greater Cutting Width and Depth, Larger Hauling Capacity and Improved Hydraulics

Figure 11. Mechanical Harvesting for Rooted Plant Control.

trips back and forth to the offloading site just south of the beach complex. With up to 64 acres of area that could be harvested to the benefit of pond uses, it will require 427 hours of effort to cover the target area, although the harvester cannot work effectively in water <2 ft deep. The harvester is operated for no more than five hours per day, no more than five days per week, and is usually operated for less time, given other responsibilities of the operator and the need for maintenance of the 25+ year old harvester. The weekly operating time of <25 hours suggests that it will take at least 17 days to harvest all target areas of the lake, but those days are spread out over at least 4 weeks (at <5 days per week), so it will take at least a month of calendar time to accomplish a single cutting. Regrowth of nuisance species is more rapid than this, and at least initial harvesting efforts need to be more aggressive.

The harvester was not operated in 2004, and the density of rooted plants in Morses Pond was higher than ever recorded before, so the harvesting program does have an impact. However, the level of impact is limited by both equipment and operational procedures. The process as explained and observed in June of 2005 involves a mid- to late June start to harvesting, having the operator assist with beach opening most days, occasional days devoted to non-harvesting tasks, some harvester and offloading equipment maintenance, up to five hours on the harvester, cutting plants in areas where the need appears greatest, hauling those plants to the disposal hopper near the outlet, and hauling the hopper away after three to five loads, the typical daily output. All of this is accomplished by one person, sometimes with aid of a second. From just a few trips on the harvester, a load appears to represent an area of not more than 7200 square feet, or 0.17 acre, based on a cutting width of 5 ft and a rate of cutting of 1 foot per second (rates as low as 0.5 ft per second were observed). Travel time from the harvesting area to the offloading site varies with the target area, but 36 minutes of an hour were consumed by travel time and offloading when working in Area 4 (Figure 3), which seemingly represents about the average distance between a target area and the offloading site.

Additional factors reduce efficiency and productivity and limit the ability to evaluate them. The cutting path is determined by eye, and the cutting depth is adjusted when excessive turbidity is noted, signaling that contact with the mucky bottom has been made. No areal or bathymetric map was kept on the harvester. The operator has no training in which species are least preferred. Bad weather will slow or preclude harvesting. No records were kept of areas harvested, loads removed, time spent harvesting, or species removed. Given the available equipment, limited manpower devoted to harvesting, and lack of focus of the harvesting program, it is not surprising that pond users generally feel that harvesting is not an effective management technique. Considerable improvement is possible, however, and a program was developed for summer of 2005 to demonstrate the potential for effective harvesting (Appendix, Harvesting Section).

For 2005, harvesting was focused on Area 4, with additional areas to be cut only when Area 4 was in an appropriate condition. The same equipment was used with only one operator and no additional offloading aids, and with no expected change in level of effort or other duties. However, by directing effort to an area that could be managed within the constraints of the program, it was intended that the performance of harvesting as a rooted plant control technique could be evaluated. Records were kept of time spent harvesting and loads removed, along with the plant species in those loads. A manual showing which species were targeted and which were to be preserved was supplied, including pictures of what these species looked like on the harvester conveyor belt.

A review of the 2005 harvesting program revealed the following:

- The harvester operated for about a week in late June without recordkeeping (June 20-27).

- Harvesting was first documented on June 28th, with 4.5 hours spent on the job focused on Area 4 and 2 hours spent actually harvesting plants; 4 full loads of mixed species were collected in that time.
- The front conveyor belt broke on June 29th, after 0.5 hour of cutting and one full load of mixed plants.
- Cutting resumed on July 20th, and was conducted on 8 days in Area 4 into August 3rd, when the harvester moved to Area 2. The record indicates an average of 5 hours per day spent in relation to the harvesting program, with an average of 2.6 hours per day spent actually cutting. It required 8.5 days of effort over a period of 15 calendar days to harvest Area 4. A total of 31 full loads of plants were removed in this time, an average of 0.7 loads per hour (1.6 loads per hour of actual cutting), or 4.2 loads per day.
- Over a period of 16 calendar days, harvesting was conducted on 10 days in Area 2 for a total of 49.5 hours or 5 hours per day, with 30.5 hours spent actually cutting (3 hr per day). 46 full loads of mixed plants were removed, a rate of 0.9 loads per hour (1.5 loads per hour of actual cutting), or 4.6 loads per day.
- Both Area 4 and Area 2 were considered to look acceptable at the conclusion of harvesting by nearby residents and users. With downtime for harvester repairs, these two areas, totaling 15 acres, required the entire summer of harvesting effort to maintain with the available equipment. Harvesting occurred on 50% of the available days between June 20th and August 18th, with an average of 5 hours per day, with actual cutting occurring during 55% of the operating time (2.8 hr/day). Between 0.5 and 1.0 acres were harvested per day. A documented 87 loads of plants were removed, projected at 109 loads for the entire harvesting period and estimated at 163,500 pounds of plant material.

Discussions with pond users, particularly those living near Areas 2 and 4, suggest that the 2005 program was successful for those areas, even though Area 2 was not harvested until August and Area 4 experienced some regrowth between the June and July harvesting periods. Plants were dense in other areas of the pond that did not receive adequate attention, but the harvester and time commitment will not allow the whole pond to be managed effectively at this time. Based on the apparent potential to gain control over nuisance species with harvesting, as accomplished in many other lakes on a maintenance basis (Mattson et al. 2004), a program for Morses Pond that will maintain the desired level of rooted plant biomass can be outlined.

With the right equipment and a commitment to a carefully crafted harvesting plan, it should be possible to control rooted plant biomass in Morses Pond in a manner consistent with the range of desired uses. It is possible that the need for harvesting could be reduced over a period of years, as the plant community shifts toward more desirable species, but it is unlikely that harvesting could ever be phased out. In that regard, mechanical harvesting is a maintenance technique, but one that offers temporal and spatial flexibility in operation.

The key to a successful harvesting program covering all target areas of Morses Pond will be new harvesting equipment capable of meeting the need. Specifications for a new harvester were provided in the Fugro (1994) report but were never acted upon; most of those features remain valid, although additional advances of the last decade are worth having as well. Key features of the harvesting equipment would include:

- 10 ft cutting width
- Minimum 7 ft cutting depth, prefer 10 ft depth
- Adjustable cutting bar aspect to allow horizontal alignment at all working depths
- Advanced, low maintenance hydraulic system
- Supplemental propulsion for faster arrival at destinations

- High capacity onboard hopper
- GPS system with display to allow accurate tracking of harvester path and proper resumption after any interruption
- Depth finder to allow cutting close to bottom without disturbing the actual bottom unless intentionally trying to remove root systems
- Transport barge for hauling loads to shore while harvester continues to cut

The existing offloading and hopper system appears adequate, but consideration of replacement at some point may be warranted. It may also be desirable to purchase trailers made for the harvester and barge, if existing trailering equipment is insufficient to carry the new equipment. The other major need will be a commitment of personnel to the program. Two people will be needed on close to a full time basis from May through August, with part time effort desirable in September. Harvesting should be a six to eight hour per day operation, with five days per week as a target, acknowledging that weather and maintenance may reduce actual harvest time.

Assuming a 10 ft cutting width at a rate of 0.5 to 1 feet per second and five hours of actual cutting time per day, an area of two to four acres could be harvested each day. At only four days per week, eight to sixteen acres could be harvested per week. Focusing on Areas 2, 3, 4 and 6, the areas in Wellesley that are expected to require repeated harvesting, the associated 41 acres would require three to five weeks to harvest completely. This should be adequate to keep up with regrowth of problem species. Successive cuttings should become easier, but continued cutting is to be expected indefinitely. The necessary intensity should decline and if the process is successful, the focus should shift toward managing to maintain desired species over a period of five to ten years.

With such a high density of target species, initial harvesting will be intensive and will involve most species in the pond. Over time more selective cutting should be possible, with some areas skipped, some areas harvested more shallowly than others, and a mid-summer period of no harvesting. Ideally, harvesting would occur in all target areas from mid-May through June, after which the harvester could be removed during July and early August to give desirable species a chance to grow and set seeds. Harvesting in other Town ponds would be possible during that period. Harvesting would resume in Morses Pond in mid-August and run into September, cutting in all targeted areas again. To use this approach to attempt to encourage a native assemblage consistent with all pond use goals, cutting will have to be carefully guided to remove target species while maintaining desired species to the extent possible. Operators will need to be trained to recognize the various plants in the pond and to harvest according to the plan.

The suggested program will require new harvesting equipment at a cost of between $200,000 and $250,000. It will also necessitate greater manpower over a longer period of time than currently provided. Assuming two people for four months, the annual cost for labor would be on the order of $56,000. There would be a need for some training and permitting, for which about $20,000 should be allocated.

It is possible to contract the harvesting operation from one of a few suppliers of such services in New England, but this is likely to result in greater long-term cost and less flexibility. At a cost of at least $1000 per acre for dense growths (Mattson et al. 2004), with 41 acres cut at least three times between May and September, the annual cost would be approximately $123,000 per year, and may not include disposal costs. If plant densities are reduced over time, the cost may decline to around $70,000 per year, but the lower level of necessary effort would also decrease Town labor costs if a harvester was purchased and operated. Overall, the cost of buying the harvester would be comparable to the cost differential from about four years of contract harvesting. Additionally, harvesting contractors will have to schedule the work to meet other client needs, limiting flexibility, and would not be available for the same total cost to harvest in other Town ponds when acceptable conditions were achieved in Morses Pond. While contract harvesting is convenient and less expensive in the short-term, purchase and operation of a harvester by the Town will more effectively and economically meet long-term goals for Morses Pond and offers the potential to solve plant problems in other Town ponds.

Hydroraking

A hydrorake is basically a backhoe on pontoons, except that the bucket is replaced with a large rake attachment with large, strong tines (Figure 12). Plants, roots, stumps, other debris of more than a couple of inches in width and coherent sediments can be removed with this device. Material caught on the rake can be placed in a hopper for disposal outside the lake, and this approach will also collect trash and other debris that is desirable to remove from swimming areas or other locations of frequent human interaction with the pond bottom. Costs per acre tend to exceed $6000, and repetition on an annual basis is expected, so this is an expensive technique on a large scale. However, for sub-acre parcels such as swimming areas this can be a useful clean-up approach. The Morses Pond Town swimming area is hydroraked in most years in the late spring, prior to the facility opening. This method could be applied to small shoreline areas by property owners as an alternative to hand pulling or benthic barriers.

Selective Planting

Selective planting offers an opportunity to determine which plants will grow in areas where unwanted plants are removed by other means. This is a science in its infancy, but one that addresses the issue of inevitable plant growth in lighted, suitable substrates. This is the second half of plant management, with initial control of undesirable species as the first step. Where only that first step is taken, the program may be incomplete. Natural recolonization from seeds or desirable species in adjacent areas may negate the need for planting, but unless control of invasive species is extreme, these tend to be the species that colonize most successfully, creating a cycle of control and undesirable regrowth. Consequently, where native propagules are insufficient, selective planting of rooted plant control areas should be considered.

Planting desirable species is a simple enough concept, but has been attempted relatively few times in plant management projects (Figure 13). Although emergent wetland species are readily available from certain ecologically oriented nurseries, there are few if any sources of submergent species. It would be possible to grow some forms and collect seeds, but some desirable species propagate mainly by vegetative means, necessitating large growing areas and transplanting. A review of available literature on selective plantings in lakes (ENSR, in preparation for the New Hampshire Department of Environmental Protection) suggests that moving mature plants from within the same lake is best, followed by transplanting mature plants from other nearby lakes. Plants should be moved before seeds are dropped, especially for annual species that depend on those seeds for survival to the next year. The same process holds true for vegetatively reproducing species, with relatively little spread expected in the year of planting. Expansion of transplanted plants tends to occur in the year following transplanting, with full coverage taking multiple years unless the target area is small and intense effort is put into the planting. A current project in New Hampshire involves two acres of area and will cost about $70,000, with a three year grow-in period expected.

For Morses Pond, with some native plants present and a likely seed bed for these and other species, natural replacement of invasive or nuisance species is possible if those problem

Figure 12. Hydroraking Plants and Debris.

Transplanting Chara in Lake Buel , MA with a Harvester, July 2000

Collecting Sclerolepis for Transfer in Lake Massasecum, NH, August 2005

Figure 13. Selective Planting.

species are controlled for several growing seasons. Yet such natural replacement has not been reliable in many other cases, so it is by no means guaranteed. Some management techniques appear more supportive than others; dredging will remove virtually all plants and necessitate recolonization of the area from other areas, while benthic barriers have fostered native plant recovery from seed after removal. Fluridone treatments have encouraged native recolonization in many but not all cases. Harvesting appears to have intermediate and highly variable effects depending upon how the program is run. Another important factor may be how long the invasive species have been dominant, with longer durations promoting less natural native recolonization.

It seems likely that Morses Pond would benefit from some strategic introductions, as noted in the Appendix (Additional Rooted Plant Control Techniques Section, Plant Competition Part). In particular, the addition of the macroalgae *Chara* and *Nitella*, both low growing plants with high habitat value and little potential to interfere with any desired use, should be encouraged. The native Robbins pondweed is also especially suitable for this waterbody and is already present, but it expands fairly slowly and may need some assistance to spread to target areas more quickly. *Chara* and *Nitella* reproduce by seed-like structures that allow rapid expansion over several years. It may be worthwhile to attempt just a “seeding” with these species, but the conventional wisdom from a limited number of efforts suggests that transplanting the whole plants with some sediment may be a better approach. Robbins pondweed reproduces by root runners and only very rarely by seeds, so transplanting whole plants will be essential in that case.

Whatever rooted plant management plan is adopted for Morses Pond, it would be appropriate to conduct it for at least two years with careful monitoring of regrowth in target areas before considering transplanting vegetation from outside the pond. The expense of transplanting even from within the pond suggests that regrowth should be monitored for a year or two under any management scenario, to see how influential natural recolonization processes will be. Ultimately, however, it may be necessary to introduce desirable species to Morses Pond to limit control needs and reduce maintenance effort.

Summary

The plant community could be reset on a lakewide basis by dredging or the herbicide fluridone, but neither of these techniques can be applied quickly on a lakewide basis and other techniques will be needed to maintain the resultant desired conditions. Additionally, the use of fluridone at this time is inconsistent with the NRC’s IPM policy. Mechanical harvesting can keep rooted plant biomass at the desirable level in this system with the right equipment and sufficient operator time, and might foster a desirable community after multiple years of intensive application. Hand harvesting and benthic barriers are appropriate local control measures to be applied by volunteers and shoreline property owners either in areas too shallow to be addressed with harvesting or dredging or as a rapid response action to combat new invasions, such as the nearly annual appearance of water chestnut. Hydroraking represents an alternative to hand harvesting and benthic barriers for areas where removal of debris is also desired, such as in the Town swimming area. Other techniques are largely inappropriate for plant control in Morses Pond, including drawdown which would negatively impact water supply and grass carp which are illegal in Massachusetts and tend to cause algal blooms by nutrient regeneration. Multiple techniques will be needed to control plants in the target areas, however, with a combination of Town managed harvesting and volunteer supported hand pulling and benthic barrier placement suggested as the most effective approach over time. Monitoring of the plant community each year is viewed as essential, and it is likely to be advantageous to actively plant desirable species in key areas such as Areas 2 and 4.

PERMITTING

Nearly all management options evaluated in this report require some form of permitting to be implemented. If a considered option was subject to a definite regulatory restriction that would prevent its application to Morses Pond, that restriction has been pointed out (e.g., development of a detention facility in an area with a conservation restriction, stocking of grass carp, herbicide treatments on Town land). However, many techniques must go through an approval process that could result in modification or rejection, and planning for that process is part of management plant development.

Activities in the watershed intended to reduce pollutant loading to Morses Pond are mainly controlled by the Wetlands Protection Act, the Wellesley Wetlands Bylaw, and associated regulations and policies. Some activities will occur outside of the area of jurisdiction, such as drainage improvements on individual residential properties more than 100 ft from a wetland. Where runoff is discharged into the Wellesley municipal storm water system, a Town bylaw may govern some aspects of design and construction, but actions ultimately recommended for application in this watershed will be consistent with the intent of that bylaw. The only watershed action potentially subject to strong scrutiny under existing permit systems is the construction of larger detention facilities, as these would be associated with wetland resources (including streams as well as emergent wetlands). Any constructed detention area would likely be largely in an upland setting, with limited impacts to wetland resources. Where any wetland resource must be altered, performance standards would have to be met.

Within Morses Pond, the Wetlands Protection Act and Wellesley Wetlands Bylaw are again the primary controlling regulations, although other permit processes could be triggered. A Notice of Intent would be required for nearly all in-lake activities, with the possible exception of hand pulling of weeds or installation of benthic barriers, both of which could be exempted in accordance with the GEIR for lake management in Massachusetts (Mattson et al. 2004) through a Negative Determination of Applicability issued by the Conservation Commission. Of the actions considered for possible application to Morses Pond, the following methods would be subject to the associated additional permit processes:

Dredging –

- Section 404 approval, administered by the Army Corps of Engineers for possible impacts to wetlands and navigable waterways.
- Section 401 approval, administered by MA DEP for consistency between federal and commonwealth environmental regulations and general impacts on water quality.
- Possible NPDES regulations, administered by MA DEP and the USEPA, relating to the discharge from the dredged material dewatering area.
- Possible disposal regulations administered by MA DEP, depending upon the ultimate material use and disposal location.

Aluminum compound application -

- License to apply chemicals, issued by MA DEP, relating to impacts of chemical addition.

Algaecide application –

- License to apply chemicals, issued by MA DEP, relating to impacts of chemical addition.
- Wellesley NRC IPM policy, administered by the Wellesley NRC, relating to application of pesticides on Town property.

Fluridone herbicide application -

- License to apply chemicals, issued by MA DEP, relating to impacts of chemical addition.
- Wellesley NRC IPM policy, administered by the Wellesley NRC, relating to application of pesticides on Town property.

We know of no known protected species or habitat issues that would trigger review or a need for approval by the Natural Heritage and Endangered Species Program. The Section 401 approval process is required only when a state or federal permit is involved, which is clearly necessary only for dredging. If the Order of Conditions issued under the Wetlands Protection Act was appealed by parties with standing, approval would pass from Town commissions to the MA DEP, which would issue a Superceding Order of Conditions if the project was approved. In such a case, the Section 401 process may then apply. With rare exceptions, issuance of a valid Order of Conditions under the Wetlands Protection Act will be the key step in permitting any management action directed at Morses Pond.

Summary

Permitting for management actions for the improvement of Morses Pond consists mainly of approval under the Wetlands Protection Act and Wellesley Wetlands Bylaw. Additional permitting processes apply for dredging and any chemical additions to the pond. Rejection or modification of projects through relevant permitting processes is possible, and recommended actions should be crafted to be acceptable under existing regulations.

RECOMMENDED MANAGEMENT PLAN

Based on the management goals, associated needs, range of available options, and the foregoing consideration of those options, the following management program is suggested for Morses Pond.

Key Elements

I. Ongoing Management (current activities to be continued)

A. Algae and Water Clarity Control:

1. **Application of Town Bylaws** – Existing bylaws (e.g., wetlands, flood/watershed districts, water supply districts, storm water drainage system rules, each described in the section on management through ordinances) provide tools for reducing contaminant inputs to Morses Pond, either directly or through its tributaries. Application of these bylaws should continue, although a review of those bylaws and probable supplemental bylaws are recommended as a core management action below. Current costs are internalized as staff time within the Town budget. Costs for additional review and bylaw development are addressed in Section II of these recommendations.

2. **Town Property Management** – Wellesley adheres to policies and utilizes programs to acquire and maintain open space, park areas, and other lands under Town jurisdiction. Town commissions and boards have demonstrated an understanding of the linkage between land management and water quality, and should continue to consider land use impacts in both managing Town lands and in acquiring new parcels. Most costs are internalized as part of the budgets of each involved Town agency. Line items for land purchase may arise from time to time, but are not readily predictable.

3. **Education and Outreach –** Wellesley currently supports a part-time education coordinator through the Natural Resources Commission and conducts forums and programs for citizens and organizations that have the potential to impact water quantity and quality in the Morses Pond watershed. A brochure relating to storm water management was sent to all Town residents as part of the NPDES Phase II storm water management program, and a website is maintained for educational purposes focused on making residents aware of their potential impact of water resources. More must be done in this regard, particularly to advance the low impact development process to existing residential areas, and an expanded program is included in Section II of these recommendations.

4. **Algaecide Application and Monitoring** – The Recreation Department arranges for application of algaecides, always copper products to date, to limit algal density and related water clarity impairment in the vicinity of the Town swimming area. The average annual cost of actual treatment is on the order of $1100 for the last four years. A number of recommendations are made in Section II for the purpose of minimizing the need for algaecide application, but this technique will remain as an option for addressing algae as warranted in the future. The current practice of monitoring algal types and abundance allows informed treatment decisions and should be continued. Additional monitoring for water quality in the pond is also valuable to long-term management of water clarity and should be continued. Annual costs for the monitoring program have averaged about

$12,500. Alum has been applied only once in the last four years, to clear the water near the Town swimming area, at a cost of $9250. A more aggressive program of alum treatment is recommended in Section II.

5. **Water Circulation** – Small aerators deployed in the Town swimming area enhance circulation in that area and minimize accumulation of algae as surface scums. Such circulation may also hasten the death of certain problem bacteria through exposure to oxygen and improve dilution of any other contaminants in that area, but there are no data to allow a scientific evaluation. The use of these circulators may be continued and has no negative effect on the swimming area. Increased circulation in the swimming area might be considered at some future date, but application on a lakewide scale is not warranted. Current annual cost for this program is about $400.

B. Rooted Plant Biomass Control:

1. **Mechanical Harvesting** – A mechanical harvester is currently used during the summer months to remove rooted plant biomass where it is dense enough to impair pond uses. The current harvester is over 25 years old and is inadequate to cover the area where rooted plant control is needed, but its use can provide benefits, and adjustment of the procedural aspects of harvesting in 2005 led to enhanced conditions over a portion of the pond and a demonstration that harvesting could control rooted plants if adequate equipment and manpower were applied. An enhanced harvesting program is recommended in Section II. The current program costs the Town about $5000 to $6000 each year, although there was a major overhaul of the harvester in 2004 that cost an additional $42,115. The enhanced program will cost considerably more, in terms of both capital investment and ongoing operational expense, to meet use goals throughout the pond.

2. **Hand Harvesting** – A volunteer group currently seeks out and hand pulls water chestnut from Morses Pond each summer. Hand harvesting of this species should continue, and expansion of this approach to other species could be instituted in shallow areas where nuisance plant density is low and other techniques are inadequate to meet needs. The current program is not monetarily supported by the Town, although the Town assists with plant biomass disposal. Recommendations for program improvements are included in Section II.

3. **Hydroraking** – The Town currently contracts for hydroraking of the Town swimming area on an annual basis to remove plants and collect larger debris from that area. This is a small area relative to the area of Morses Pond in need of rooted plant control, but this approach enhances conditions in the Town swimming area for a cost of about $2500 per year. There is some interest in possibly expanding this effort to the “Old Town Beach” area, to facilitate boat access, and would carry additional cost. This technique could be applied to other shallow areas by private citizens as desired, after acquiring a permit under the Wetlands Protection Act, and such action is suggested as a possible supplemental action in Section III of these recommendations. However, other actions on a wider scale, most notably an enhanced harvesting program but also application of benthic barriers and hand harvesting, may negate the need for expanded hydroraking away from the Town beach.

II. Core Management Actions (new or altered actions implemented to meet use goals)

A. General:

1. **Professional Lake Manager Assistance** – Retain the services of a professional lake manager to oversee and coordinate all core management activities. This represents a commitment to getting knowledgeable leadership for the preparation of Requests for Proposals, bid evaluation, activity scheduling, grant applications, budget and technical planning support, data evaluation, and program coordination and adjustment. The Lake Manager would not have to be a Town employee, but would have a clear commitment to the management of Morses Pond with possible extension to other Town ponds and would devote a considerable amount of time to designated tasks as laid out in a contract. The Lake Manager would report to a designated supervisor and would communicate regularly with all interested Town boards and commissions.
   - ♦ Contract cost – $20,000 in the first year, then $51,000 to $55,000 per year.
   - ♦ Total cost over a 5 year period = $230,200.

B. Algae and Water Clarity Control:

1. **Phosphorus and Sediment Inactivation** - Install a buffered alum dosing station serving the northern basin (Area 1) and operate it from May through June, with possible use in July and August as warranted. Target storm events to get a reduction in phosphorus concentration and suspended solids (including algae, sediment, and even bacteria) levels that meet water clarity goals. Monitor phosphorus and turbidity on a weekly basis while the system is in operation. Monitor the build-up of settled material in the northern basin on an annual basis.
   - ♦ Design, permitting and related support costs – $20,000.
   - ♦ Capital cost - $133,000.
   - ♦ System operation cost over 5 years– $130,000 (includes inflationary factor).
   - ♦ Monitoring cost over 5 years – $29,000 (includes inflationary factor).
   - ♦ Total cost over a 5 year period = $312,000.

2. **Northern Basin Dredging** – Hydraulically dredge the northern basin (Area 1). Remove all soft sediment and some additional material to maximize detention, targeting 20,000 cy of sediment. Coagulate and belt press the removed material to minimize the containment area needs, most likely working near the beach complex between early September and late November. Ultimate disposal location is to be determined, but material has beneficial uses and is not a large quantity by construction standards. Conduct this dredging after at least two years of monitoring of the alum treatment system, to allow determination of the accumulation of solids relating to alum application and any necessary adjustments to protect the investment represented by dredging.
   - ♦ Design, permitting and related support costs – $100,000.
   - ♦ Capital cost - $500,000.
   - ♦ System operation cost – None.
   - ♦ Monitoring cost – $50,000 (construction oversight and related monitoring).
   - ♦ Total cost over a 5 year period = $650,000 (done only once).

3. **Watershed Education** – Conduct an ongoing education program, utilizing the Education Coordinator currently supported by the Town, with a focus on reducing loading of pollutants from residential areas. Emphasize the need to infiltrate precipitation into the ground rather than allowing runoff to occur, providing background on low impact runoff control techniques that property owners can employ. Also stress the lack of a need for

phosphorus in fertilizers for established lawns and the need to contain yard wastes. Create a website and a supporting brochure, and generate media coverage of the effort. Populate the website with interactive information about the best approaches for minimizing the impacts of urbanization on water resources in general and Morses Pond specifically. Utilize this website as a resource for teaching watershed residents, supporting information needs for desirable property management and addressing issues, questions and concerns by property owners. The website can also serve as a resource for education in the school system. Costs may be internalized to some degree, but estimates for outside assistance are provided here.

- Website development – $50,000.
- Brochure – $30,000.
- Periodic updates and reprinting over 5 years - $12,200 (includes inflationary factor).
- Monitoring cost over 5 years - $18,000 (repeated survey of attitude and practice changes).
- Total cost over a 5 year period = $110,200.

4. **Review and Development of Land Management Bylaws** – Perform a thorough review of existing Town bylaws and related regulations (including state and federal statutes) to determine where improvements are needed to more adequately protect Morses Pond. Develop improved or new bylaws to meet protection needs and support other management efforts such as Low Impact Development. Enhancements may include application of existing rules or policies on a smaller scale (e.g., to all parcels, not just those above certain thresholds) or development of new bylaws to address problems associated with new construction (e.g., limiting impervious surface area). Assist the Town in moving any new or revised bylaws through the approval process.
   - Review and bylaw development costs – $75,000.
   - Education cost – part of education program (Section II.4).
   - Monitoring cost – part of Low Impact Development program (Section II.6).
   - Total cost over a 5 year period = $75,000.

5. **Low Impact Development Program** - Implement Low Impact Development techniques on existing and new residential sites. Build on the education program that informs residents of the need and opportunities for storm water management, providing support and incentives to manage storm water. Conduct demonstration projects on Town property in various locations to showcase this approach. Support private application with technical advice, design support and monitoring assistance. Encourage adoption of this approach in Natick and Weston as well.
   - Design, permitting and related support costs – $100,000.
   - Capital cost - Uncertain; 1000 sites at $1000 per site = $1,000,000, which would be a substantial start, with costs borne by property owners. Assume $25,000 in Town demonstration projects as examples for the community.
   - System operation cost – None.
   - Monitoring cost – Uncertain; selected site specific monitoring set at $17,000 for several years of a program, with evaluation and adjustment thereafter.
   - Total cost over a 5 year period = $142,000 to the Town; private costs in excess of $1,000,000 over a more extended period of time.
   - This effort could be accelerated to the extent that funds are available and cooperation is obtained, but a 10 to 20 year process is envisioned.
   - Note that this would not address all possible sites in Wellesley or any in Natick and Weston.

B. Rooted Plant Biomass Control:

1. **Enhanced Mechanical Harvesting** – Purchase harvesting equipment capable of harvesting plants over a 41-acre area in under 5 weeks and commit to the labor necessary to aggressively harvest in Areas 2, 3, 4 and 6 for four months per year. Harvest from mid-May through June, after which the harvester can be used in other ponds (if the expected level of control is achieved) until mid-August, when harvesting in Morses Pond would resume through mid-September. Gradually shift the focus from overall plant biomass reduction to control of nuisance species with encouragement of desirable species. Monitor plants at established locations on an annual basis in September. Consider installing a floating plant fragment barrier around major harvesting areas or the Town swimming area if fragment entry to the swimming area is unacceptably high.
   - ♦ Design, permitting and related support costs – $40,000.
   - ♦ Capital cost - $250,000.
   - ♦ System operation cost over 5 years – $250,800 (includes inflationary factor for labor and maintenance).
   - ♦ Monitoring cost over 5 years – $12,400 (includes some inflation).
   - ♦ Total cost over a 5 year period = $553,200.

2. **Manual Harvesting and Benthic Barrier Placement** – Continue the water chestnut harvesting program, which has been a volunteer effort, providing equipment to enhance efficiency and comfort for the volunteers as warranted. Encourage shoreline residents to manage weeds in shallow areas not accessible to the harvester and around docks and other structures where the harvester cannot work effectively. Such management would involve hand pulling or manually raking plants in <2 feet of water and applying benthic barrier around docks or other structures as needed to supplement control by harvesting. Facilitate acquisition of a permit under the Wetlands Protection Act to allow all interested shoreline residents who would like to apply these techniques to do so. Establish thresholds for reasonable plant removal (not to exceed 10% of littoral zone by the MA GEIR, but also set a reasonable linear threshold for shoreline management, most likely 50 ft per property parcel), and hold a training session for proper application. Costs for materials and labor would be borne by shoreline residents.
   - ♦ Design, permitting and related support costs – $10,000.
   - ♦ Hand harvesting capital support - $5000 (e.g., boat, electric motor, disposal container).
   - ♦ Hand harvesting labor – Internalized by residents and volunteers, estimated at up to $25,000 in value as an annual cost.
   - ♦ Benthic barrier materials – Cost assumed by private users, estimated at $120,000 for 3 acres of managed area.
   - ♦ Benthic barrier labor - Internalized by residents, estimated at up to $25,000 in value as an annual cost.
   - ♦ Monitoring over 5 years - $4,100 for site inspections (includes inflationary factor).
   - ♦ Barrier would be re-useable indefinitely (assume 10-20 years).
   - ♦ Hand harvesting and benthic barrier use would be mutually exclusive in any given area; costs for one negate the need for expense on the other.
   - ♦ Total cost over a 5 year period = $19,100 to the Town, up to $180,000 for private users, although the $60,000 labor allocation might be by volunteers.
   - ♦ These techniques supplement mechanical harvesting, and are not suitable for larger areas of the pond.

3. **Selective Planting** – It is likely that desirable native species will not colonize and become dominant in response to any plant control technique fast enough to provide maximum limitation of nuisance species invasion. While several years of rooted plant management and monitoring should be conducted before proceeding with any plant introduction, the active addition of desirable species through planting should be considered. Planting programs are still somewhat experimental and methods are under development and refinement. Assume an actual planting cost of $10,000 per acre, based on recent programs, with Areas 2 and 4 (15 acres) as the likely initial targets.
   - Design, permitting and related support costs – $10,000.
   - Capital cost - $150,000.
   - Monitoring cost over 5 years – $10,000.
   - Total cost over a 5 year period = $170,000.

III. Supplemental Management (actions to be considered if core elements do not meet needs)

A. Algae and Water Clarity Control:

1. **Expanded Upstream Detention** – Establish detention systems wherever land availability allows, with the identified area upstream of Reeds Pond as the logical first location. Resolve the conservation restriction at Kelly Park that current inhibits maximally effective detention at that site. Identify additional areas or acquire land opportunistically to support this program. Monitor results locally to determine the loading reductions achieved.
   - Design, permitting and related support costs – $80,000.
   - Capital cost - $420,000.
   - System operation cost – $12,000 over 5 years after construction (maintenance).
   - Monitoring cost – $12,000 over 5 years.
   - Note that the above costs cover only the identified area upstream of Reeds Pond. Assume $50,000 in investigations for additional areas and two more such detention systems at $1 million each over an extended time period.
   - Total cost = $2,574,000 (provides only 25% of the desired upstream detention).

2. **Storm Water Diversion and Treatment** – Should there be insurmountable issues with the application of aluminum compounds in the northern basin (Area 1), it may be possible to collect and treat storm water outside of the pond. The logical alternative discussed in this report is routing some portion of the Bogle and Boulder Brooks storm flows within or along the Cochituate Aqueduct to a location on Town land near the water treatment facility and beach complex, allowing for treatment in a containment area and discharge from that point, most likely into the pond. It may also be possible to acquire property along Route 9 at a much higher cost, creating the containment and treatment area at such a location. Approximate costs are suggested here, but until a site is selected, these are very uncertain.
   - Design, permitting and related support costs – $125,000.
   - Capital cost - $700,000.
   - System operation cost – $142,200 (same unit costs as for in-lake system, five year period, but option initiated later in time).
   - Monitoring cost – $38,300 (same process as for in-lake system, initiated later).
   - Total cost = $1,005,500 (provides 5 years of operation).

B. Rooted Plant Biomass Control:

1. **Selective Dredging** – Hydraulically dredge Areas 2 and 4 if the harvesting program does not provide acceptable conditions by itself. Remove all soft sediment from these areas, targeting a total of 60,000 cy. Also dredge the nearshore portion of Area 6, targeting a total of 20,000 cy. Coagulate and belt press the removed material to minimize the containment area needs, most likely working near the beach complex between early September and late November over a period of four years (20,000 cy each year). Ultimate disposal location is to be determined, but this material has beneficial uses.
   - Design, permitting and related support costs – $300,000.
   - Capital cost - $1,500,000 (2005 dollars, no inflation assumed).
   - System operation cost – None.
   - Monitoring cost – $200,000.
   - Total cost = $2,000,000.

2. **Expanded Hydroraking** – The Town will continue periodic hydroraking of the swimming area for plant and debris control. This is a minor effort not considered as a significant component of plant management in the pond overall. However, shoreline residents may wish to capitalize on the presence of equipment when the swimming area is hydroraked. Such action would reduce the need for nearshore hand harvesting or benthic barrier placement, but is less selective, will not eliminate some species, and will require more shoreline clean-up afterward (plants, debris and sediment). It should not be necessary if a thorough dredging is performed in any target area. Costs would be borne by all property owners using the service. A permit would be needed, perhaps acquired on behalf of a group as a single approval process.
   - Design, permitting and related support costs – $10,000 (could be internalized by Town staff).
   - Contract cost – Average of up to $20,000 every year (assumes 3 acres, disposal by property owners) or $100,000 over 5 years, funded by private property owners.
   - Monitoring cost – $5,200 (simple check of nearshore conditions each year, with inflationary factor), supported by Town.
   - Total cost = $115,200 (plus any disposal costs), but only $15,200 would be expended by the Town.

3. **Test Fluridone Treatment** – The current policy of the Natural Resources Commission with regard to integrated pest management does not allow the use of pesticides (including herbicides) on Town resources without first attempting non-chemical means of control and demonstrating a health or safety threat associated with non-treatment. If treatment of Morses Pond with herbicides becomes eligible for consideration in Wellesley, seek to perform a fluridone demonstration project in Area 2. Sequester the area and treat with 6-10 ppb for at least 90 days, boosting the concentration whenever it approaches 6 ppb. This recommendation would be nullified by implementation of the above dredging recommendation, as dredging should provide the level of control of unwanted species that would be gained from fluridone treatment.
   - Design, permitting and related support costs – $7500.
   - Capital cost - $15,000.
   - System operation cost – None.
   - Monitoring cost – $7500.
   - Total cost = $30,000 (test only; expansion to more areas would cost much more).

Program Costs

The cost to the Town for current management is estimated at $25,000 per year, exclusive of staff time other than that expended by the actual harvester operator and not considering power, fuel and some other costs difficult to itemize. Including a small inflationary factor, a projected five year cost of $130,000 is derived. The cost of the core elements of the plan in Section II is itemized in Table 6 and totals to approximately $2.3 million, to be expended over a five year program period and overlapping with the current program costs by at least $68,000. It is possible that nearly all current program costs would be eliminated if the recommended program was successful. If the program was continued for another 15 years beyond the initial five year period described above, additional operational costs are estimated to require an additional $2.4 million. Supplemental management options, to be considered only if needs are not met by the core elements, are itemized in Table 7. The total cost for supplemental actions is approximately $6 million over a hypothetical operational period comparable to the 5-year recommended program, but this is not a particularly relevant figure, as some options are mutually exclusive and the timing of application is flexible and will affect costs.

Permitting

Recommended actions have nearly all been applied in the past, albeit not necessarily in the form or at the scale being recommended now. Permitting for most actions consists of approval under the Wetlands Protection Act and the Wellesley Wetlands Bylaw, with phosphorus inactivation also requiring a License to Apply Chemicals to cover the addition of aluminum compounds. Dredging also requires approval under Sections 401 and 404 of the Clean Water Act. All of these permits have been granted in the past for work on Morses Pond, and no significant problems are anticipated in getting approval for the recommended actions.

Timeline for Implementation

The costs in Table 6 provide an indication of the implementation schedule, but as the fiscal year for Wellesley begins on July 1st and the period for most in-lake management activities spans the period of May into September, some additional explanation is needed to foster a complete understanding of the proposed implementation schedule. Dates can be adjusted to meet planning, financial or regulatory needs, but are proposed here to maximize the benefit to the pond in a realistic timeframe (Table 8).

Summary

The recommended plan expands on current management actions to achieve goals for water clarity and rooted plant biomass that will facilitate all desired uses of Morses Pond. Long-term algae and suspended solids control to increase water clarity should focus on watershed management, with application of Low Impact Development techniques wherever possible over an extended period of time (10-20 years). This approach should be facilitated by an education program and review and enhancement of Town bylaws. To support desired uses in the interim and provide back-up control for very wet spring-summer periods, injection of aluminum compounds into the northern basin of the pond is suggested. To reverse the effects of past inputs and maximize detention capacity in the northern basin of Morses Pond, that portion of the pond should be thoroughly dredged (removal of approximately 20,000 cubic yards of sediment). Additional techniques have been identified that might improve conditions if the recommended approach is not sufficient.

Table 6. Morses Pond Core Management Plan Elements, Timeline and Cost

	Cost ($) over Time					
Element	**FY07**	**FY08**	**FY09**	**FY10**	**FY11**	**Total**
Core Elements (planned management)						
Professional Lake Manager	$20,000	$51,000	$52,020	$53,060	$54,122	**$230,202**
Water Clarity						
Phosphorus/sediment Inactivation						
Design, permitting, other support	$20,000					$20,000
Construction	$133,000					$133,000
Operation	$25,000	$25,500	$26,010	$26,530	$27,061	$130,101
Monitoring		$7,000	$7,140	$7,283	$7,428	$28,851
Subtotal						**$311,952**
Dredging Area 1						
Design, permitting, other support		$100,000				$100,000
Construction			$500,000			$500,000
Monitoring			$25,000	$25,000		$50,000
Subtotal						**$650,000**
Education						
Website design and population	$30,000	$20,000				$50,000
Brochure		$30,000				$30,000
Updates/expansion			$4,000	$4,080	$4,162	$12,242
Monitoring	$5,000		$6,000		$7,000	$18,000
Subtotal						**$110,242**
Bylaw review and enhancement						
Bylaw review and development		$50,000	$25,000			$75,000
Subtotal						**$75,000**
Low impact development						
Design, permitting, other support		$50,000	$20,000	$20,000	$10,000	$100,000
Construction - Town demonstration		$25,000				$25,000
Construction - Private parties			Private	Private	Private	$0
Monitoring		$3,500	$4,000	$4,500	$5,000	$17,000
Subtotal						**$142,000**
Rooted Plants						
Enhanced harvesting						
Design, permitting, other support	$40,000					$40,000
Equipment purchase	$250,000					$250,000
Operation	$20,000	$56,000	$57,120	$58,262	$59,428	$250,810
Monitoring		$3,000	$3,060	$3,121	$3,184	$12,365
Subtotal						**$553,175**
Manual harvesting/benthic barriers						
Design, permitting, other support		$10,000				$10,000
Hand harvesting labor	Volunteer	Volunteer	Volunteer	Volunteer	Volunteer	$0
Hand harvesting support	$5,000					$5,000
Benthic barrier materials		Private	Private	Private	Private	$0
Benthic barrier labor		Volunteer	Volunteer	Volunteer	Volunteer	$0
Monitoring		$1,000	$1,020	$1,040	$1,061	$4,122
Subtotal						**$19,122**
Selective planting						
Design, permitting and other support			$10,000			$10,000
Planting				$75,000	$75,000	$150,000
Monitoring				$4,000	$4,000	$8,000
Subtotal						**$168,000**
Total	**$548,000**	**$432,000**	**$740,370**	**$281,877**	**$257,445**	**$2,259,692**

Table 7. Morses Pond Supplemental Management Plan Elements, Timeline and Cost

	Cost ($) over Time								
Element	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Total**
Supplemental Management (if needed)									
Water Clarity									
Expanded upstream detention									
Design, permitting and other support	$80,000		$125,000		$125,000				$330,000
Construction		$420,000		$900,000		$900,000			$2,220,000
Operation (maintenance)			$2,000		$4,000		$6,000		$12,000
Monitoring			$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$12,000
Subtotal									**$2,574,000**
Storm water diversion and treatment									
Design, permitting and other support	$125,000								$125,000
Construction		$700,000							$700,000
Operation		$27,876	$28,155	$28,436	$28,721	$29,008			$142,196
Monitoring		$7,505	$7,580	$7,656	$7,732	$7,810			$38,283
Subtotal									**$1,005,479**
Rooted Plants									
Dredging Areas 2, 4 and part of 6									
Design, permitting and other support	$150,000	$150,000							$300,000
Construction			$500,000	$500,000	$500,000				$1,500,000
Monitoring			$50,000	$50,000	$50,000	$50,000			$200,000
Subtotal									**$2,000,000**
Hydroraking									
Design, permitting and other support	$10,000								$10,000
Contract hydroraking - private shoreline	Private	Private	Private	Private	Private				Private
Monitoring	$1,000	$1,020	$1,040	$1,061	$1,082				$5,204
Subtotal									**$15,204**
Fluridone test treatment									
Design, permitting and other support	$7,500								$7,500
Treatment		$15,000							$15,000
Monitoring		$2,500	$2,500	$2,500					$7,500
Subtotal									**$30,000**
Supplemental actions are mutually exclusive in some cases and years of application will be flexible; annual totals are not appropriate at this time.									

Table 8. Morses Pond Core Management Plan Timeline Details

	Actions over Time				
Element	**FY07**	**FY08**	**FY09**	**FY10**	**FY11**
Core Elements (planned management)					
Professional Lake Manager	Hire manager by end of summer 2006, prepare RFPs for harvester and phosphorus inactivation by end of calendar year	Prepare RFP for dredging, follow up on implementation of harvesting and phosphorus inactivation	Follow up on implementation of all program elements	Follow up on implementation of all program elements	Follow up on implementation of all program elements
Water Clarity					
Phosphorus/sediment Inactivation					
Design, permitting, other support	Prepare design, acquire permits, get bids and select contractor(s) by February 2007				
Construction	Construct and test system by end of May 2007				
Operation	Operate in June 2007	Operate in July 2007, May-June 2008	Operate in July 2008, May-June 2009	Operate in July 2009, May-June 2010	Operate in July 2010, May-June 2011
Monitoring		Monitor in July 2007, May-June 2008	Monitor in July 2008, May-June 2009	Monitor in July 2009, May-June 2010	Monitor in July 2010, May-June 2011
Dredging Area 1					
Design, permitting, other support		Prepare design and acquire permits by June 2008, select contractor			
Construction			Perform dredging in Sept-Nov 2008; Follow up dredging as warranted in April-June 2009	Complete any containment area restoration by September 2009	
Monitoring			Construction monitoring during dredging	Results and restoration monitoring	

Table 8 (Continued). Morses Pond Core Management Plan Timeline Details

	Actions over Time				
Element	**FY07**	**FY08**	**FY09**	**FY10**	**FY11**
Core Elements (planned management)					
Education					
Website design and population	Design website and add relevant materials	Expand and improve website, use to support LID program			
Brochure		Prepare and distribute brochure			
Updates/expansion			Update as needed	Update as needed	Update as needed
Monitoring	Survey attitudes and practices prior to website and brochure		Survey attitudes and practices after website and brochure		Re-survey attitudes and practices after website and brochure
Bylaw review and enhancement					
Bylaw review and development		Perform review, craft revisions and additions as warranted	Support approval process		
Low impact development					
Design, permitting, other support		Design systems for town properties, private ones as feasible	Assist private development to meet LID standards	Assist private development to meet LID standards	Assist private development to meet LID standards
Construction - Town demonstration		LID demonstration projects			
Construction - Private parties		Conduct LID projects	Conduct LID projects	Conduct LID projects	Conduct LID projects
Monitoring		Monitor results	Monitor results	Monitor results	Monitor results
Rooted Plants					
Enhanced harvesting					
Design, permitting, other support	Prepare bid specs by October 2006, acquire permits by April 2007, train operator(s) by May 2007				
Equipment purchase	Acquire new harvesting equipment by May 2007				
Operation	Harvest in May-June 2007	Harvest in July-Sept 2007, May-June 2008	Harvest in July-Sept 2008, May-June 2009	Harvest in July-Sept 2009, May-June 2010	Harvest in July-Sept 2010, May-June 2011
Monitoring		Plant community assessment in September 2007	Plant community assessment in September 2008	Plant community assessment in September 2009	Plant community assessment in September 2010
Manual harvesting/benthic barriers					
Design, permitting, other support		Develop program for interested shoreline residents, acquire permits, train potential users			
Hand harvesting labor	Remove water chestnut	Remove water chestnut andother invasive species	Remove water chestnut andother invasive species	Remove water chestnut andother invasive species	Remove water chestnut andother invasive species
Hand harvesting support	Acquire boat and equipment for volunteer group				
Benthic barrier materials		Get materials	Get materials	Get materials	Get materials
Benthic barrier labor		Apply barrier	Apply barrier	Apply barrier	Apply barrier
Monitoring		Inspect target areas	Inspect target areas	Inspect target areas	Inspect target areas
Selective planting					
Design, permitting and other support			Develop plan, acquire permits		
Planting				Perform planting	Perform planting
Monitoring				Monitor results	Monitor results

Rooted plant management would appear to be most effectively achieved by an enhanced mechanical harvesting program utilizing new equipment and requiring more operator time. Hand pulling and benthic barrier placement can support this approach on a localized basis, addressing new infestations in small areas or shoreline growths not addressed by mechanical harvesting due to shallowness or obstructions. Hydroraking may be substituted for hand pulling and bottom barriers in areas where debris control is also warranted. Additional techniques have been identified, evaluated and cost estimated for possible use if the recommended program is not sufficient.

The cost to the Town for current management is estimated at more than $25,000 per year, with a projected five year cost in excess of $130,000. The cost of the core elements of the recommended plan is almost $2.3 million, to be expended over a five year program period and eliminating most of the current program costs. Continuation of the recommended program for another 15 years beyond the initial five year period described above is projected to cost an additional $2.4 million. Supplemental management options, to be considered only if needs are not met by the core elements, could cost approximately $6 million over a hypothetical period of 5 to 8 years, but these options may not be needed at all, some options are mutually exclusive, and the timing of application is flexible and will affect costs.

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APPENDIX:

SUPPORTING INFORMATION RELATING TO SPECIFIC MANAGEMENT OPTIONS

Topics in Order

EVALUATION OF MANAGEMENT POTENTIAL IN THE MORSES POND WATERSHED

Reasons to apply this approach:
- Attacks phosphorus and other contaminant loading at or near the source
- Relocates detention function of MP to upstream areas, potentially improving MP condition
- Maximizes water quality and biotic enhancement throughout the watershed and stream system, not just in MP
- Creates tighter link between watershed activities and management needs/actions

Target areas:
- Watershed divided into 7 drainage areas (see summary table below and Morses Pond Watershed and Land Use figures in the Appendix):
    1. Upper Bogle Brook, mostly in Weston
    2. Lower Bogle Brook, in Wellesley and Weston
    3. Boulder Brook, mostly in Wellesley
    4. Jennings Brook, in Natick and Weston
    5. North Basin, including the upper part of MP and surrounding land south of Rte 9 but north of the islands
    6. Natick direct drainage, just west of MP
    7. Wellesley direct drainage, just east of MP
- All of the above contribute directly or indirectly to the main body of MP, including the south basin, with town beach and adjacent well field

Summary of Land Use Area for Morses Pond Subbasins

BASIN	AREA (acres)				
	Urban	Agric	Forest	Open	Total
Basin 1 - Upper Bogle	1022.8	54.6	782.2	90.5	1950.0
Basin 2 - Lower Bogle	746.3	4.0	232.7	16.5	999.6
Basin 3 - Boulder	614.4	0.0	78.6	17.9	710.8
Basin 4 - Jennings	963.2	8.4	350.0	165.1	1486.7
Basin 5 - North Basin	20.1	0.0	3.3	8.7	32.1
Basin 6 – Direct Drainage - Natick	147.6	0.0	61.1	19.0	227.7
Basin 7 - Direct Drainage - Wellesley	223.8	0.0	93.1	114.1	431.0
Total Area (acres)	3738.2	67.1	1601.0	431.7	5837.9
Percent of Total	64	1	28	7	100

Loading analysis:
- Simple spreadsheet model used to generate loads in drainage areas based on land use, route the load to MP, attenuate the load by natural means or existing BMPs en route, and predict existing conditions in MP.
- Calibrated with actual water quality data where available
- Current conditions:
    - Confluence of Bogle and Jennings Brooks (entry to Morses Pond) – annual average 0.05-0.11 mg/L phosphorus, 1.13-1.74 mg/L nitrogen

    - North Basin – annual average 0.03-0.06 mg/L phosphorus (suggests 40% attenuation in the north basin), 0.42-0.60 mg/L nitrogen
    - South Basin – annual average 0.01-0.05 mg/L phosphorus, 0.19-1.50 mg/L nitrogen
- After adjustment to make flows and concentrations approximate known field conditions, the results of the model predict a phosphorus load to Morses Pond of 0.025-0.030 mg/L and a nitrogen load of 0.360-0.397 mg/L. See tables A1 and A2 in the Appendix for a loading summary by basin.
- The majority of phosphorus and nitrogen entering Morses Pond is contributed by low and medium residential areas and highways.
- Current loading scenario assumes the following attenuation coefficients (40% attenuation means 60% phosphorus or nitrogen capture/removal) per basin:

Basin	Attenuation - P	Attenuation - N
Upper Bogle	40%	50%
Lower Bogle	60%	60%
Boulder	60%	60%
Jennings	40%	50%
Upper Morses	50%	50%
Direct - Natick	60%	80%
Direct - Wellesley	60%	80%

  It is assumed that the basins containing ponds, Upper Bogle (Nonesuch Pond) and Jennings, will have greater phosphorus removal (lower attenuation coefficient) than the other basins. Attenuation factors for the other basins were chosen based on land forms and known BMPs, and were calibrated using real data.
- Desirable phosphorus loading is 0.020 mg/L or less (0.010 mg/L would be ideal but not realistic for this watershed). This loading could be achieved by decreasing the attenuation (increasing the phosphorus removal) of the basins flowing into Morses Pond.

Options for management:

- Four basic options:
    1. Eliminate sources – convert land to lower impact uses, restrict land uses or activities
    2. On-site source control – minimize generation and release of contaminants
    3. Downstream pollutant trapping – creation of detention and/or infiltration systems to trap pollutants from upstream
    4. In-lake management – addressing pollutants once in the lake, as with alum treatment, dredging, circulation, algaecides, etc.
- Source elimination – difficult to enact and enforce on private land, especially outside Wellesley; focus on education, but consider bylaw adjustments
- On-site source controls – focuses on low impact development and retrofits, capturing runoff and re-using as irrigation water highly desirable, rain gardens or rooftop collection and infiltration useful in many cases, need to educate and provide incentives
- Downstream pollutant trapping – usually necessary when watershed:lake area ratio is large and urbanization is substantial; usually requires 2-7% of watershed area for detention or infiltration facilities (100+ acres in this case) – difficult to find enough appropriate area. Most of the watershed (79%) lies outside of Wellesley. Sites for consideration would have the following characteristics:
    - Sites adjacent to major tributaries with significant upstream watershed
    - Sites with flat slopes
    - Non-wetland sites
    - Sites containing soils conducive to infiltration
- Specific sites to be considered for downstream pollutant trapping include:
    - Open space adjacent to Wellesley Lower Basin of Morses Pond

  - Lower Bogle Brook, channel upstream of Reeds Pond
  - Kelly Park (Boulder Brook Reservation)
  - Others per review with Wellesley DPW
- In-lake management – not really part of watershed management approach, but often have limited alternatives in urbanizing watersheds, and in-lake options can help mitigate impacts

Potential for improvement:
- Dredging of northern basin (Area 1 of lake, Drainage basin 5 in watershed) – Increasing average depth by 1-2 ft would increase detention by 20-30%, expect increased P attenuation from 50% to 40% (from 50 to 60% capture)
- Greatest practical BMPs in basins controllable by Wellesley:
  - Decreasing the attenuation coefficient of the Lower Bogle Brook Basin to 40% reduces the phosphorus load to 0.026 mg/L
  - Decreasing the attenuation coefficient of the Boulder Brook Basin to 40% reduces the phosphorus load to 0.028 mg/L
  - Decreasing the attenuation coefficient of the Direct Drainage – Wellesley Basin to 40% reduces the phosphorus load to 0.026 mg/L
  - Decreasing the attenuation coefficients of Lower Bogle, Boulder Brook, and the Wellesley Direct Drainage basins reduces the phosphorus load to 0.024 mg/L
  - Decreasing the attenuation coefficients of the three basins above in addition to dredging the North Basin of Morses Pond (decrease attenuation of North Basin to 40%) reduces the phosphorus load to 0.021 mg/L

Needed actions:
- Education to minimize sources – ongoing, past work admirable, but more needed. Must continually remind and catch new people, seek to measure changes in homeowner actions based on education. Generally not expected to provide >?10-20% change, but a valuable component for both load reduction and gaining support for other actions.
- LID (Low Impact Development) techniques – need to provide incentive for establishing infiltration of roof runoff, detention of rainwater (rain gardens), and most critically, use of captured precipitation and runoff for irrigation.
- Pollutant trapping – need to look for detention opportunities; do not expect to find large parcels, so need to find many smaller ones, avoid flood issues, avoid water supply issues, yet detain runoff. A very difficult task in this watershed; best potential is in association with re-development.
- By-Laws – if possible, need by-law adjustment or creation to limit lawn fertilization (require soil testing first), require detention/infiltration in association with re-development (tear-downs), create incentives for LID.

Cost:
- Dredging handled in a separate info sheet
- Rough rule for minimum structural BMP expense is $50,000/acre, and >100 ac of activity needed, so expect at least $5M to be spent on BMPs; due to high cost of land in this watershed area, cost could exceed $10M

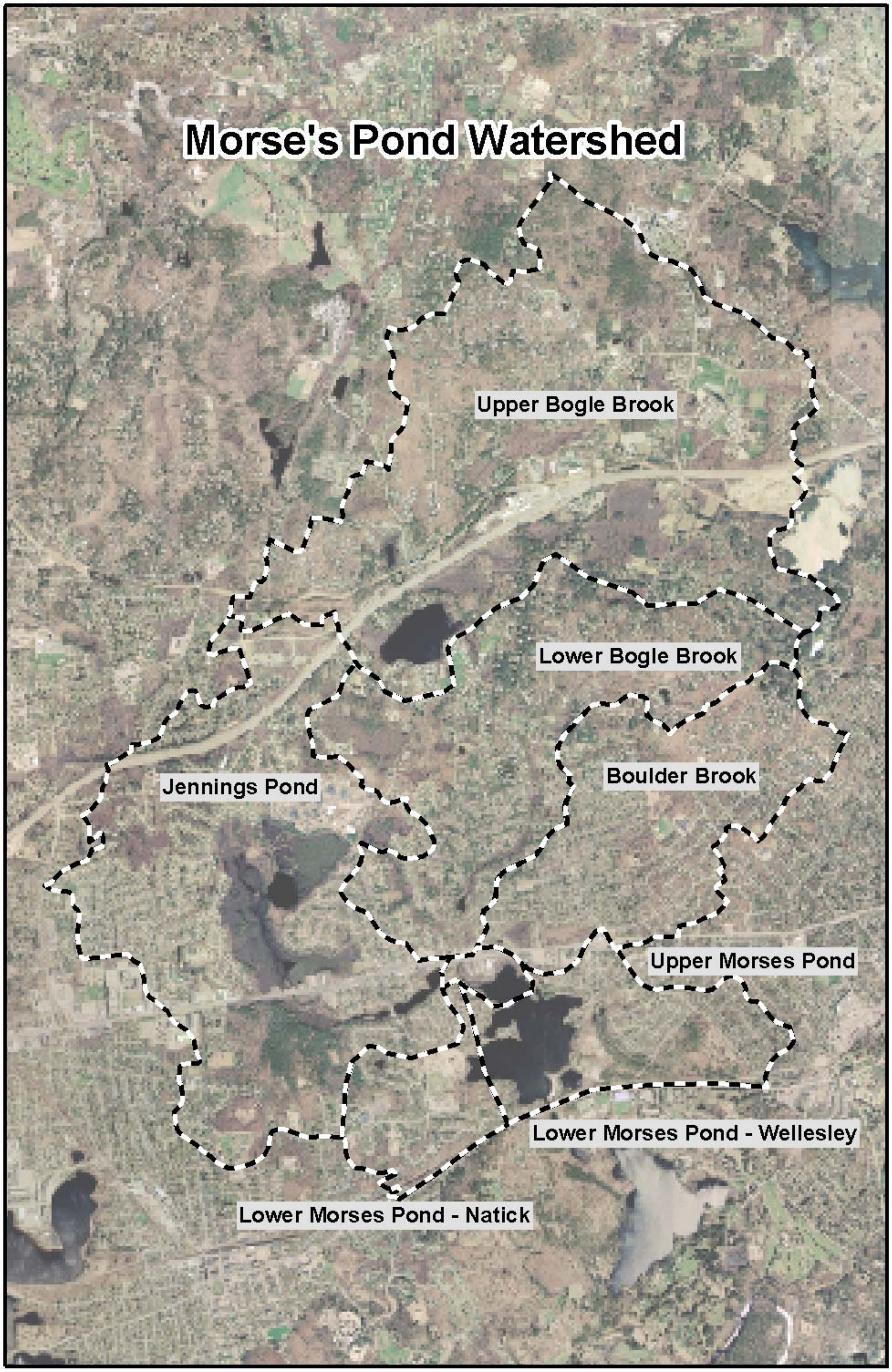
Table A1 – Phosphorus Loading Summary by Basin

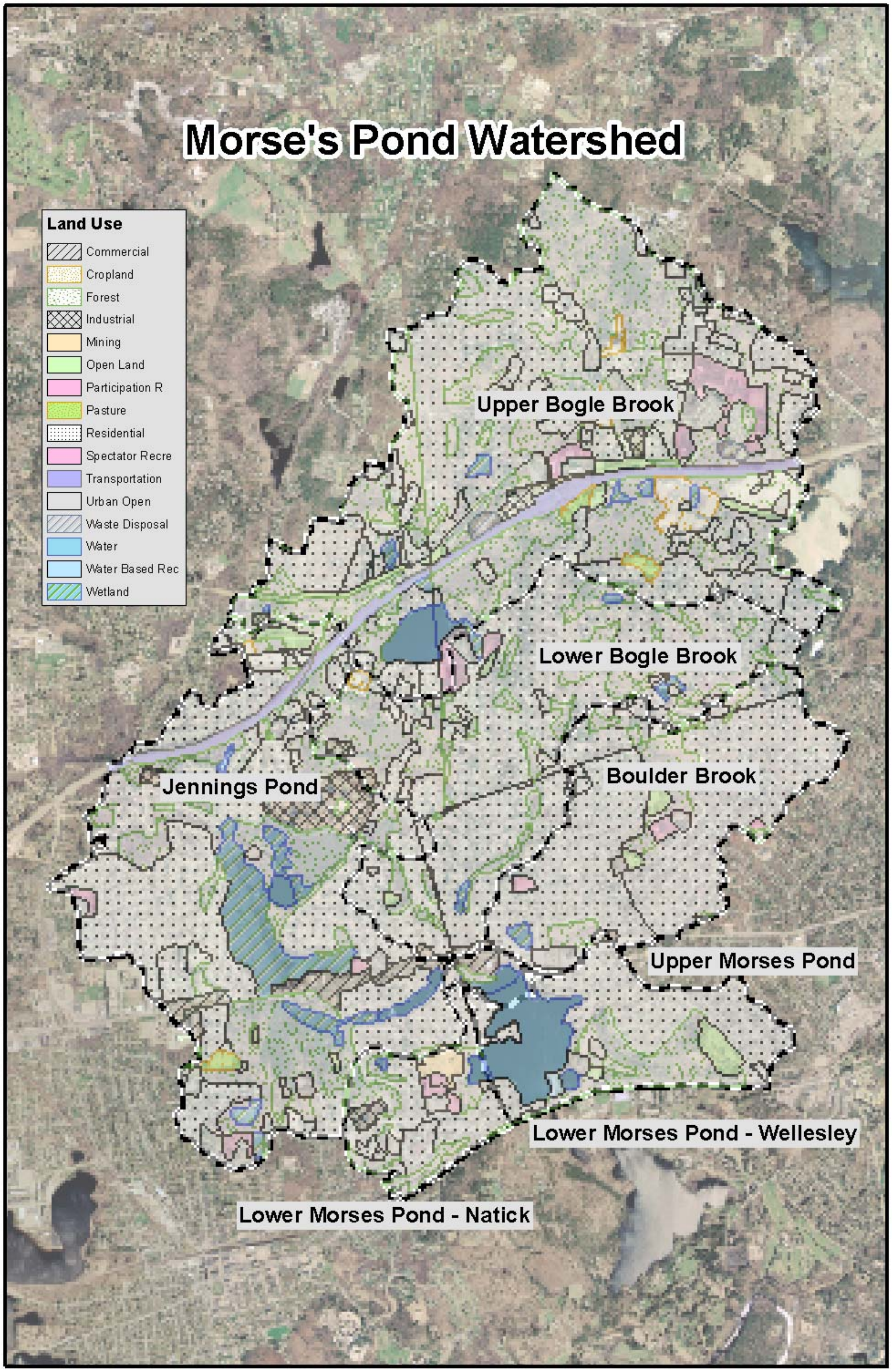
LOAD AND CONCENTRATION SUMMARY: PHOSPHORUS							
	Upper Bogle	Lower Bogle	Boulder	Jennings	North Basin	S. Basin Natick	S. Basin Wellesley
OUTPUT (CU.M/YR)	5250890	7822128	1886971	3878964	10940349	608937	1069319
OUTPUT (KG/YR)	200.9	300.0	140.6	160.5	304.7	38.5	59.7
OUTPUT (MG/L)	0.038	0.038	0.075	0.041	0.028	0.063	0.056

Table A2 – Nitrogen Loading Summary by Basin

LOAD AND CONCENTRATION SUMMARY: NITROGEN							
	Upper Bogle	Lower Bogle	Boulder	Jennings	North Basin	S. Basin Natick	S. Basin Wellesley
OUTPUT (CU.M/YR)	5250890	7822128	1886971	3878964	10940349	608937	1069319
OUTPUT (KG/YR)	2935.9	2305.2	1710.9	2471.6	3295.7	614.3	996.1
OUTPUT MG/L	0.559	0.295	0.907	0.637	0.301	1.009	0.932

Note: Lower Bogle Brook loading is the sum of Upper and Lower Bogle inputs, attenuated through each basin; Lower Bogle loads include remaining Upper Bogle loads. Likewise, North Basin load is the cumulative load of Bogle, Boulder and Jennings passed through the North Basin and delivered to the South Basin; it is not a separate load from just the small area of land and water associated with the North Basin.


Morse's Pond Watershed
Upper Bogle Brook
Lower Bogle Brook
Boulder Brook
Jennings Pond
Upper Morses Pond
Lower Morses Pond - Wellesley
Lower Morses Pond - Natick


Morse's Pond Watershed
Land Use
Commercial
Cropland
Forest
Industrial
Mining
Open Land
Participation R
Pasture
Residential
Spectator Recre
Transportation
Urban Open
Waste Disposal
Water
Water Based Rec
Wetland
Upper Bogle Brook
Lower Bogle Brook
Boulder Brook
Jennings Pond
Upper Morses Pond
Lower Morses Pond - Wellesley
Lower Morses Pond - Natick

MORSES POND DREDGING EVALUATION OUTLINE

Reasons For Dredging:
- Regain detention capacity in northern basin (Area 1)
- Alter/reduce rooted plant growths (substrate and/or light limitation)
- Reduce internal nutrient reserves/recycling

Existing and Proposed Bathymetry:
- See bathymetric map
- Existing mean depths and volumes in accompanying table
- Dredging of soft sediment would regain <1 ft avg depth in Area 1, 2-3 ft in Areas 2-6
- Represents a volume increase of 20% in Area 1, 34% for Area 2, 45-58% for Areas 3-6

Volume Of Material To Be Removed:
- In-situ volume to be removed shown in accompanying table, by area
- Most sediment is part sand, part organic muck; only two samples (one near Bogle inlet and one near the borders of Areas 3, 4 and 7) had substantial solids content; all others were <20% solids, typical of lake sediments. Will expand to about 1.5 to 2 times in-situ volume upon removing, then compact to lower volume (usually about 0.5 time in-situ volume) through dewatering.

Physical Nature of Material To Be Removed:
- Grain size distribution: Wide range in most samples, bulk is fine sand/coarse organic matter. Variability among sites is similar to variability among duplicate samples (no discernible major differences)
- Solids content: Low except in 2 samples, which were moderate.
- Organic content: 5-15% carbon – high but typical for pond muck
- Settling rate: Not directly tested – will be moderate to slow
- Bulking factor: Expect 1.5
- Drying factor: Expect 0.5
- Residual turbidity: Expected to be high

Chemical Nature of Material To Be Removed:
- Metals levels: Surprisingly low, below all regulatory thresholds
- Organic contaminant levels: Low, below all regulatory thresholds
- Oil and grease or TPH: Low, below all regulatory thresholds
- Other contaminants: Low, below all regulatory thresholds
- Nutrient levels: Tested for available P only – values ranged from 103-203 mg/kg, translates into 4.9 to 9.7 g P/m2. Assuming a typical release of about 10-20% per year, the change in P conc. in the pond would be 16-32 ug/L, a significant amount when the range of 10-20 ug/L is the desired target, but much lower than the external load (from the watershed). In terms of an annual load, a release of 0.5-1.0 g/m2/year equates to 21-43 kg/yr released into the pond; past estimation of internal loading by sediment release ranged from 22 to 31 kg/yr, a reasonable match.

Nature of Underlying Material To Be Exposed:
- Type of material: Appears to be silt and sand; lower organic content than overlying material, but still capable of supporting plant growths if light is sufficient.

Protected Resource Areas:
- Wetlands: Bank resources are significant in some areas, and there are contiguous bordering vegetated areas to the north, but no impacts from dredging are expected except at access points.
- Endangered species: None listed or observed.
- Habitats of special concern: None listed or observed.
- Species of special concern: None listed or observed.
- Regulatory resource classifications: Target areas are all Land Under Water – even the north basin is not yet a BVW (where islands have formed, they have invasive species).

Dewatering Capacity of Sediments:
- Dewatering potential: Appears to be substantial, and high sand content will help.
- Dewatering timeframe: Not specifically tested, but appears to be on the order of weeks without pressure addition. Pressurized dewatering should work very well too.
- Methodological considerations: Will need tests of bulking, shrinkage and drying, but sediments appear more amenable to dewatering than typical pond mucks. (Note that we are talking about peripheral, not deep hole sediment; the latter may be more contaminanted and dewater less well, but is not being considered for dredging).

Flow Management:
- System hydrology: Pulsed large inflows possible; dry dredging will require substantial routing of water and still pose risks to the work area.
- 13.3 million m3/yr = 15 cfs on average, can peak at >100 cfs during storms.
- Provisions for controlling water level could include sequestering target areas with porto-dams or sheet pile and having pump systems in place for underflow or leakage.
- Methodological implications: May be better as a hydraulic dredging project.

Equipment Access:
- Possible input and output points: Can launch from Town Beach property; other accesses less advantageous due to slopes and wetlands.
- Pipeline routing: Hydraulic dredging pipeline could be routed almost anywhere through the lake. Wetlands and slopes remain as impediments at shore, but are surmountable.
- Property issues: The Town owns adequate land for accesses.

Relationship To Lake Uses:
- Impact on existing uses during project: Could support some uses during work, including swimming at Town Beach and boating in non-work areas. Pipeline avoidance is less of an issue with non-motorized boating, but may want to limit access for liability reasons.
- Impact on existing uses after project: All uses will be enhanced, but level and duration of enhancement vary with areas dredged. Expect plant regrowth, but probably not at current density for many years.
- Facilitation of additional uses: Sailing and other boating uses may be facilitated where light or substrate limits are imposed on plant growth.

Potential Disposal Sites:
- Possible containment sites: Limited options near lake. Could use tanks and belt press to limit needed footprint, with trucking to further sites. Unlikely to create major disposal area

(temporary or permanent) anywhere near well fields or on park land. Possible use of church land along Rt 9 is worth exploration (for sale now).
- Soil conditions: Generally sandy, if area can be found for in-ground containment.
- Necessary site preparation: Major for in-ground containment, limited for tank and belt press operation.
- Volumetric capacity: See accompanying table. Assuming initial bulking factor of 1.5, have initial volume of about 27,500 cy for Area 1, 316,000 cy for all possible target areas. Done in increments, would need much less space.
- Property issues: Possible disposal areas not yet researched.
- Long term disposal options not yet researched.

Dredging Methodologies:
- Hydraulic option: Appears most applicable; avoids flow control, sediment appears amenable to hydraulic removal, pipeline routing straightforward. Compatible with tanks and belt press system for dewatering and loading for disposal elsewhere. Clogging of pipeline with plants may be an issue for work during growing season.
- Wet excavation: Too many possible downstream impacts likely, will require shoreline disposal (at least temporary) or in-lake barges for transfer. Not a likely option.
- Dry excavation: Could be very effective, but flow control issues will necessitate sequestering target area while work in progress, with extensive pump controls in area. Could work in conjunction with temporary drawdown, if feasible.

Applicable Regulatory Processes:
- General Federal or State review (NEPA or state equivalent): Applicable MEPA process.
- Environmental impact reporting: May be necessary.
- Wetlands protection statutes: Applicable but not a major impediment.
- Dredging permits: Not a Great Pond – Chapter 91 should not apply.
- Aquatic structures permits: None should be needed.
- Drawdown permits: Not a Great Pond – goes with Ch 91 approval
- Water diversion/use permits: Not applicable.
- Clean Water Act Section 401 (Water quality certification): May be necessary, no problems anticipated.
- Clean Water Act Section 404 (US Army Corps of Engineers): May be necessary, no problems anticipated.
- Fish and wildlife permits/notification: Applicable but no apparent problems.
- Dam safety/alteration permits: Inapplicable unless larger drawdown performed.
- Waste disposal permits: Sediments clean; should not be a problem.
- Discharge permits: Can discharge back to pond, supplemental treatment workable if needed.

Removal Costs:
- Engineering and permitting costs: Depends on volume and approach – assume 20% of dredging cost.
- Construction of containment area: Depends on volume and approach – assume $10/cy for initial planning purposes.
- Equipment purchases: More likely a contract job.
- Operational costs: More likely a contract job.
- Contract dredging costs: Depends on volume and approach – assume $10/cy for initial planning purposes.

- Ultimate disposal costs: Depends on accepting site – assume $5/cy for initial planning purposes.
- Other costs: Unknown at this time.

Total cost: Assuming $30/cy, have costs as follows:

Area 1	$548,340
Area 2	$528,030
Area 3	$1,398,030
Area 4	$1,245,630
Area 5	$451,890
Area 6	$2,153,520

Could be half that, but do not assume less.

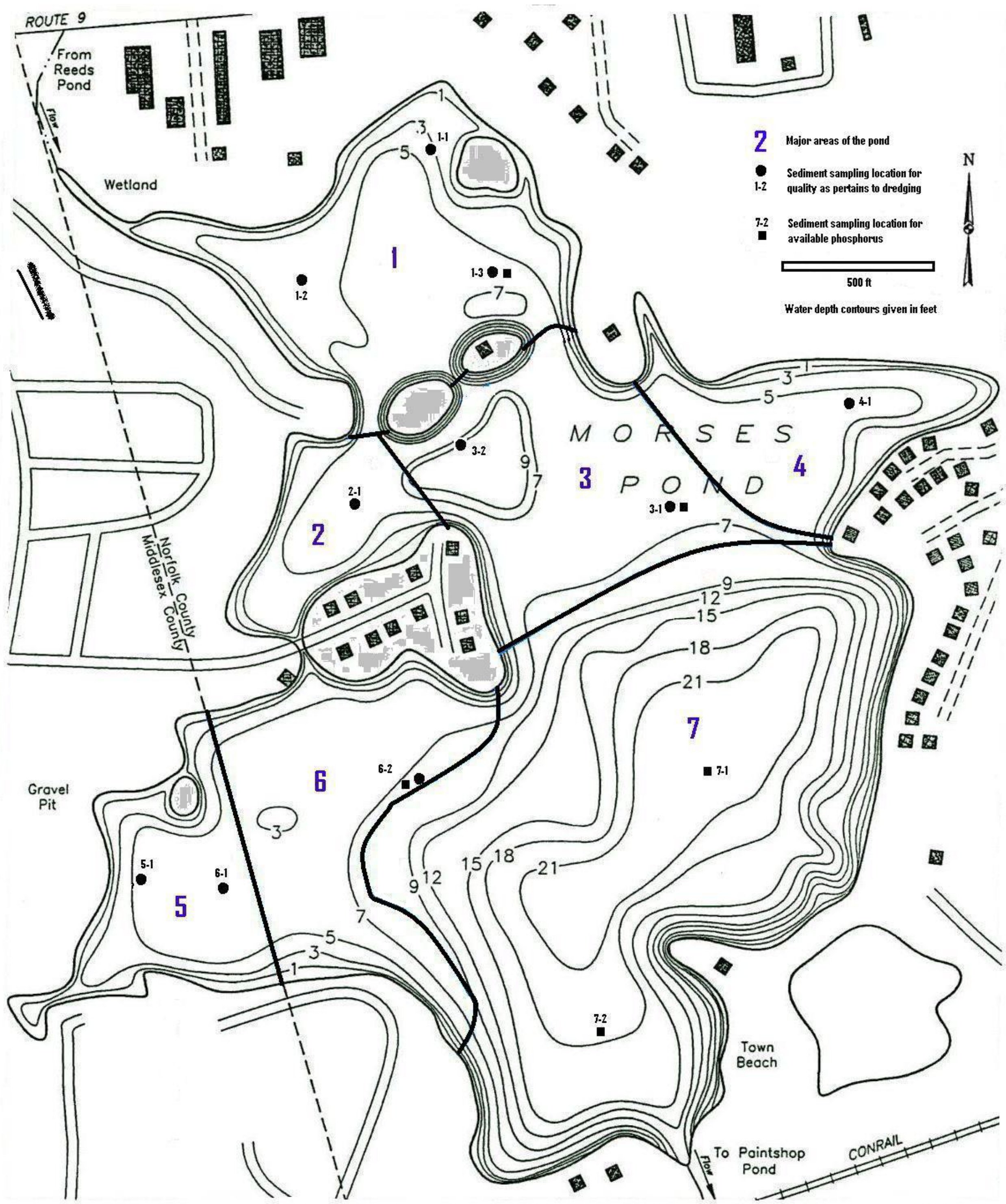
Uses Or Sale Of Dredged Material:

- Possible uses: Material is possible top soil amendment, maybe with minimal prep.
- Possible sale: Possibly up to about $2/cy; getting it hauled away at no cost would reduce disposal costs markedly (worth $5/cy in above scenario).
- Target markets: Construction sites in eastern MA.

Other Mitigating Factors:

- Necessary watershed management: Not a big issue for sediment, but a major issue for nutrients.
- Ancillary project impacts: Gains detention capacity as well as possible plant control. However, regrowth by plants expected.
- Economic setting: Difficult to obtain funding these days for in-lake work.
- Political setting: See above.
- Sociological setting: Definite interest in rehabilitating the pond, strong organization to lead.

Summary of Sediment Depth and Volume and Plant Cover and Biovolume							
Area #	Area (ac)	Avg. Actual Water Depth (ft)	High Water Depth (ft)	Actual Water Volume (cy)	High Water Volume (cy)	Avg. Sediment Depth (ft)	Volume of Soft Sediment
1	15.0	3.8	5.6	92013	136216	0.8	18313
2	5.9	4.4	6.3	42156	59596	1.9	18051
3	12.7	5.9	7.7	120625	158088	2.1	42308
4	9.4	4.7	6.5	71408	99145	2.7	41318
5	7.5	4.4	6.3	53637	75706	2.5	30723
6	13.0	4.9	6.7	102989	141474	2.6	53825
7	42.2	13.5	15.3	918746	1043249	NA	NA
Total	105.6			1401574	1713474		204537
Area 7 was too deep in most places to get an estimate of sediment depth							
All values based on September/October 2004 survey of Morses Pond, with 4 boards out of the outlet structure.							



Morses Pond bathymetry, 2004 sediment sampling stations, and delineated general areas.

Sediment Quality Variable and Method		MA Mean Lake and Pond Sediment Data (ppm)	MA DEP Background Soil Data Set 90th Percentile (ppm)	MCP RCS-1. GW-1 (ppm)	Sample MP1-1	Sample MP1-2	Sample MP1-3	Sample MP2-1	Sample MP2-1D	Sample MP3-1	Sample MP3-2	Sample MP4-1	Sample MP4-1D	Sample MP5-1	Sample MP6-1	Sample MP6-2
Metals																
Aluminum	6010B		13,000		7990	2450	2960	441	415	7580	315	291	444	193	288	358
Arsenic	6010B	17.1	16.7	30	<6.07	6.89	<2.80	<2.74	<2.89	<5.91	<2.95	<2.83	2.97	<2.63	4.59	<2.93
Cadmium	6010B	4.6	2.06	30	<1.01	<0.498	<0.467	<0.456	<0.482	<0.985	<0.492	<0.471	<0.445	<0.439	<0.477	<0.489
Chromium (total)	6010B	23	28.6	1000	14.9	4.96	5.28	1.52	1.60	13.9	7.88	7.56	2.22	1.31	2.48	2.20
Copper	6010B	41.8	37.7	1000	31.2	12.9	13.8	<6.30	<6.26	18.0	<9.45	<8.39	<8.82	<4.04	<6.87	<6.84
Iron	6010B	16,692	17,000		10200	2890	2280	901	912	9300	531	479	868	321	1170	928
Mercury	7471	203	98.7	300	<0.392	<0.163	<0.162	<0.164	<0.179	<0.358	<0.169	<0.163	<0.175	<0.158	<0.160	<0.164
Manganese	6010B	382	300		127	48.4	54.9	10.9	10.6	133	6.97	6.28	69.2	23.2	123	53.2
Nickel	6010B	23	17	300	9.61	2.68	2.02	<0.913	<0.963	7.76	<0.984	<0.943	<0.891	<0.878	<0.954	<0.977
Zinc	6010B	195	116	2500	93.7	<49.8	<28.0	<9.22	<9.15	37.6	<11.0	<11.1	<11.7	<7.02	<10.1	<12.1
Polychlorinated Biphenyls																
PCB-1016	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
PCB-1221	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
PCB-1232	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
PCB-1242	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
PCB-1248	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
PCB-1254	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
PCB-1260	8082			2	<0.078	<0.091	<0.053	<0.067	<0.064	<0.097	<0.061	<0.062	<0.066	<0.080	<0.073	<0.067
Pesticides																
Aldrin	8081			0.03	<0.030	<0.030	<0.026	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
alpha-BHC	8081				<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
beta-BHC	8081				<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
delta-BHC	8081				<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
gamma-BHC (Lindane)	8081				<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
Chlordane	8081			1	<0.195	<0.227	<0.132	<0.167	<0.159	<0.242	<0.152	<0.154	<0.164	<0.199	<0.183	<0.168
DDT and derivatives	8081			2	<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
Dieldrin	8081			0.03	<0.030	<0.030	<0.026	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Endosulfan or derivatives	8081			20	<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
Endrin/Endrin aldehyde	8081			0.6	<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
Heptachlor	8081			0.1	<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
Heptachlor epoxide	8081			0.06	<0.039	<0.045	<0.026	<0.033	<0.032	<0.049	<0.030	<0.031	<0.033	<0.040	<0.037	<0.034
Toxaphene	8081				<0.195	<0.227	<0.132	<0.167	<0.159	<0.242	<0.152	<0.154	<0.164	<0.199	<0.183	<0.168

Sediment Quality Variable and Method		MA Mean Lake and Pond Sediment Data (ppm)	MA DEP Background Soil Data Set 90th Percentile (ppm)	MCP RCS-1, GW-1 (ppm)	Sample MP1-1	Sample MP1-2	Sample MP1-3	Sample MP2-1	Sample MP2-1D	Sample MP3-1	Sample MP3-2	Sample MP4-1	Sample MP4-1D	Sample MP5-1	Sample MP6-1	Sample MP6-2
Extractable Petroleum Hydrocarbons																
C9-C18 Aliphatics	EPH			1000	<63.6	<29.4	<29.8	<31.4	<35.8	<59.1	<32.8	<30.3	<30.5	<30.7	<30.0	<32.5
C19-C36 Aliphatics	EPH			2500	70.7	<29.4	<29.8	<31.4	<35.8	<59.1	<32.8	<30.3	<30.5	<30.7	<30.0	<32.5
C11-C22 Aromatics	EPH			200	<63.6	39.7	<29.8	<31.4	<35.8	<59.1	<32.8	<30.3	<30.5	<30.7	<30.0	<32.5
Polynuclear Aromatic Hydrocarbons																
Acenaphthene	8270			20	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Acenaphthylene	8270			100	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Anthracene	8270			1000	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Benzo(a)anthracene	8270			0.7	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Benzo(a)pyrene	8270			0.7	<0.317	0.216	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Benzo(b)fluoranthene	8270			0.7	<0.317	0.258	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Benzo(k)fluoranthene	8270			7	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Benzo(g,h,i)perylene	8270			1000	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Chrysene	8270			7	<0.317	0.211	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Dibenzo(a,h)anthracene	8270			0.7	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Fluoranthene	8270			1000	0.654	0.301	0.210	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Fluorene	8270			400	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Indeno(1,2,3-cd)pyrene	8270			0.7	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Naphthalene	8270			4	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Phenanthrene	8270			100	<0.317	<0.146	<0.149	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Pyrene	8270			700	0.625	0.293	0.212	<0.157	<0.178	<0.294	<0.163	<0.151	<0.152	<0.153	<0.149	<0.162
Solids																
Total solids (%)	2540B				44.1	19.5	16.9	14.8	12.3	48.3	7.4	6.0	10.6	10.3	8.5	8.2
Total organic carbon (mg/kg)	SW846				88400	82800	88800	137000	70800	66000	91900	49700	98500	88600	87500	156000
Grain Size																
% greater than 4.75 mm (Sieve 4)					2.8	0.9	0.3	1.1	1.2	1.5	1.4	1.6	1.2	1.2	1.1	0.5
% between 4.75-2.00 mm (Sieve 10)					6.6	12.4	3.2	16.9	8.8	5.5	12.0	10.5	23.3	22.0	14.4	9.1
% between 2.00-0.850 mm (Sieve 20)					16.4	18.1	16.9	32.4	30.9	15.8	23.3	24.5	33.3	32.5	26.0	25.6
% between 0.850-0.425 mm (Sieve 40)					18.9	19.0	35.8	18.3	18.9	24.5	17.9	19.0	15.6	15.8	18.8	19.9
% between 0.425-0.250 mm (Sieve 60)					17.0	10.8	9.0	9.6	9.2	18.9	10.7	11.7	7.9	8.8	13.2	11.4
% between 0.250-0.150 mm (Sieve 100)					13.0	6.3	6.0	6.5	9.6	13.1	9.0	8.8	5.9	5.9	7.8	9.0
% between 0.150-0.075 mm (Sieve 200)					12.1	14.6	8.3	7.0	10.0	10.5	11.5	10.4	6.7	6.5	9.4	9.9
% finer than 0.075 mm (Sieve 230)					13.1	17.9	20.4	8.3	11.2	10.2	14.2	13.4	6.2	7.4	9.3	14.7

Sediment Quality Variable	MP1-3P	MP1-3P Duplicate Sample	MP1-3P Duplicate Test	Spike 24.8/306	MP3-1P	MP6-2P	MP7-1P	MP7-1P Duplicate Sample	MP7-2P
Percent Total Solids	8.8	8.1	8.1	8.1	11.8	9.9	10.2	12.9	10.3
Loosely-sorbed P (mg/kg dry)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Iron Bound P (mg/kg dry)	203	177	180	360	103	118	136	103	120

EVALUATION OF ENHANCED WETLAND TREATMENT IN MORSES POND

Reasons to apply this approach:
- The northern basin (Area 1) is filling in and will become an emergent wetland over the next few decades. However, without some engineered alteration, it will lose its detention and treatment capacity for incoming water.
- Altering the northern basin independently of any effort to retain open water could enhance its pollutant trapping capability.

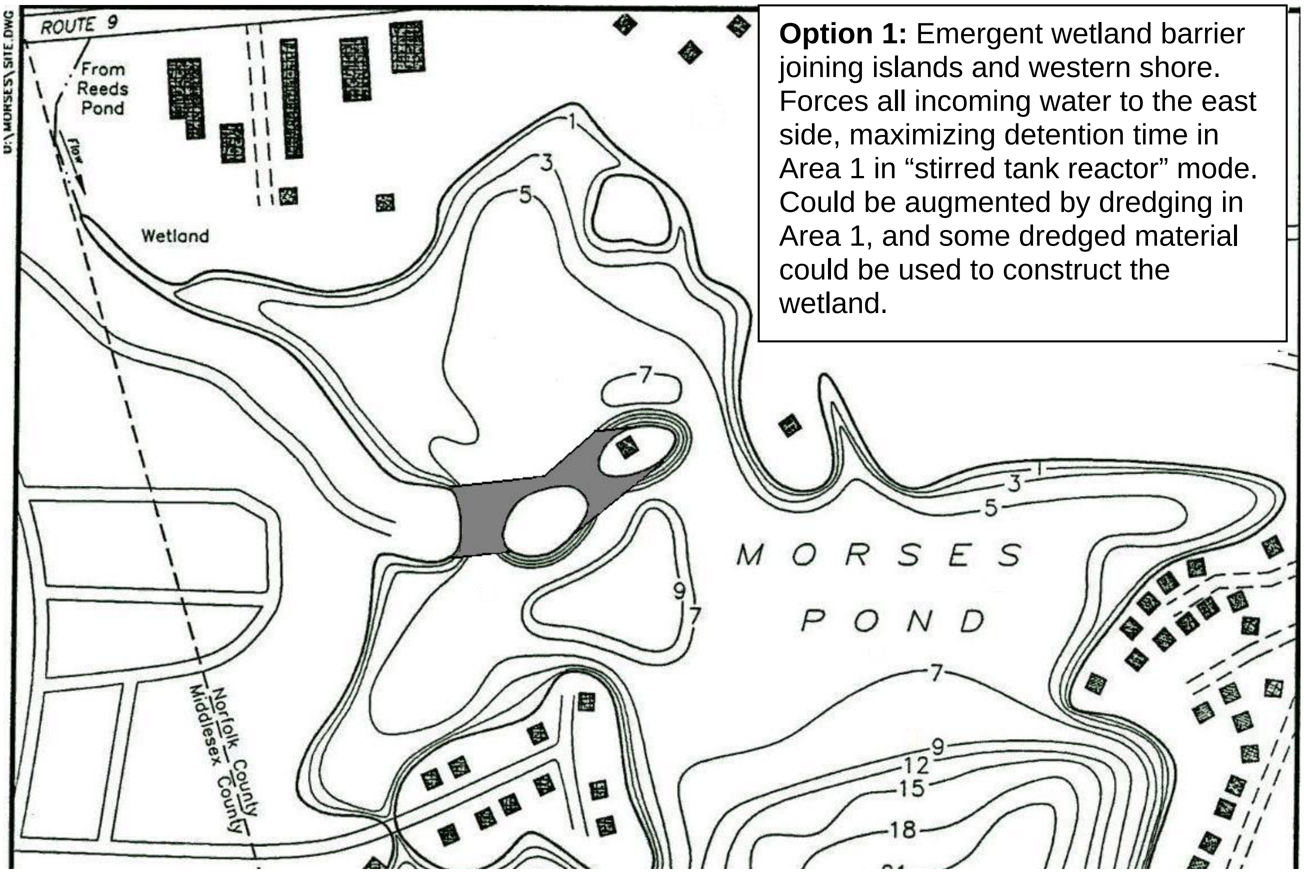
Target area and results:
- Area 1, the northern basin, north of the two islands that separate Area 1 from Area 3, is the detention basin for the southern basin (Area 7) of MP. About ¾ of all water enters the pond through Area 1, with a larger portion of the pollutant load (about 80% of all P).
- A reduction in P load to the southern basin averaging about 30% is desired over what is achieved now. The best estimate of current removal in Area 1 is about 46%, most of which is particulate P that settles in Area 1 after entry from Bogle, Jennings and Boulder Brooks. This means that what is sought is an increase in load reduction in Area 1 from 46% up to 62%. This is within the realm of possible reductions based on assessment of removal from detention systems and constructed wetland basins elsewhere. Assuming a shift from continuous flow stirred tank reactor mode to plug flow reactor mode induced by wetland baffles (one option), removal efficiency should increase by about 25% for range of detention typically experienced in smaller storms; suggests increase from 46% to 58%, if actual switch in treatment mode is achieved.
- Ideally, the removal rate would be 50-60% higher than it is now (an increase to 73% of the total load to Area 1), to provide a margin of safety suitable for all possible input conditions, but this exceeds the realistic rate of removal for most detention and wetland systems.

Design options: See attached sheets.

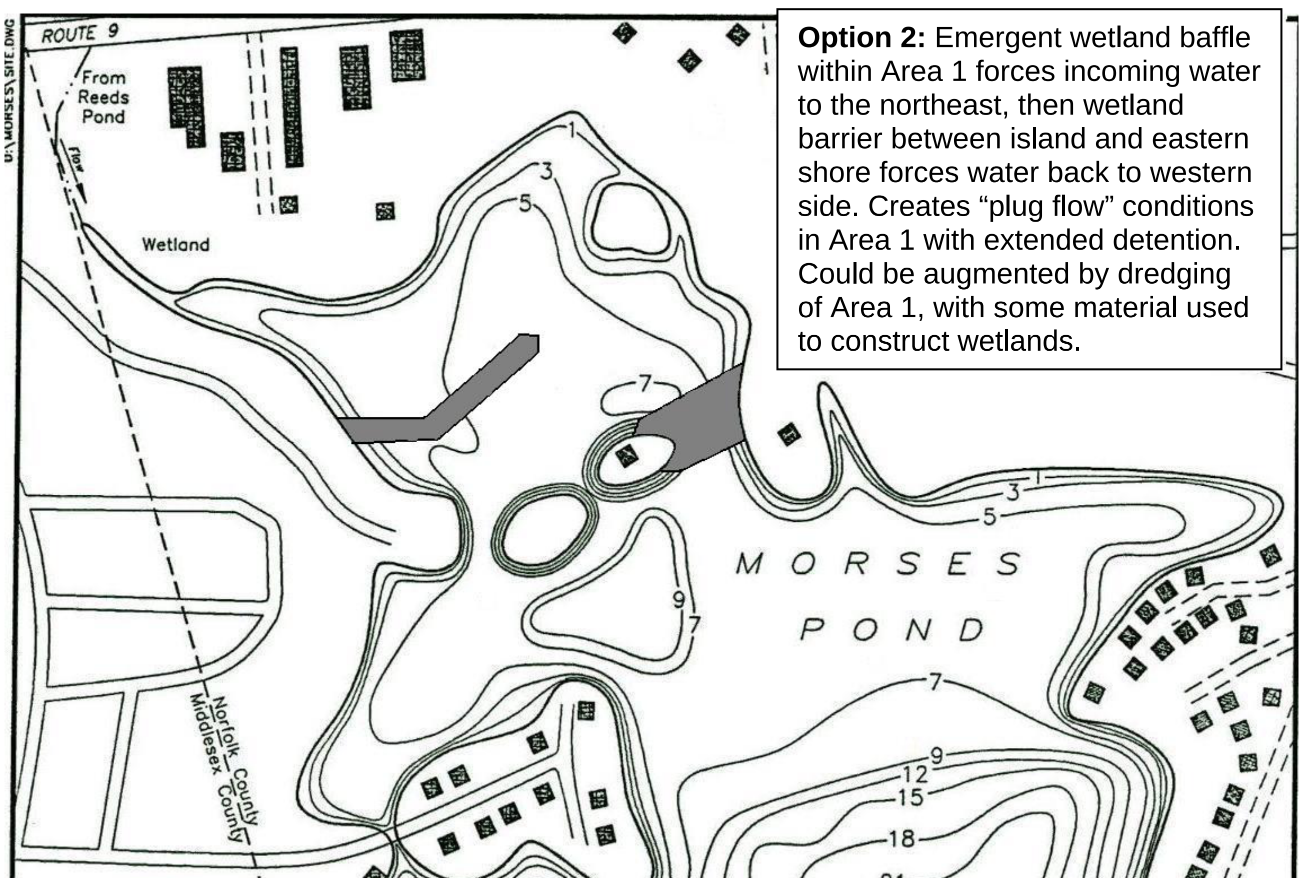
Logistics of wetland creation:
- Would almost certainly need to lower the lake to work in target area. Could route water past Area 1 along the west side and pump out area, but expensive and unreliable. A 4 ft drawdown is possible without extreme impact to water supply and may be sufficient for some designs.
- Construction access is limited, but would have to be created. Alternative is to barge equipment to Area 1 from the beach area and land on “dry” area created by drawdown.

Additional considerations:
- Movement of material and possible addition of new materials constitutes filling; permitting process will be more involved than for many techniques (probably similar to dredging).
- Initial calculations indicate no significant impact on flood control; no major back-up of water expected in the vicinity of Rt 9 with added wetland area in northern basin (Area 1).
- Simplest scenario is blocking off flow between islands and west side, forcing flow to the east through as much of Area 1 as possible. Greatest impediment is flood control issue for Rt 9 and shoreline surrounding Area 1.
- May get some loss of treatment efficiency during larger storms, as wetlands will occupy area that could be dredged to provide more detention.

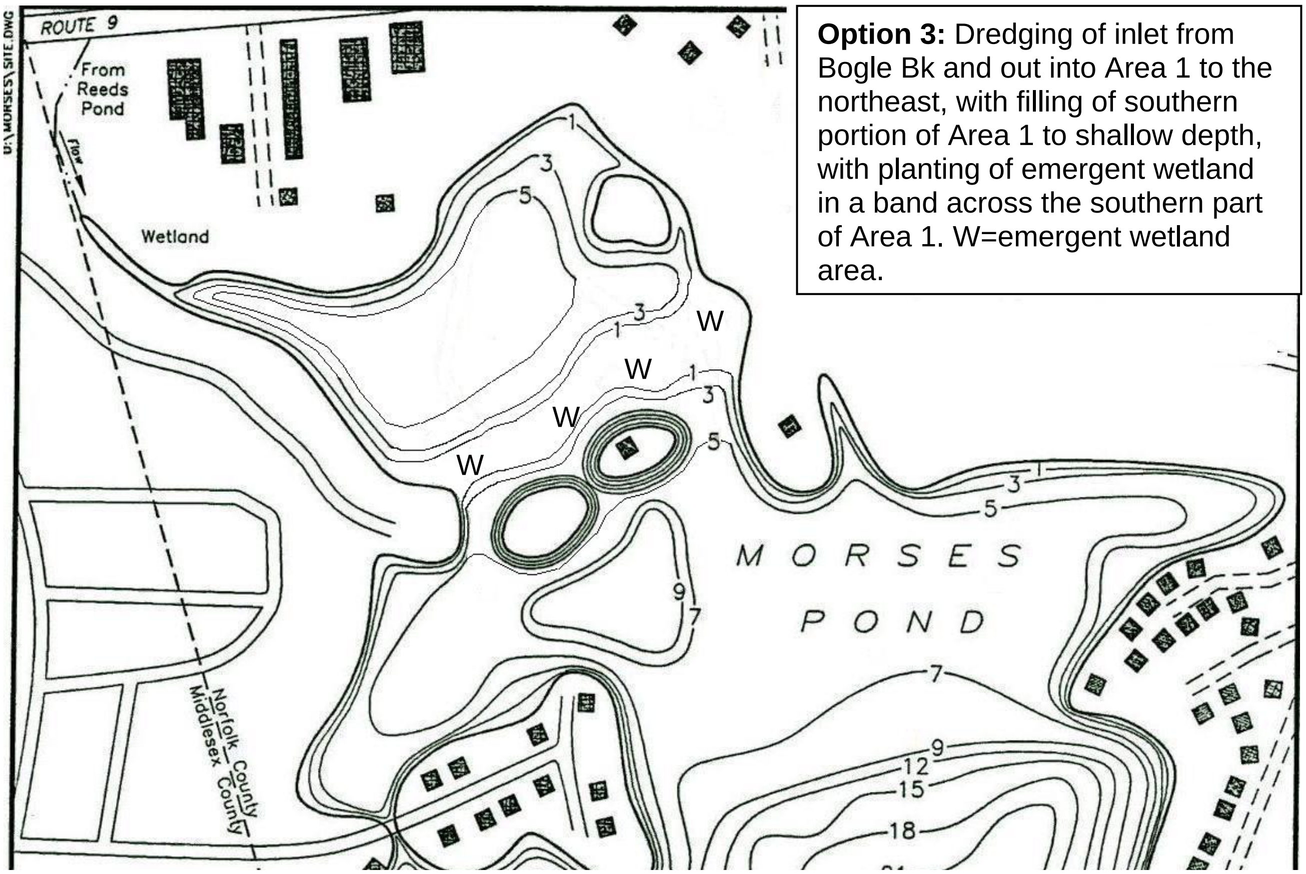
Cost:
- Option 1 fills about 50,000 SF at $10-15/SF = $500,000 to $750,000 (all inclusive).
- Option 2 fills about 35,000 SF at $20-25/SF = $700,000 to $875,000 (all inclusive).
- Option 3 places material over about 100,000 SF, but involves less prep and containment work; assume $10/SF = $1,000,000 (all inclusive).



Option 1: Emergent wetland barrier joining islands and western shore. Forces all incoming water to the east side, maximizing detention time in Area 1 in "stirred tank reactor" mode. Could be augmented by dredging in Area 1, and some dredged material could be used to construct the wetland.



Option 2: Emergent wetland baffle within Area 1 forces incoming water to the northeast, then wetland barrier between island and eastern shore forces water back to western side. Creates "plug flow" conditions in Area 1 with extended detention. Could be augmented by dredging of Area 1, with some material used to construct wetlands.



Option 3: Dredging of inlet from Bogle Bk and out into Area 1 to the northeast, with filling of southern portion of Area 1 to shallow depth, with planting of emergent wetland in a band across the southern part of Area 1. W=emergent wetland area.

EVALUATION OF POSSIBLE PHOSPHORUS INACTIVATION IN MORSES POND

Reasons to apply this approach:

- Inactivation of available sediment phosphorus – if internal releases of P from sediment represent a significant portion of the load, algal blooms can be controlled by making this source of P unavailable.
- Inactivation of water column phosphorus - Where watershed loading is not controllable, inactivation of either the incoming P or P already mixed in the lake can reduce available P and minimize algal blooms.

Sediment P inactivation issues:

- Tested for available P in sediment at 5 sites – values ranged from 103-203 mg/kg, translates into 4.9 to 9.7 g P/m2 (4 cm deep into the sediment). Assuming a typical release of about 10-20% per year, the change in P conc. in the pond would be 16-32 ug/L, a significant amount when the range of 10-20 ug/L is the desired target, but much lower than the external load (from the watershed). In terms of an annual load, a release of 0.5-1.0 g/m2/year equates to 21-43 kg/yr released into the pond; past estimation of internal loading by sediment release ranged from 22 to 31 kg/yr, a reasonable match.
- Sediment P could be an issue under prolonged dry conditions with anoxia over deeper areas, so some algal control could be gained by sediment P inactivation. However, the load from the watershed is substantially higher; total load to S basin is 264 to 555 kg/yr, so sediment P release is around 10% of total. The higher watershed load overwhelms any sediment P inputs under most conditions. Inactivation of just sediment P would provide minimal relief under wet conditions (with elevated watershed P inputs) and sediment P may be replenished rapidly from watershed sources (duration of effectiveness therefore limited).
- If sediment P is to be inactivated, aluminum would be the inactivator of choice, as its effectiveness is not dependent on oxygen and the pH is appropriate in MP. A dose about 10 times the target P conc. is appropriate, or 50-100 g Al/m2. This is on the high end of typical Al treatments, and may require buffering or sequential additions over time to avoid adverse impacts to aquatic biota.
- Note that alum has been applied previously to MP. The available P levels in sediment suggest that past inactivation has been short-lived.

Incoming P inactivation issues:

- P load from Bogle Bk represents about half of total load, inputs from Jennings Bk combine with Bogle Bk at inlet to increase this overall source to about two thirds of total P load. See 2002 review of Morses Pond information for more details on loading and preferred reductions.
- Typical concentrations in Bogle/Jennings Bks inflow to MP range from 0.02 to 0.11 mg/L. Storm flows tend to yield highest concentrations, however (typical for non-point sources), as well as greatest volume of input water, with values peaking at as high as 0.5 mg/L.
- Typically add Al at a level at least 20 times the targeted P concentration and get 90-99% reduction in P. Floc containing inactivated P settles out of water column and continues inactivation of bottom sediment as it combines with them, over a period of days to weeks.
- For Bogle/Jenning Bks system, would expect to treat at a dose of 5-10 mg Al/L and reduce P level to <0.05 mg/L with a target of 0.01 to 0.02 mg/L. Tests done previously indicated that doses of up to 10 mg Al/L provide about 50 % reduction (35% of total load to MP). Variability was high, complicating effective P inactivation at the inlet point.
- Could consider installing an inactivation system involving multiple injection points with air-induced mixing in north basin. Commercial systems have been developed for this purpose and applied in FL, NJ, and IL with success. This would add treatment of inputs from Boulder Bk (enters N basin) and mitigate any WQ and sediment impacts over the area and volume of that basin.

- Need to know more about the circulation pattern in N basin, especially during storms. Are there short circuited patterns of flow? What is the range of detention times? Where would be the best place to install injection points?
- May gradually inactivate existing sediment P with repeated water column P inactivation. Will at least reduce rate of accumulation of available P in S basin by such an approach.
- May be able to run system from late spring through summer only, in response to storms.
- Alternative of treating the whole lake or just the S basin as warranted. This has been done previously (most of lake in 1970s, S basin in recent years) with short duration success.

Potential adverse effects:

- Aquatic toxicity – reactive aluminum (e.g., aluminum sulfate, sodium aluminate) is toxic to many species of fish and invertebrates at levels >50 ug/L, usually >100 ug/L, although the form of Al (largely pH dependent), duration of exposure, and other water quality variables play a role in determining actual toxicity.
  - The Al reacts quickly, however, and drops below toxic levels within minutes to hours in the vast majority of cases. The hydrolysis reaction is non-reversible, so later toxicity is not an issue. With pH kept between 6 and 8, Al toxicity is not expected to be a problem at doses of 5-10 mg/L (5000-10,000 ug/L).
  - A treatment for sediment P inactivation of 50 g/m2 would equate to 8.5 to 34 mg Al/L in MP in waters with a depth range of 5 to 20 ft. This may therefore necessitate sequential additions to target areas over an extended period of time, as some toxicity could occur at the 50 g/m2 dose.
  - A treatment for water column P inactivation of 5-10 mg Al/L would not be expected to induce toxicity as long as a pH of 6-8 was maintained.
  - Results of informal studies in FL and NJ on aquatic impacts of repeated Al addition do not indicate any unacceptable impacts.
- Human health – There was a long debate in the literature over the possible impacts of aluminum on human health. Large summaries have been written and are available. Areas of potential concern include contact during recreation and ingestion of aluminum laden water.
  - The least biased accounts indicate minimal threat to human health. Postulated links to Alzheimer's disease have proven not to be a cause and effect relationships. Coagulant effects are limited to a threat to dialysis patients. Skin contact with raw alum or aluminate is undesirable, but after dilution in a lake and reaction of the Al, the threat dissipates.
  - Al addition is very common in the water supply industry, as a coagulant treatment to reduce dissolved and particulate materials in water before distribution. Levels in finished drinking water are often >50 or 100 ug/Lm but the Al is largely non-reactive at that point.
  - Treated lakes suffer no recreational impairment as a result of the treatment, although swimming is usually curtailed during actual treatment of swimming areas or nearby lake sections. There is no documented case of human illness from contact with treated waters.
  - It appears unlikely that any reactive aluminum could pass through the soil and arrive in the MP wellfield. This does not erase concern that Al might appear in well water, however. Previous treatments have been in a southern area presumed to be outside the Zone II influence.

Potential for application at Morses Pond:

- Tests were performed in Bogle Brook back in 1996-97, showing promise for water column P inactivation but inadequate success to encourage establishment of a more permanent dosing station at that time. Revisiting such a station, either at the Bogle/Jennings Bks inlet or in the N basin of MP, is warranted. Past doses may have been inadequate to inactivate all sediment P, but with rapid replacement, benefit of this approach is limited.
- P inactivation is not an ideal long-term substitute for watershed management, but is applicable and appropriate as an interim measure or where watershed management is simply not possible. We would essentially be treating the water as it enters the lake, with the primary goal of enhancing water quality in the S basin. Both algal and non-algal turbidity could be controlled.

- Installation of an injection system in the N basin would allow management of most incoming water for minimized available P content. It would also be far enough away from more used areas of the pond to minimize interference with uses.
- An automated system could be installed for something approaching $150,000, with an annual operating cost estimated at $20,000 to $100,000 (spring –summer). Cost could be scaled back with reduced results.
- As a test, the N basin (Area 1) could be treated by barge (treatment as with parts of the S basin in recent years) two to four times over late spring and early summer, in response to storms, and the impact on overall MP water quality could be evaluated. This should cost $25,000 to $40,000, although alum costs have been rising and could affect future estimates. Could also set up a makeshift dosing system for the north basin using a small aeration system and alum feed arrangement for a slightly higher cost.

EVALUATION OF ADDITIONAL ALGAE CONTROL TECHNIQUES IN MORSES POND

Algaecides:

- While management of nutrient inputs to a lake from its watershed or internal sediments is clearly the preferred option for controlling algae, this is not an easy task, and algaecides are useful as the last line of defense in preventing blooms. See attached primer, expanded from the section that appears in the Practical Guide to Lake Management in Massachusetts.
- Of the 3 active ingredients available, endothall cannot be used in a drinking water supply and peroxide has a very limited track record. This leaves copper, which has been used in MP as needed in the past.
- Interestingly, oxidants were tried in MP over 20 years ago with limited success. New formulations are better, but at their higher cost and considering the potential recurrence rate for algal blooms, this is not an attractive option.
- Copper is effective on most algae that are potential bloom formers in MP. Repeated use is undesirable, and there is a risk of toxicity to zooplankton and some invertebrates (minimal risk to any fish in MP). Used in conjunction with an algal monitoring program to allow early detection of possible bloom formation and rapid response, copper represents a reasonable last line of defense for MP.
- Treatment of just the southern end of the lake ignores the production of algae in other areas, most notably Areas 1 and 3, and provides only the shortest term relief.
- Other controls, in the watershed or in Area 1 (alum) should reduce the need for copper, but having it as a potential tool is worthwhile.
- Cost is nominal (<$10,000 each year).

Barley straw:

- Barley straw creates natural algaecides upon decay, and the associated bacteria seem to compete with algae for nutrients, making this an attractive approach to algae control, at least on paper. See attached primer from the Practical Guide to Lake Management in Massachusetts.
- The primary risk is low oxygen as a function of oxygen uptake during decay and high BOD in any digester effluent (where straw is not put directly in the lake).
- Impacts appear greatest on blue-greens, less so for other forms. May actually promote algae that can use dissolved organic compounds. More research is needed to determine mode of action and ways to optimize effects.
- Considered to be an unlicensed herbicide by USEPA; licensed applicators therefore can not apply it. Volunteer efforts often suffer from a lack of application knowledge, leading to improper and/or ineffective use.
- There is some potential to make this technique work in Area 1, as a protective approach for the rest of MP. This is not, however, a “mainstream” technique and should be approached as an experiment with uncertain results. Reception by Natural Resources Commission is uncertain; may be complications in light of herbicide policy. Impact on water supply unknown.

Artificial circulation:

- Artificial circulation serves two purposes: increase oxygen levels and disrupt algal growth cycles for species that prefer static conditions. The mechanisms in this approach are more complicated than may be apparent. See attached primer from the Practical Guide to Lake Management in Massachusetts.
- Increased oxygen limits internal P recycling and alters pH, forms of available carbon and other water chemistry variables important to determination of which algae become dominant. For slowly flushed lakes, this can be an important factor in algal community dynamics. For Morses Pond, it would enhance habitat in Area 7 and at the sediment-water interface in other areas, but periodic flushing would negate many water quality influences that affect algae.

- Increased mixing tends to favor green algae and diatoms over blue-greens. Each of these groups has potential to bloom in MP, but blue-greens are the most objectionable. Mixing systems, with or without a strong oxygenation component, could improve the types of algae present, but are unlikely to control the quantity of algae present in MP.
- Small system with two air driven circulators is in use in Town swimming area; could be improved or expanded.
- Cost of mixing Area 7 in MP, with or without air/oxygen addition, is on the order of $50,000-$100,000. There is virtually no risk of negative impacts if designed, installed and operated properly, but there is no guarantee of a change in algal density. This may be a useful technique at some future date, but is not a high priority approach at this time.

Biomanipulation:
- While bottom-up control of algae through nutrient management is considered the most reliable approach to algae control, top-down control is possible with the right biotic community. See attached primer from the Practical Guide to Lake Management in Massachusetts.
- Key features of a biotic system to limit algal biomass at any point in time include:
  - Many larger fish that eat smaller fish.
  - Fewer smaller fish that eat zooplankton
  - More and larger zooplankton, particularly Daphnia, that graze on algae
  - High algal productivity, but low algal biomass as a function of constant consumption by zooplankton
- A number of factors in MP (and most lakes) work against this biotic structure:
  - Fisherman catch and keep larger fish
  - Dense plant growths protect smaller fish from predation
  - Reproduction of all fish generates small fish that eat zooplankton, at least in early life stages
  - Algal communities adapt to predation by favoring larger particle size or toxic cells, limiting consumption
- The desired biotic structure is usually achieved stocking larger fish that eat the smaller fish or by directly removing the smaller fish that eat zooplankton. Rooted plant densities will interfere with the effectiveness of either approach in MP.
- Reducing plant density in MP may lead to a natural shift in the fish community that favors more and larger zooplankton and less algal biomass. Supplemental stocking of piscivores (bass, pike, walley) or direct removal of planktivores (sunfish, perch, shiners) might then be considered fruitful.
- Fishing derbies rarely make a dent in the planktivore population. Use of fish poisons is no longer acceptable in Massachusetts and would not be allowed near the MP wellfield anyway. Direct netting of planktivores is possible but tedious. Stocking of piscivores would be the preferred approach, with a lower plant density, if needed.
- Costs relate to labor to net planktivores or capital to stock piscivores. Expenses of $5000 to $10,000 per year for 3-5 years should be expected to implement this approach, but would not be recommended under the current plant density.

Sonication:
- Sound waves are used to disrupt algal cell walls; causes death in existing algae and prevents growth of additional algae, although some types are more resistant than others.
- Commercial units used mostly in small ponds, most effective at keeping growths off structures, intake pipes and bottom of basin.
- Use on plankton limited; some concern over lysing blue-greens grown outside of area of sonication impact, as these may contain toxins.
- Concern over power supply needs; would need to run a live electrical line into swimming area if units placed there.

- Cost ranges from $5000 to $15,000 for units; would need one or two to do swimming area, many more to do whole lake. Not a top priority item, and has considerable uncertainty and perceived safety risk.

Dilution or Flushing:
- Dilution requires cleaner water than in the target pond, while flushing just requires enough water to keep the detention time to about two weeks.
- No obvious source of higher quality water. Possible increased flow from Cochituate Aqueduct, but would need the water when least available, in the summer.
- Average detention time is about one month. Getting detention to about 2 weeks in the summer will require about 281 million gallons over that time period, or 31 cfs. With existing inflow, might get benefit with as little as 140 million gallons, or 15.5 cfs. No known source of this quantity of water.

Dyes:
- Natural lake water color already provides most benefits of artificial dyes.
- Could get more appealing color, but will heat lake surface more rapidly and may have negative impacts on system biota.
- Flushing to downstream Paintshop Pond and Lake Waban may create permitting issues.

Rooted Plant Interactions:
- Morses Pond already has a maximal amount of plant biomass, and it does not prevent algal blooms.

EVALUATION OF DRAWDOWN FOR PLANT CONTROL IN MORSES POND

Plant Community and Probable Impact:
See herbicide evaluation for species review. Species susceptibility shown in accompanying table. Milfoil, fanwort and lilies all affected. Other invasive or nuisance spp. unaffected or may increase, most notably naiad. Many desirable species unaffected or increased, but a few also decreased.

Current Level of Drawdown:
Normal full pond elevation = 121.5. With all boards removed, elevation = 119.4 (2.1 ft decline). Last board, inset into concrete spillway, is usually left in place (last 3 inches of lowering sacrificed), so typical drawdown water level is at 119.7 ft above MSL. Therefore, a maximum drawdown of 1.8 ft achieved by removal of all but bottom board in outlet structure each winter. Spillway is 23 ft wide. With outflow, expect at least a 1.5 ft drawdown in most winters. Very limited impact is noted in plant community as a result of this drawdown from 2004 analysis (areas <2 ft deep vs. areas >2 ft deep).

Necessary Level of Drawdown:
Bathymetry and plant distribution indicate minimal benefits at <4 ft, control of nuisance plants in key areas necessitates drawdown of at least 6 ft or even 7 ft, with 8 ft set as maximum plausible drawdown. A 4 ft drawdown would expose about 21acres, while a 6 ft drawdown would expose roughly 40 acres and an 8 ft drawdown would expose around 64 acres (nearly all of Areas 1-6).

Key Issues for Drawdown:
1. Ability to lower pond –Gradient of about 9 ft exists between MP and Paintshop Pond, 13 ft between MP and Waban. Current outlet allows for board removal to just over 2 ft; normally 22 inches of boards are removed; would need an auxiliary pipe to lower MP further. Downstream flood issues need evaluation, but would plan to pass flows within natural range.
2. Ability to refill pond – With large watershed, refill will occur within two weeks in most years, perhaps six weeks in a dry spring, so no refill issue. Must facilitate some discharge during refill, but not difficult.
3. Impaired water supply – a distinct issue for Morses Pond, critical in this case, see analysis below.
4. Impacts on protected species – none known for MP.
5. Affects on emergent wetlands – minimal impacts observed in other systems, wetlands at MP not especially susceptible to drying impacts over winter, and not of high quality.
6. Threat to minimally mobile invertebrates – limited shellfish resources in MP, no major impacts expected, but some additional investigation warranted if drawdown is considered further.
7. Threat to reptiles and amphibians – possible threat, more investigation needed for MP, but no evidence of major impacts from most other drawdowns.

Impact of Expanded Drawdown on Water Supply:
<u>1. Water Supply System</u>
- Wellesley gets its water from 4 main sources: 3 wellfields and the MWRA. Rosemary has two wellfields, each with a WTP, that together provide slightly more water than the Morses wellfield and WTP.
- Morses wellfield provides 30-45% of the town's water; 388.6 Mgal out or about 1 billion gal in 2003.
- MWRA water comprises 10-25% of town water, while Rosemary system provides 45-60%.

- Winter demand drops by about 20%, allowing elimination of MWRA water purchase.

2. Morses Well System

- Bedrock occurs at about 80 ft below ground surface. Water storage in the soil above the bedrock is not optimal, but there is a conductive layer of soil between MP and the wellfield that allows induced infiltration (i.e., water is pulled from the pond through soil, with a much larger area contributing to the pond via surface runoff).
- 3 wells: 47, 48 and 55 ft deep, 2 ft in diameter, 10 ft of screen at bottom, static airspace of about 5.5 ft (between water level in well and ground surface, if no pumping was going on). Therefore, have expected water columns of 41.5, 42.5 and 49.5 ft to work with before any pumping occurs. Pumping then draws water from the wells, lowering the water level in the wells to the point where inflow from surrounding soil offsets the pumping rate. Actual water column height is typically about 40 ft.
- Pump system is an older suction operation. Maximum depth to which suction systems typically draw water is 27 ft. This system is not expected to draw water from below about 20 ft (vertical depth).
- Bioclogging (build up of iron bacteria and related microbial community) is an issue for these wells. Cleaned twice a year with chemicals and pressure.
- Pump test conducted in 1991 for the 55 ft well, but represents output by the wellfield as a whole. Transmissivity = 70,000 gpd/ft, hydraulic conductivity = 71.4 m/day, output was about 2.0 MGD. Storativity = 0.02 to 0.38, indicating relatively rapid replacement of water laterally with well pumping (this again relates to MP inputs).
- Yield will vary with many factors over time. May be able to get 4.15 MGD from wells, pump test suggests 2.8 MGD is likely, approved yield by DEP is 2.0 MGD, all based on a full Morses Pond.
- Zone II area = 142 acres. This is small contributory area in comparison to most wellfields, attributable to induced infiltration from Morses Pond.
- During the pump test, MP provided 68% of the water to the wells. During a 180 day drought, it is expected that MP would provide 92% of the water to the wells.

3. Impact of Drawdown

- Assessment #1 – Father’s Day Storm Event, 2001 – MP level = 118.6 before storm on 6/15, rose to 121.3 on 6/18. Well yield rose from 990 gpm to 1046 gpm over same period, peaked on 1/21 at 1074 gpm. Despite unstable, transient conditions, suggests a yield change of 35 gpm/ft of pond level.
- Assessment #2 – Yield before, during and after a drawdown – USEPA mandated drawdown of MP to about 117.5 to work on contamination at Paintshop Pond in 2001. Summer yields in gph for 3 years:

Year	June	July	August	Average	
2000	57,491	52,899	51,908	54,099	Average without drawdown = 53,630
2001	49,766	45,063	42,306	45,712	Average with drawdown = 45,712
2002	56,125	52,964	50,395	53,161	Change = 7918 gph/60 min/hr/3.5 ft dd = 38 gpm/ft

- The two assessments yield similar values that equate to 50,000-55,000 gpd of lost yield per ft of drawdown for the upper few feet of pond level. Efficiency of pumping and rate of recharge will decline as the water level decreases, so the lost yield will increase in a non-linear manner with greater drawdown, either multiplicative, logarithmic or exponential.
- Additionally, highest permeability of sediments is near shore in shallow water. Deeper drawdown will necessitate water passing through less porous pond sediments, further slowing recharge of wells.
- See accompanying graphs for projected impact of drawdown on wells by multiplicative, exponential or logarithmic models.

4. Potential to Maintain Supply Under Drawdown

- Normal winter practice to lower MP by 1.8 ft (4 boards from outlet). Winter pumping rate is 1 to 1.1 MGD. Not an appreciable decrease from summer rate. Small drawdown has limited impact on wells.
- Could pump wells more to make up for loss due to drawdown; have no more than 1/3 "excess" capacity in the winter, so could tolerate no more than 1/3 loss of yield (about 350,000 gpd).
- Winter demand declines by about 20% (550,000 gpd). Allows reduction in MWRA water purchase, but could take reduction from MP wellfield. MP wellfield contribution is about twice the MWRA contribution, however, so would still need the wells to function at 50% of normal winter withdrawal (550,000 gpd), or purchase more MWRA water, if available.
- With no winter MWRA water, can afford no more than 350,000 gpd loss; equates to dd <4-6 ft.
- With continued purchase of MWRA water (at summer volume) in the winter, may be able to support 4-8 ft drawdown, but uncertainty is high and stress on equipment may also be high.
- It would be best to assume that the Morses wellfield would be shut down to do a trial winter drawdown, with increased purchase of MWRA water. Operate pump system during drawdown to determine impact empirically during trial.
- Could change the pump system for Morses wellfield, but the available water may still be insufficient.

Needed Structural Outlet Alteration:

- Outflow must equal inflow + drawdown volume over 15-30 days, then match inflow: this equates to 27-40 cfs.
- Piped outflow will depend on pipe diameter, material, and head pressure.
- Typical pipes are 2-4 ft diameter metal or concrete pipe: 2 ft pipe will require about 8 ft initial head to meet need, 4 ft pipe would need about 2 ft of initial head. Culvert invert elevation is 113.0, or 8.5 ft below full water level (121.5). Would have to use 4 ft pipe or alternative outflow shape if flow passes through existing culvert.
- Could run a trial drawdown with pump or siphon arrangement, but will not be easy.

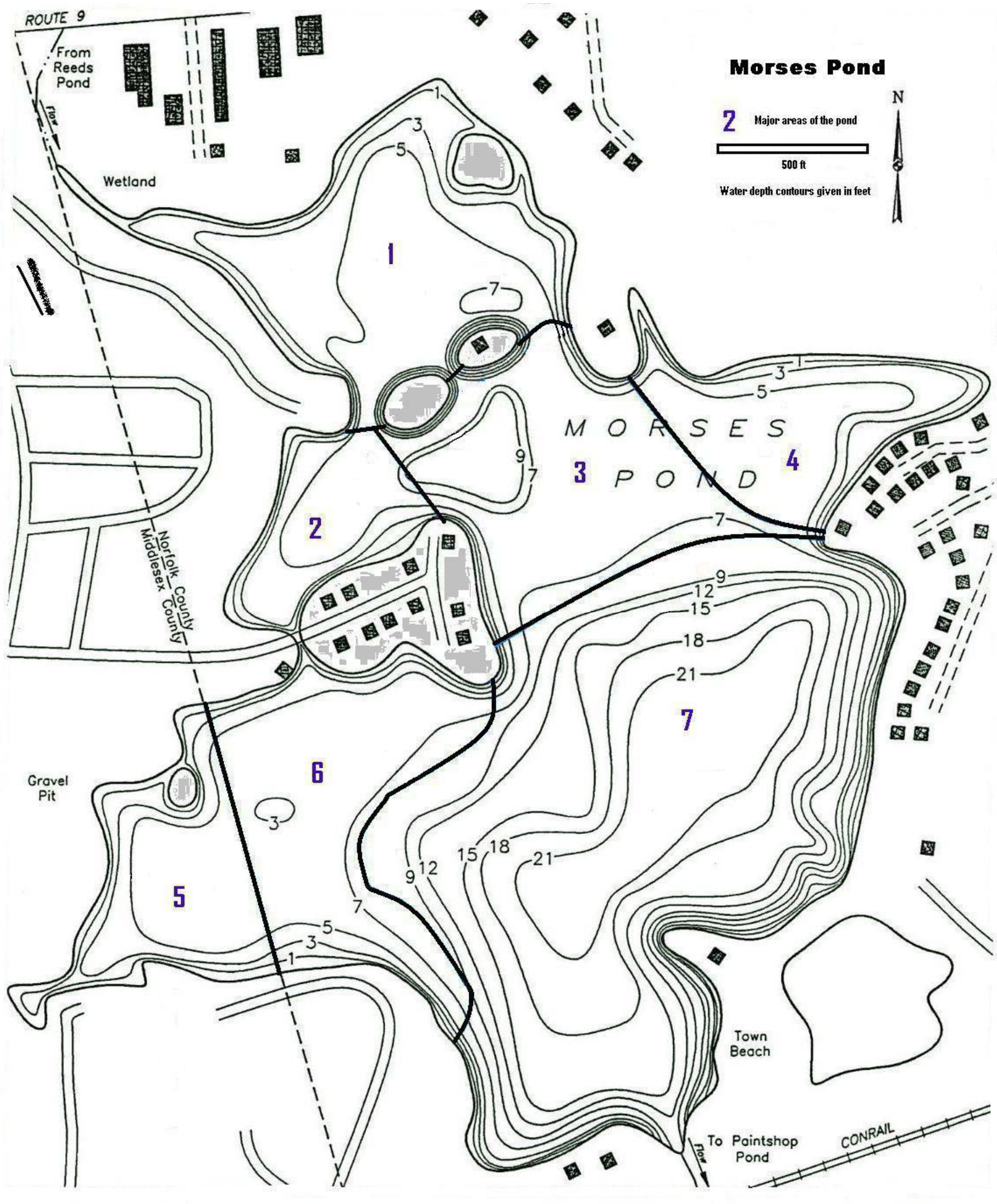
Cost:

- Best case scenario is that extra pumping of the well (more hours per day) in winter could increase production by 30%, almost offsetting expected loss of production with 4 ft drawdown. However, a 4 ft drawdown is the minimum to have any measurable impact on plants in MP, but the maximum likely drawdown before the wellfield becomes critically impaired for production.
- Possibly 4 ft drawdown necessitates use of MWRA water to make up the difference at 200,000 to 400,000 GPD for 120 days; at $2500/MG = $60,000-120,000.
- Drawdown to 6-8 ft would most likely eliminate use of Morses wellfield at a winter cost of $330,000 (1.1 MGD X 120 days X $2500/MG).
- Major rework of existing outlet would be required to facilitate more than a 1.8 ft drawdown at a likely cost of >$200,000, probably on the order of $300,000. More detailed construction and flow evaluation needed if there is interest in proceeding. See accompanying outlet drawings from Rizzo Associates.

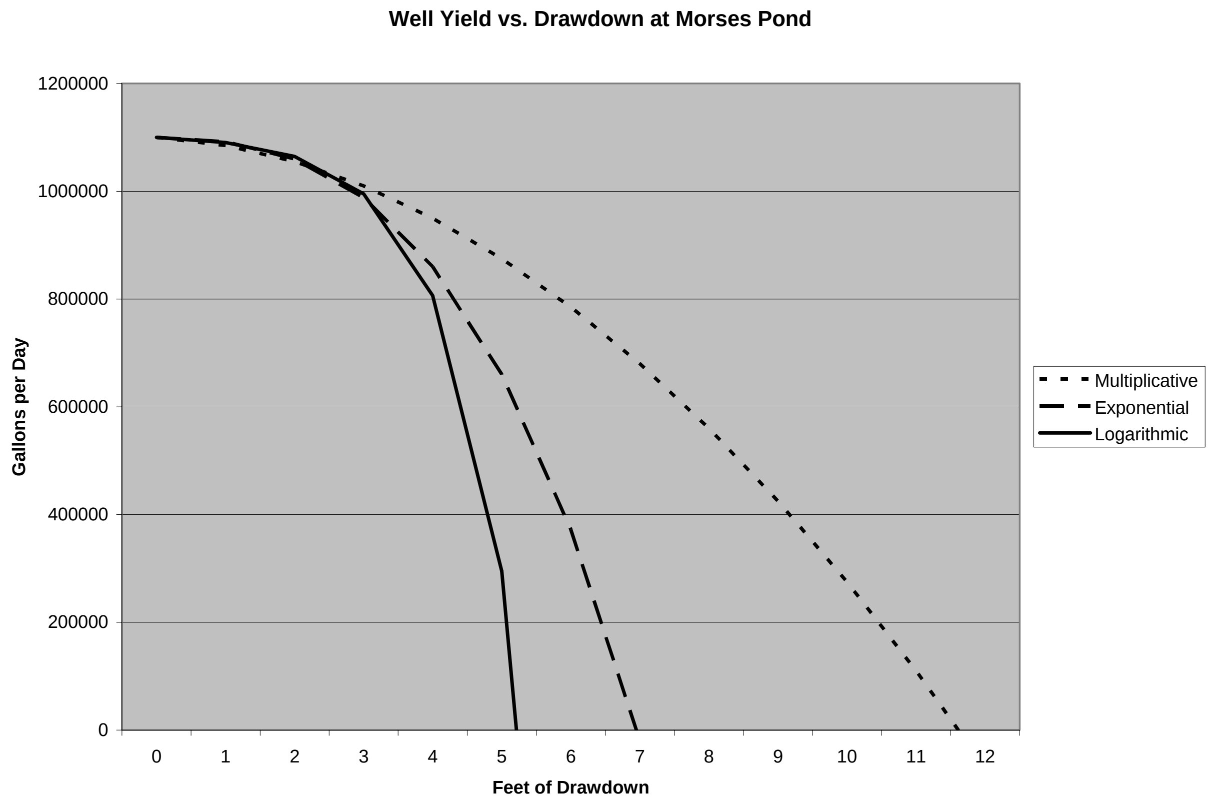
Anticipated Response of Morses Pond Aquatic Plants to Winter Drawdown.

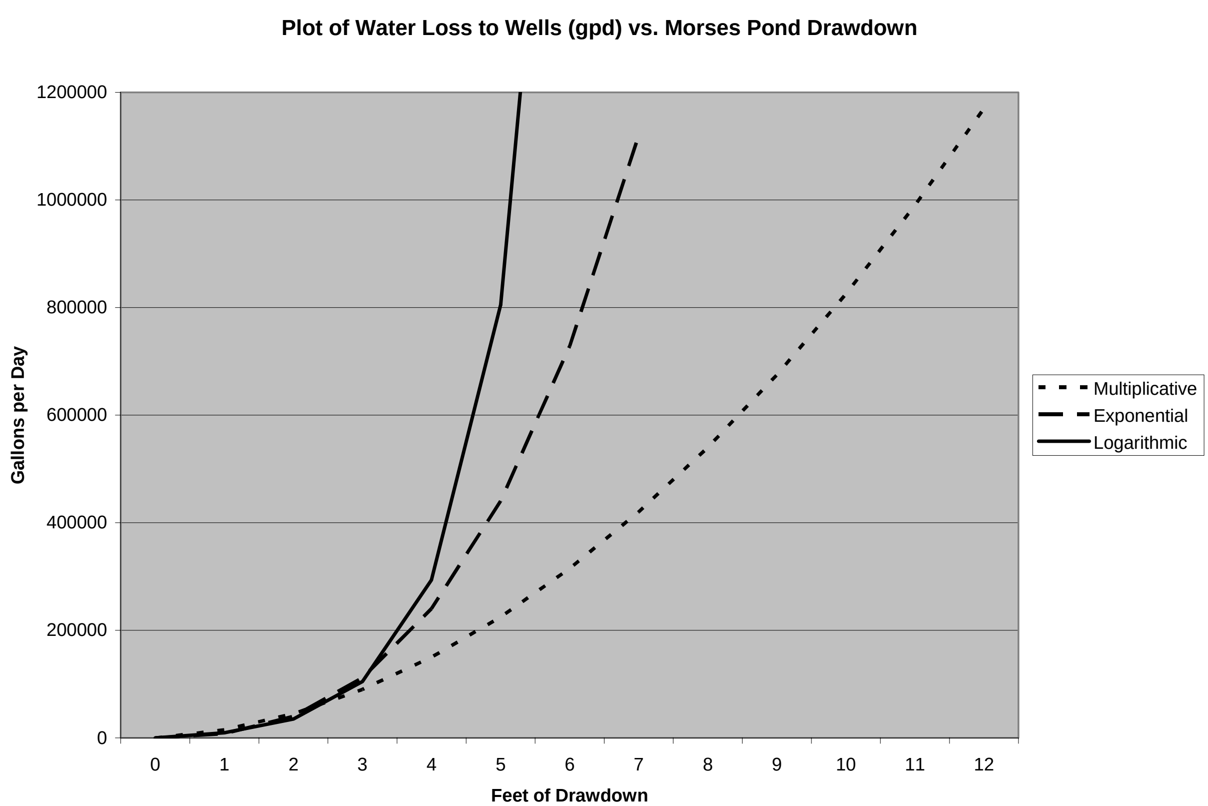
	Change in Relative Abundance		
	Increase	**No Change**	**Decrease**
Cabomba caroliniana (fanwort)			S
Ceratophyllum demersum (coontail)			S
Decodon verticillatus (swamp loosestrife)	E	E	
Elodea canadensis (waterweed)	S	S	S
Lythrum salicaria (purple loosestrife)		E	
Myriophyllum spp. (milfoil)			S
Najas flexilis (bushy pondweed)	S		
Nuphar spp. (yellow water lily)			E/S
*Nymphaea odorata (*water lily)			S
Polygonum amphibium (water smartweed)		E/S	
Polygonum coccineum (smartweed)	E		
Pontederia cordata (pickerelweed)		E	
Potamogeton amplifolius (broadleaf pondweed)	S		
Potamogeton epihydrus (leafy pondweed)	S		
Potamogeton robbinsii (Robbins' pondweed)			S
Trapa natans (water chestnut)	S	S	
Typha latifolia (common cattail)	E	E	
Utricularia spp. (bladderwort)		S	S

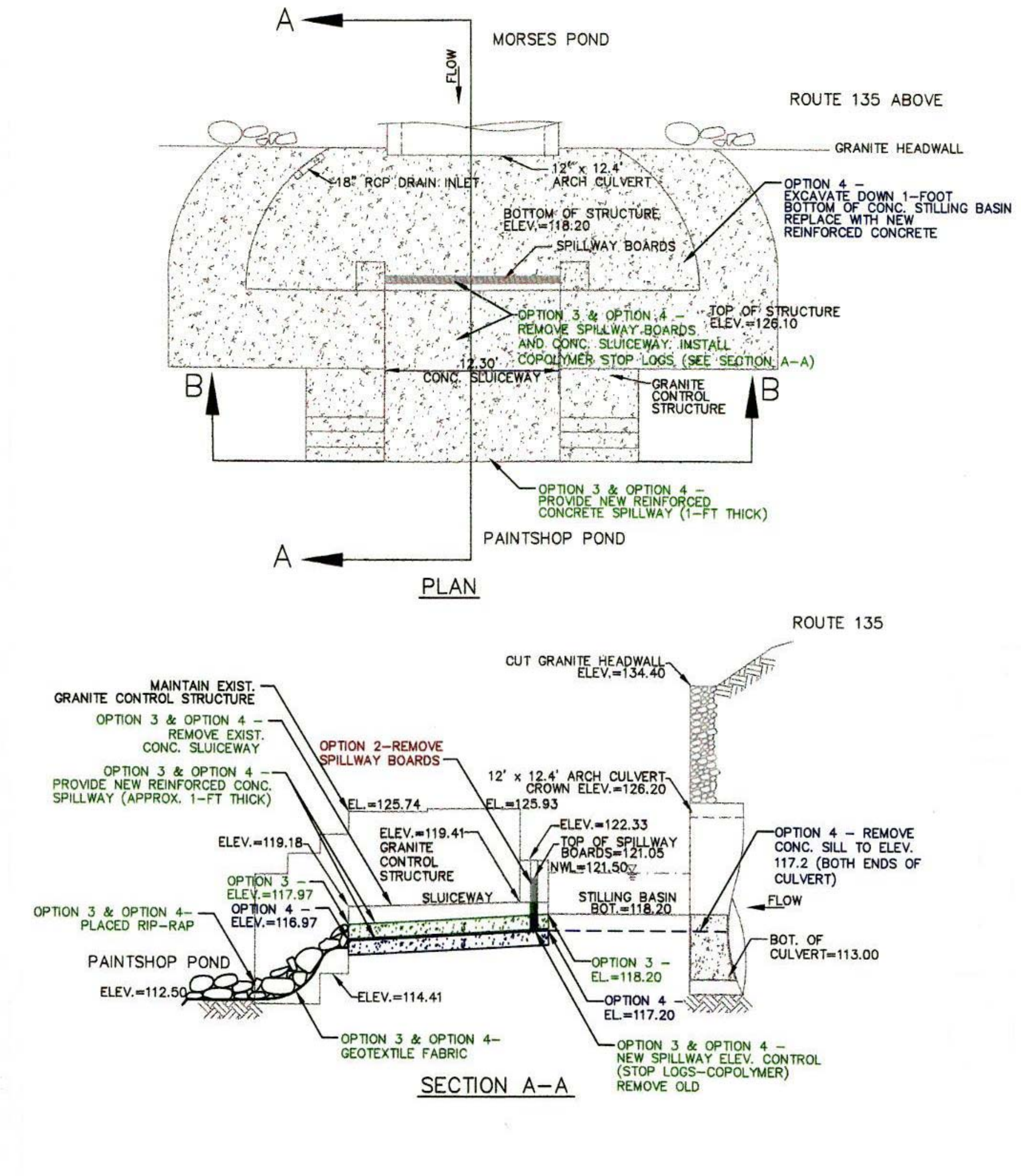
E=emergent growth form; S=submergent growth form (includes rooted species with floating leaves); E/S=emergent and submergent forms



Morses Pond Bathymetry and General Areas for Management


Well Yield vs. Drawdown at Morses Pond
1200000
1000000
800000
600000
400000
200000
0
Gallons per Day
0 1 2 3 4 5 6 7 8 9 10 11 12
Feet of Drawdown
Multiplicative
Exponential
Logarithmic


Plot of Water Loss to Wells (gpd) vs. Morses Pond Drawdown
1200000
1000000
800000
600000
400000
200000
0
Gallons per Day
0 1 2 3 4 5 6 7 8 9 10 11 12
Feet of Drawdown
Multiplicative
Exponential
Logarithmic



Morses Pond Outlet Structure

EVALUATION OF PLANT HARVESTING IN MORSES POND

Reasons to apply this approach:
- Maintenance of open water in areas where the plant community is too dense and control by other less temporary means is not practical.
- Gradual elimination of seed producing nuisance species by removal before seeds are released.

Target areas:
- Areas 2-6 could be much more suitable for boating and swimming if dense plant assemblages were removed or thinned.
- Area 1 is less used for recreation, but could be more useable. However, plants in this area aid detention and turbidity control.
- Area 7 does not need much attention, although selected areas along the eastern shore and the beach area could be improved.

Hand harvesting:
- Only appropriate to low density assemblages or target plant populations; water chestnut is the prime example, has been harvested from Morses Pond, and this program should continue as is.
- Other potential problem species may be controlled by hand pulling, but current nuisances cannot be effectively managed with this form of harvesting.
- A valuable follow-up to herbicide treatment for invasive milfoils and fanwort; requires trained labor, but not difficult if target plants are sparse.

Mechanical harvesting:
- Typical rate of 0.2 to 0.6 ac/hr, but MP will be at low end of this range with high density and limited offloading points. Assume 0.2 ac/hr.
- See attached table of effort per target area. One harvester at 0.2 ac/hr with a 3 week regrowth rate cannot meet all needs in MP. At 0.5 ac/hr and 4 weeks regrowth, it could be done.
- Need to maximize harvester efficiency and cut as close to sediment as possible in areas dominated by nuisance non-seed producing plants.
- Consider leaving some areas uncut to both preserve habitat/refuges and limit harvesting needs.
- Starting the harvest earlier in the growing season (May) could enhance control of invasive species.
- Avoiding desirable pondweeds (seed producers, usually come up late) will be difficult, but is possible.
- The current harvester is over 20 years old; while repairs and upgrades have been made, newer designs provide enhanced effectiveness that should be considered. It appears unlikely that the current harvester can meet the cutting needs of MP, but could do a better job of selected areas.
- Cutting width of 10-11 ft and 7 ft cutting depth now available on newer models; these may be necessary to increase efficiency at MP.
- Transport barge would minimize downtime for offloading; probably essential to making harvesting work at MP.
- Could use more than one harvester (old one and a new one in combination).
- Should assume that more than one truck/container load will be hauled away each day; set-up at beach should be arranged to minimize conflict with swimming but maximize efficiency of plant removal.
- Will need to dedicate two personnel to harvesting operation, full time for part of year (May-August, or May-June and September-October – alternate strategies) to make it effective.

Hydroraking/Rotivation:
- Will create longer regrowth time by virtue of root system disturbance.

- Not likely to eliminate any problem species
- Will create high turbidity in at least some areas.
- Not highly appropriate for MP.

Additional Considerations:

- For a 100-ac lake with dense plants and multiple nuisance species, harvesting could be a cost effective long-term maintenance approach, especially compared to the alternatives.
- Offloading areas have been an issue in the past; suitable arrangement needed if this technique is to work.
- Have to be able to do a complete harvesting cycle in considerably less than the minimum regrowth period; otherwise there will be dissatisfied users in parts of the pond.
- A carefully crafted and executed harvesting plan could limit nuisance species and favor more desirable, lower growing forms, but it will take multiple years and a very adept operator.

Possible Scenarios:

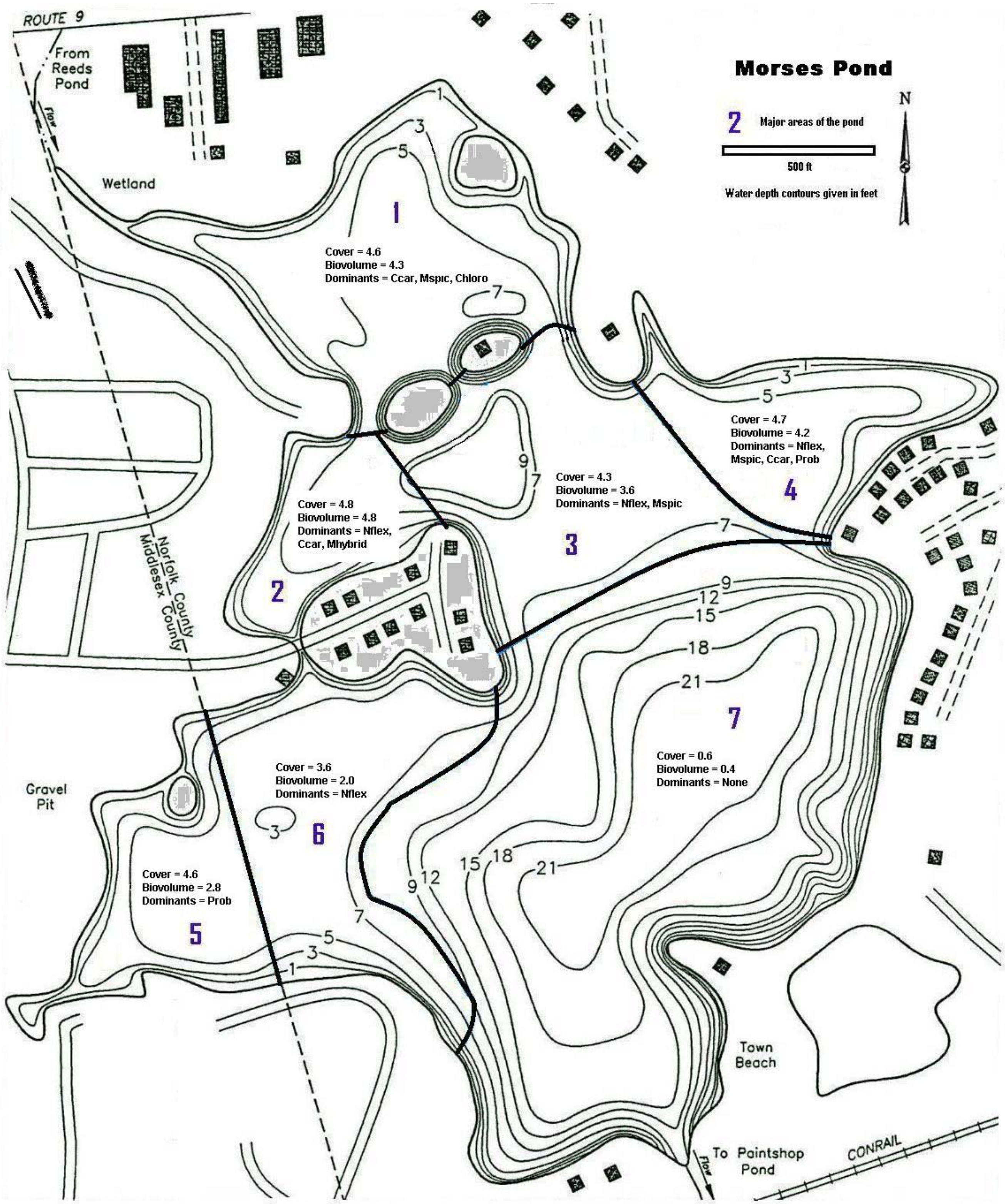
1. Current harvester maintained and used most effectively – target only enough area that it can be cut every 3-4 weeks. Cut close to bottom wherever possible, offload at beach to a hopper to be hauled away daily or as needed. Two personnel needed full time during May-August. Could probably maintain 30 acres this way, with Areas 3, 6 and the eastern edge of 7 as logical high use targets.
2. New harvester with expanded capability and transport barge acquired – doubling to tripling of area covered would be possible, allowing harvesting of all likely target areas in 3 weeks time. Two to three personnel needed full time when harvesting is in progress. Cut close to bottom in May and early June, 2 cycles (6 weeks). Offload at beach area and haul away plants as needed (probably 2-3 times per day). After mid-June, two operational options to be considered:
   - Continue cutting at a depth 2-3 ft above bottom in June-August, avoiding areas of desirable species and focusing on areas with milfoil and fanwort (and possibly naiad, if too abundant). Cut all areas close to the bottom again after seeds have been set by desirable species (typically late August for pondweeds).
   - Cease cutting while the beach is in operation, then resume intense near-bottom cutting after beach closed for 1-2 cycles (September-October).

   Some degree of trial and error with adjustment is likely for either of the above options. The intent is to maintain open water for boating and swimming while encouraging lower growing species, as having no plants is not a realistic option.

Cost:

- A new harvester, with transport barge, offloading conveyances, and trailers is likely to cost around $250,000.
- Labor and trucking costs are a function of Town arrangements; an approximation of annual labor costs would be 2 personnel full time for 9 weeks at $75/hr (fully loaded cost), or $54,000.
- Maintenance and related operational costs are typically estimated at 5% of capital cost/year, or around $12,000.
- Labor and operational costs could decline if plant density is kept under control and a more desirable plant community develops.

Potential Harvesting Effort for Morses Pond:Ac/hr rate=					0.2	
		Weeks of regrowth period =			3.0	
Area #	Affected Area (ac)	Assumed Rate (ac/hr)	Hours to Harvest	Expected Regrowth Period (weeks)	# of Harvests/ Summer	Hours of Harvesting/ Summer
1	15.0	0.2	74.9	3	4	299.4
2	5.9	0.2	29.5	3	4	118.1
3	12.7	0.2	63.4	3	4	253.8
4	9.4	0.2	47.0	3	4	187.9
5	7.5	0.2	37.4	3	4	149.5
6	13.0	0.2	65.2	3	4	260.7
7	2.0	0.2	10.0	3	4	40.0
Total	65.5		327.4			1309.5
Potential Harvesting Effort for Morses Pond:Ac/hr rate=					0.5	
		Weeks of regrowth period =			4.0	
Area #	Affected Area (ac)	Assumed Rate (ac/hr)	Hours to Harvest	Expected Regrowth Period (weeks)	# of Harvests/ Summer	Hours of Harvesting/ Summer
1	15.0	0.5	29.9	4	3	89.8
2	5.9	0.5	11.8	4	3	35.4
3	12.7	0.5	25.4	4	3	76.1
4	9.4	0.5	18.8	4	3	56.4
5	7.5	0.5	15.0	4	3	44.9
6	13.0	0.5	26.1	4	3	78.2
7	2.0	0.5	4.0	4	3	12.0
Total	65.5		130.9			392.8


Morses Pond
2 Major areas of the pond
500 ft
Water depth contours given in feet
N
ROUTE 9
From Reeds Pond
Flow
Wetland
Cover = 4.6
Biovolume = 4.3
Dominants = Ccar, Mspic, Chloro
Cover = 4.8
Biovolume = 4.8
Dominants = Nflex, Ccar, Mhybrid
Cover = 4.3
Biovolume = 3.6
Dominants = Nflex, Mspic
Cover = 4.7
Biovolume = 4.2
Dominants = Nflex, Mspic, Ccar, Prob
Norfolk County
Middlesex County
Gravel Pit
Cover = 3.6
Biovolume = 2.0
Dominants = Nflex
Cover = 4.6
Biovolume = 2.8
Dominants = Prob
Cover = 0.6
Biovolume = 0.4
Dominants = None
Town Beach
To Paintshop Pond
CONRAIL

A GUIDE TO HARVESTING MORSES POND IN 2005:

PILOT PROGRAM TO CONTROL WEEDS IN AN AREA SUITABLE TO AVAILABLE EQUIPMENT AND MANPOWER

Program outline
Record keeping
Map of pond areas
Plant identification

Plant Harvesting in Morses Pond: 2005

Approach:

- Maintenance of open water in Area 4, the eastern cove, an area of approximately 9.4 acres. This area has top priority, as it should be manageable with the equipment and manpower available, while a larger area will strain that capacity and result in less acceptable conditions overall.
- Harvesting in other areas as time permits, with a focus on surface growths such as waterlilies and milfoil or fanwort that has reached the surface.
- This program will demonstrate the ability to control rooted plants and create desired conditions in an area appropriate to harvesting capacity. If successful, the program could expanded through additional equipment and manpower.

Target areas:

- Area 4, the eastern cove, is shown on the attached map.
- Areas 2 and 6 would have the next highest priority, but cannot be properly managed with the available harvesting capacity. Work in area 4 will have priority whenever harvesting is needed in that area. Residents will be informed of this focus, which will result in limited harvesting elsewhere.

Mechanical harvesting:

- Estimated rate of about 0.15 ac/hr for harvesting, or about 1.1 load per hour; operator to keep records of hours worked and loads delivered to hopper at beach. Rate may increase after first cutting as plant density decreases.
- Operator to determine most efficient path for area 4; probably best to follow a path that results in least need to change cutting depth for each pass through the area (i.e., cut a swath at 3 ft depth, then another at 4 ft, etc., as opposed to going in a straight line and constantly changing cutting depth); maximize cutting time and rate. Cut as much of the area as possible, recognizing limitations in very shallow water.
- Current estimate of 40% of time spent actually cutting plants, 60% spent on transport and offloading; operator to estimate actual cutting time per day and total time worked on lake per day.
- Current estimate of <5 hours per day and <5 days spent on water in harvesting program; operator to record hours and days worked on Morses Pond.
- Operator to cut nuisance species as close to bottom as possible without cutting any existing, low growing desirable plants; few if any of these were found in area 4 (Robbins pondweed, *Potamogeton robbinsii* was present in 2004, but not observed yet in 2005) – see addendum for target species, species to avoid, and intermediate species.
- Operator to avoid areas of desirable species when dominant; only broadleaf pondweed (*Potamogeton amplifolius*) appears to qualify in area 4 in 2005, but Robbins pondweed (*Potamogeton robbinsii*) was present in 2004.

Aggressively Harvest:

Eurasian watermilfoil (*Myriophyllum spicatum*)
Variable watermilfoil (*Myriophyllum heterophyllum*)
Fanwort (*Cabomba caroliniana*)
Water chestnut (*Trapa natans*)

Species to Harvest as Opportunity is Presented

Waterweed (*Elodea canadensis*)
Naiad (*Najas flexilis*)
White water lily (*Nymphaea odorata*)
Yellow water lily (*Nuphar variegata*)

Species to Avoid when Harvesting
Broadleaf pondweed (*Potamogeton amplifolius*)
Robbins' pondweed (*Potamogeton robbinsii*)
Coontail (*Ceratophyllum demersum*)

Other species in the lake are uncommon, especially in area 4; collect a sample and inquire before harvesting if something different is encountered.

Harvesting Information to be Collected

For each day and area of harvesting: Record for each area on each day of harvesting

Date: ______ Allows a record of when and how often

Area harvested: ______ Use map; Area 4 has top priority

Hours related to harvesting: ______ Time spent on water or in maintenance

Hours spent actually cutting: ______ Actual harvesting time; exclude transport/offload

Full loads brought to beach: ______ Hopper full or close to it

Partial loads brought to beach: ______ Hopper <75% full

Identifiable plants harvested: ___________ List any plants that could be identified, in order of abundance

____

____

____

Notes or comments:

(Photographs provided in original document)

EVALUATION OF POSSIBLE HERBICIDE USE IN MORSES POND

Plant Community: Dense in areas <8 ft deep, dominants vary by location, but include:

Common Name	Latin Name	Introduced Invasive?	Nuisance?	Habit
Eurasian watermilfoil	Myriophyllum spicatum	Yes	Yes	Submergent
Fanwort	Cabomba caroliniana	Yes	Yes	Submergent
Bushy naiad	Najas flexilis	No	Sometimes	Submergent
Robbins pondweed	Potamogeton robbinsii	No	No	Submergent
Variable Milfoil hybrid	M. heterophyllum cross?	Yes?	Yes	Submergent

Other species that are locally abundant but not dominant include:

Variable watermilfoil	Myriophyllum heterophyllum	Yes	Yes	Submergent
Purple loosestrife	Lythrum salicaria	Yes	Yes	Emergent
White water lily	Nymphaea odorata	No	Sometimes	Floating
Yellow water lily	Nuphar variegatum	No	Sometimes	Floating
Waterweed	Elodea Canadensis	No	Sometimes	Submergent
Coontail	Ceratophyllum demersum	No	Sometimes	Submergent
Broadleaf pondweed	Potamogeton amplifolius	No	Sometimes	Submergent
Bladderwort	Utricularia spp.	No	Sometimes	Submergent

Other species currently not abundant but of concern include:

Water chestnut	Trapa natans	Yes	Yes	Floating
Duckweed	Lemna minor	No	Sometimes	Floating
Watermeal	Wolffia Columbiana	No	Sometimes	Floating
Big duckweed	Polyrhiza spirodela	No	Sometimes	Floating

See greater detail in accompanying data tabulation and maps.

Potential Herbicides:
Copper considered for algae control, but not rooted plants as addressed here.
Not Endothall or 2, 4-D – threat to drinking water supply
Diquat – approved registration allows use, but this contact herbicide will not kill whole plant in most cases, allowing regrowth within 2 years unless other measures are applied.
Glyphosate – approved registration allows use, systemic would be used only on emergent or floating forms, with localized, direct application; most often applied to purple loosestrife and lilies.
Fluridone – approved registration allows use, low dose over extended time period may control nearly all nuisance species and many potential nuisance species; shorter exposure time will limit results.
Triclopyr – approved registration allows use, but at dose (0.5 mg/L) lower than desired for primary nuisance species (milfoil at >0.75 mg/L); should have minimal impact on some desirable species, but experience is limited in MA at this time.

See additional detail in modified excerpt from the GEIR for Lake Management in MA.

Susceptibility of Morses Pond Plants:
See accompanying table. All plants can be controlled by at least one herbicide, but no one herbicide can control all plants effectively.

Most Likely Use of Herbicides in Morses Pond:
Focus on possible fluridone treatment of sections of Morses Pond to control problem plants, especially invasives. Note that glyphosate could be used for purple loosestrife control or where water lilies are considered excessively dense.

Fluridone Approach:

1. Areas 2 and 4 make the best trial target areas; they are out of the main path of water flow and are naturally somewhat isolated.
2. Sequester target area(s) with vertical curtain (typically coated fiberglas) with floats and anchors, roped firmly to shore. This will both limit area of impact during trial treatment and maximize exposure time in what can be a highly flushed system.
3. Dye test to determine detention time in sequestered area(s). Adjust curtain to maximize detention.
4. Add fluridone in liquid form unless gradual release pellet formulation appears better suited to detention situation (i.e., prolonged sequestration not possible). Use a dose of 8-10 ppb, with weekly testing of concentration and further fluridone addition back to initial concentration when it approaches 4 ppb). Maintain target concentration range for ≥90 days.
5. Test for fluridone outside curtain as well.
6. Remove curtain when concentration inside curtain declines to <2 ppb.

Health and Ecological Risks:

1. Fluridone is approved for use in drinking water supplies at <20 ppb. There is no Zone II restriction for well supplies. There is no recreational use restriction for waterbodies treated with fluridone, although most applicators request a 24 hour "no swimming" period.
2. Fluridone is not known to have any effect on aquatic fauna or people at doses allowed by the federal and state registration label.
3. Dilution between Area 2 and Town wells is extreme; with no water inflow to Morses Pond and no outflow, plus passage in a straight line to the wells with mixing in only Areas 3 and 7, dilution is estimated at 60X; this would result in a fluridone concentration in the wells of <0.16 ppb, well below any effect level (50,000 times lower than dose for detectable impact on aquatic life, 63 million times lower than dose for detected ingestion impact on mammals).
4. For Area 4, movement through Area 7 would result in a dilution factor of about 25X, but movement directly into the soil could provide lesser dilution. Such movement is limited by the thick muck layer in Area 4, however.

Follow-Up:

1. With areas opened up by treatment, colonization by plants is expected. It may be necessary to guide that colonization, as the most likely species to colonize completely open areas are invasive plants like those removed, unless nearby populations of desired species are present and capable of expansion.
2. Track colonization of trial area(s) and develop a planting plan if desirable species are not becoming dominant.
3. Apply localized physical means to keep invasive plants out (e.g., hand harvesting, bottom barriers).

Cost:

For an experimental program with sequestration, multiple treatments to maintain the desired dose, and an appropriate level of monitoring, assume $5,000 per acre. For Area 2, this will cost about $30,000. For Area 4, a cost of $47,000 is estimated, but the same curtain used to sequester Area 2 could be applied, with a slight extension, reducing Area 4 costs to around $41,000. Area 3 may require additional sequestration to facilitate through flow from Area 1; such a treatment would require as much as 2000 ft of additional curtain and $1000 more per acre. This suggests a treatment cost for Area 3 of approximately $76,000. Area 5 is in Natick, but would logically be treated along with Area 6 in Wellesley. The cost to treat Areas 5 and 6 would be about $100,000, independent of other areas. Re-use of curtains from the other areas could reduce cost to about $80,000. Total cost is estimated at $227,000, but with experience and possible reductions in monitoring, the total could be $170,000 to $200,000. No treatment of Areas 1 or 7 would be expected.

Natural Resources Commission

10/11/2002

Integrated Pest Management Policy

for

Land Owned by

the

Town of Wellesley, Massachusetts

Land-Owners include:

Natural Resources Commission
School Department
Selectmen
Library Trustees
Police Department
Fire Department
Department of Public Works

Statement on Pesticides

The Town of Wellesley Natural Resources Commission agrees with the U.S. Environmental Protection Agency that all pesticides are toxic to some degree, and that even at low levels, may cause serious adverse health and. environmental effects.

The Town of Wellesley Natural Resources Commission recognizes that all its citizens, particularly children, have a right to protection from exposure to hazardous chemicals and pesticides in particular.

Furthermore, the Town of Wellesley Natural Resources Commission recognizes that it is in the best interest of public health to take precautionary action to protect our citizens and their drinking water supply by reducing the use of toxic pesticides in Wellesley.

Therefore, the Town of Wellesley Natural Resources Commission adopts the following policy:

Integrated Pest Management Policy

- The use and application of toxic chemical pesticides, either by Town of Wellesley employees or by private contractors, is prohibited on all Natural Resources Commission lands, including school fields which shall comply with the School Children and Families Protection Act; except for certain exemptions and emergency waivers as described below.
- Pre-emptive turf, landscape and grounds cultural, biological and physical maintenance practices shall be undertaken to understand, prevent, and control potential pest problems.
- All control products used under the terms of this policy shall be in keeping with, but not limited to, those products on the preferred list of Northeast Organic Farmers' Association as stated in their Standards for Organic Land Care, and/or the Organic Materials Review Institute of Eugene, Oregon.
- An IPM Advisory Committee shall be formed.

Exemptions

All outdoor pest management activities taking place on Town of Wellesley land shall be subject to this IPM policy, except as follows*:*

1. Pesticides otherwise lawfully used for the purpose of maintaining a safe drinking water supply at drinking water treatment plants and at wastewater treatment plants and related collection, distribution, and treatment facilities.
2. Pesticides in contained baits or traps for the purpose of rodent control.
3. Pesticides classified by the United States Environmental Protection Agency as exempt materials under 40CRF 152.25, or those pesticides of a character not requiring FIFRA regulation.

Emergency Waivers

If an emergency public health situation warrants the use of pesticides which would otherwise not be permitted under this policy, the Town of Wellesley Board of Health shall have the authority to grant a temporary, one-time waiver if **:**

1. The pest situation poses an immediate threat to human health AND
2. Viable alternatives consistent with this IPM policy do not exist.

If an emergency environmental health situation warrants the use of pesticides which would otherwise not be permitted under this policy, the Town of Wellesley Natural Resources Commission shall have the authority to grant a temporary, one-time waiver if:

1. The pest situation poses an immediate threat to environmental health AND
2. Viable alternatives consistent with this IPM policy do not exist.

If pesticides are used under the emergency waiver clause, then the area treated shall be conspicuously sign posted as soon as possible after application and for a period of at least 48 hours. Furthermore, the IPM committee shall be notified as soon as practical, and a specific IPM plan developed to prevent further such emergencies.

IPM Advisory Committee

An IPM Advisory Committee shall be created to oversee and assist in the implementation of the IPM policy, to develop an IPM program consistent with this policy, and to assist the Town of Wellesley Departments to achieve the full and successful implementation of this policy. In addition, their duties will include:

- Creating a 5 year turf management plan for athletic fields consistent with this policy.
- Compiling a registry of all pesticides currently stored on Town owned premises, with a goal of proper disposal through a Hazardous Wastes Collection program.
- Ensuring that the Town compost be tested on a yearly basis for contaminants, including, but not limited to, heavy metals and pesticides.
- Ensuring that Town water be tested for pesticides at least every three years based upon recommendations by the IPM Advisory Committee.
- Ensuring that Town of Wellesley employees who work with turf, landscape, or grounds receive yearly education and training in natural, organic turf, landscape, and grounds management.

The Advisory Committee will seek broad community participation on a non-voting basis. Membership on the IPM Advisory Committee shall be comprised of a representative from each of the following:

- Town of Wellesley, Board of Health
- Town of Wellesley, Natural Resources Commission
- Town of Wellesley, School Department
- Town of Wellesley, Recreation Department
- Town of Wellesley, Department of Public Works
- Town of Wellesley, Selectmen
- Town of Wellesley, Playing Fields Task Force
- Up to 3 Citizen Representatives, knowledgeable about environmental toxins and/or integrated pest management techniques

The following members of the Natural Resources Commission hereby approve and adopt the "Integrated Pest Management Policy for Land Owned by the Town of Wellesley."

Heidi K. Gross, Chairman

Joan E. Gaughan, Vice Chair

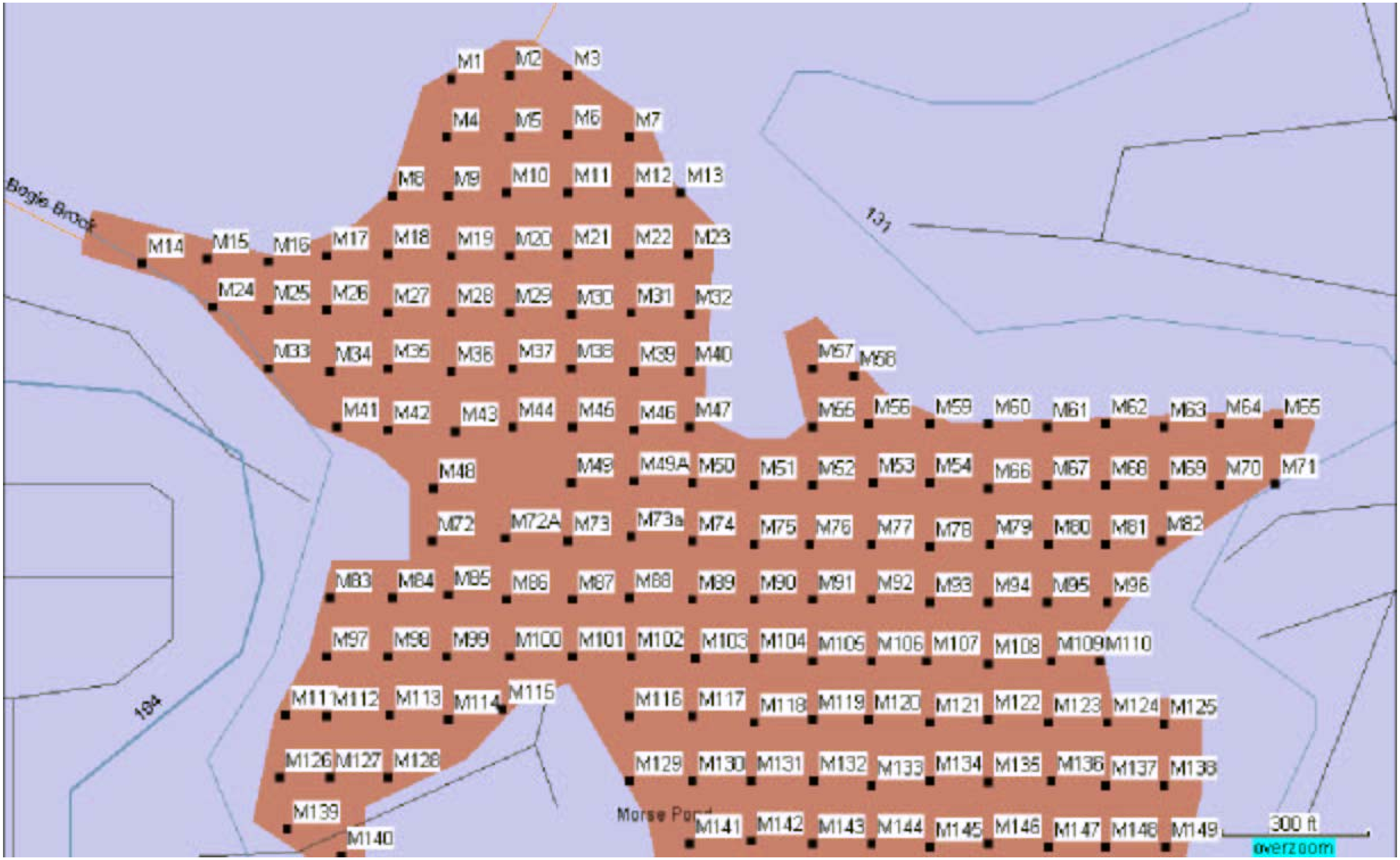
Richard J. Gleason,

Richard J. Gleason,, Secretary

Dot Brown

Maureen Febiger

October 22, 2002



Morses Pond plant monitoring locations, part 1.

Morses Pond plant monitoring locations, part 2.

Morses Pond Plant Data 2004

Data Per Plant Species

	Non-native Species						Common Native Species							
Plant Frequency	Ccar	Mspic	Mhet	Mhybrid	Lsal	Tnat	Nflex	Cdem	Ecan	Pamp	Prob	Ugib	Nodo	Nvar
# of sites present in littoral zone	97	157	11	15	4	0	119	90	44	83	138	45	80	31
Percent Frequency in littoral zone	41.6	67.4	4.7	6.4	1.7	0.0	51.1	38.6	18.9	35.6	59.2	19.3	34.3	13.3
# of sites trace (T) in littoral zone	5	11	0	1	1	0	2	33	23	22	15	14	2	9
Percent frequency trace in littoral zone	2.1	4.7	0.0	0.4	0.4	0.0	0.9	14.2	9.9	9.4	6.4	6.0	0.9	3.9
# of sites sparse (S) in littoral zone	22	41	4	6	0	0	27	51	17	25	48	19	32	6
Percent frequency sparse in littoral zone	9.4	17.6	1.7	2.6	0.0	0.0	11.6	21.9	7.3	10.7	20.6	8.2	13.7	2.6
# of sites moderate (M) in littoral zone	22	57	1	3	3	0	22	6	4	25	53	10	31	15
Percent frequency moderate in littoral zone	9.4	24.5	0.4	1.3	1.3	0.0	9.4	2.6	1.7	10.7	22.7	4.3	13.3	6.4
# of sites dense (D) in littoral zone	48	48	6	5	0	0	68	0	0	11	22	2	15	1
Percent frequency dense in littoral zone	20.6	20.6	2.6	2.1	0.0	0.0	29.2	0.0	0.0	4.7	9.4	0.9	6.4	0.4

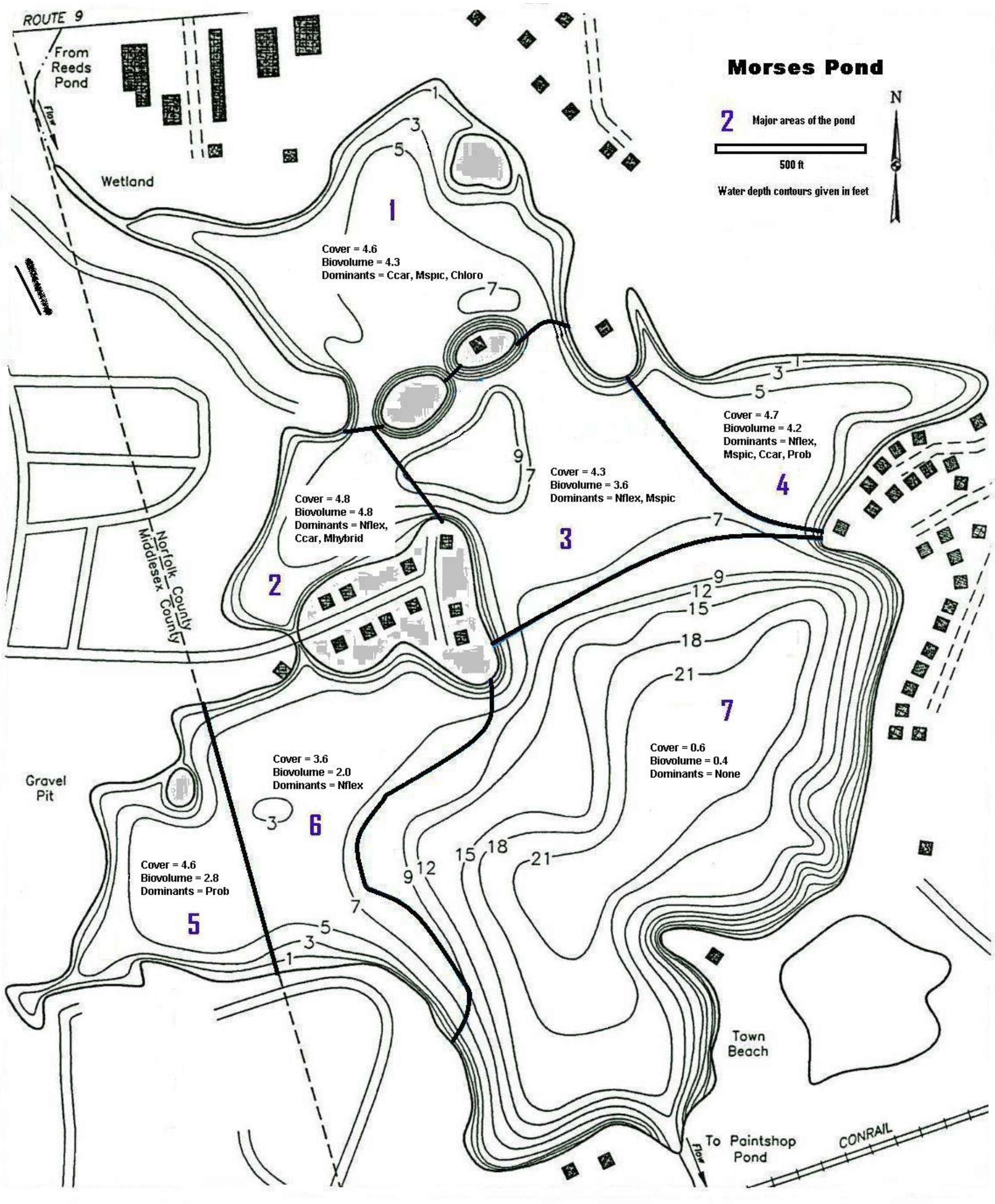
	Less Common Native Species											Floating Species		
Plant Frequency	Ppul	Ugem	Pcord	Poly	Sgram	Calli	Dver	Ranu	Salix	Tlat		Lmin	Wcol	Spol
# of sites present in littoral zone	18	1	2	8	8	2	6	0	0	0		46	44	6
Percent Frequency in littoral zone	7.7	0.4	0.9	3.4	3.4	0.9	2.6	0.0	0.0	0.0		19.7	18.9	2.6
# of sites trace (T) in littoral zone	0	1	2	2	2	2	2	0	0	0		28	24	6
Percent frequency trace in littoral zone	0.0	0.4	0.9	0.9	0.9	0.9	0.9	0.0	0.0	0.0		12.0	10.3	2.6
# of sites sparse (S) in littoral zone	3	0	0	4	6	0	1	0	0	0		15	20	0
Percent frequency sparse in littoral zone	1.3	0.0	0.0	1.7	2.6	0.0	0.4	0.0	0.0	0.0		6.4	8.6	0.0
# of sites moderate (M) in littoral zone	10	0	0	1	0	0	3	0	0	0		3	0	0
Percent frequency moderate in littoral zone	4.3	0.0	0.0	0.4	0.0	0.0	1.3	0.0	0.0	0.0		1.3	0.0	0.0
# of sites dense (D) in littoral zone	5	0	0	1	0	0	0	0	0	0		0	0	0
Percent frequency dense in littoral zone	2.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0

Total # of sites in littoral zone	233
Total # of sites in littoral zone with plants	229
Total number of plant observations	1055
Total number of non-native observations	284
% frequency of non-native observations	26.9
Average # of species per site	4.5
Average # of native species per site	3.3
Average # of non-native species per site	1.2

(shaded) indicates non-native species

Occurrence of algal mats (green or blue-green) not included in this summary

Abbreviation	Scientific Name	Common Name
Ccar	*Cabomba caroliniana*	Fanwort
Calli	*Callitriche sp.*	Water starwort
Cdem	*Ceratophyllum demersum*	Coontail
Dver	*Decodon verticillatus*	Swamp loosestrife
Ecan	*Elodea canadensis*	Waterweed
Lmin	*Lemna minor*	Duckweed
Lsal	*Lythrum salicaria*	Purple loosestrife
Mhet	*Myriophyllum heterophyllum*	Variable watermilfoil
Mspic	*Myriophyllum spicatum*	Eurasian watermilfoil
Nflex	*Najas flexilis*	Common naiad
Nvar	*Nuphar variegatum*	Yellow water lily
Nodo	*Nymphaea odorata*	White water lily
Poly	*Polygonum amphibium*	Water smartweed
Pcord	*Pontederia cordata*	Pickerelweed
Pamp	*Potamogeton amplifolius*	Broadleaf pondweed
Prob	*Potamogeton epihydrus*	Leafy pondweed
Ppul	*Potamogeton robbinsii*	Robbins pondweed
Ranu	*Ranunculus sp.*	Water crowfoot
Sgram	*Sagittaria gramineus*	Submerged arrowhead
Salix	*Salix sp.*	Willow
Spol	*Spirodela polyrhiza*	Big duckweed
Tlat	*Typha latifolia*	Cattail
Tnat	*Trapa natans*	Water chestnut
Ugem	*Utricularia geminiscapa*	Bladderwort
Ugib	*Utricularia gibba*	Bladderwort
Wcol	*Wolffia columbiana*	Watermeal
Notes: *Potamogeton pulcher* is now believed to be a thin-leaved variety of P. amplifolius.		
A *Myriophyllum heterophyllum* variant that may be a hybrid is also listed in the raw data.		



Summary of Plant Community Features by Area in Morses Pond.

Morses Pond Aquatic Plants Controlled by Commonly Used Herbicides in Massachusetts
C = consistent control (with correct dose, proper formulation and suitable conditions),
P = partial control (control sometimes achieved, but may require a higher dose or be affected by conditions that are difficult to control). The ability to control a plant with an herbicide does not necessarily indicate that the plant requires control in Massachusetts. NE indicates that there is no experience with the management of this species in Massachusetts, while NNM signifies that the species is not normally managed in Massachusetts.

	Diquat	Glyphosate	Fluridone	Triclopyr
Emergent Species				
Lythrum salicaria (purple loosestrife)		C		C
Pontederia cordata (pickerelweed)	P	C		C
Typha spp. (cattail)	P	C	P	
Floating/Floating leaf Species				
Lemna spp. (duckweed)	P		C	
Nuphar spp. (yellow water lily)		C	P	C
Nymphaea spp. (white water lily)		C	P	C
Polygonum amphibium (water smartweed)		C	P	
Spirodela polyrhiza (big duckweed) NE			C	
Trapa natans (water chestnut)			P	
Wolffia spp. (watermeal)	P		C	
Submergent Species				
Cabomba caroliniana (fanwort)			C	
Ceratophyllum demersum (coontail)	C		C	
Elodea canadensis (waterweed)	C		C	
Myriophyllum heterophyllum (variable watermilfoil)	C		P	C
Myriophyllum spicatum (Eurasian watermilfoil)	C		C	C
Najas flexilis (bushy naiad)	C		C	
Polygonum spp. (water smartweed)		C	P	
Potamogeton amplifolius (largeleaf pondweed)	P		P	
Potamogeton epihydrus (pondweed)	C		P	
Potamogeton robbinsii (Robbins' pondweed)	P			
Ranunculus spp. (buttercup)	C		P	
Sagittaria spp. (submergent arrowhead) NNM	P			
Utricularia spp. (bladderwort)	C		C	

Note: Copper and peroxide based algaecides are not included above, as they are not the primary active ingredients for vascular plant control. However, they are approved for use in potable water supplies, and could be applied in an effort control the green (chlorophyta) or blue-green (cyanobacteria) algal mats in Morses Pond as well as planktonic growths.

EVALUATION OF ADDITIONAL ROOTED PLANT CONTROL TECHNIQUES IN MORSES POND

Benthic barriers:

- Materials can be placed on the lake bottom, covering plants and preventing or minimizing regrowth. See attached primer from the Practical Guide to Lake Management in Massachusetts.
- All plants under the barrier will be killed after 30-60 days. Regrowth from seeds can occur if barrier is removed. Open areas suitable for plant growth may be subject to invasive species colonization. Some species will grow through porous barriers (woven material with small apertures for gas escape) or re-root from fragments landing on porous barriers.
- Porous barriers require cleaning annually. Solid barriers must be vented to maintain negative buoyancy, but may not require annual cleaning if sediment accumulation rates are low.
- Porous barriers are well suited to swimming areas, where they can be placed at the end of the season and removed at the start of the season, providing weed-free swimming. Many people do not like the feel of barriers on the bottom in swimming areas, although they may be preferable to muck.
- Solid barriers are better suited to maintaining open water around docks or in boating lanes where barriers are not removed and human contact with the bottom is limited. Solid barriers may be useful, however, in mucky swimming areas where covering the bottom is desirable.
- Cost is typically on the order of $40,000/acre. Large areas (>2 acres) are rarely if ever managed by this approach. Annual labor costs for cleaning, removing, and/or repositioning barriers are considerably less, but still on the order of $1000-$4000/ac.
- Individual shoreline residents may want to use benthic barrier to open the lake by their shoreline for access (swimming or boating). Where invasive species are the target, an Negative Determination of Applicability can be issued by the Natural Resources Commission (no formal permit required).
- The Town might consider using benthic barrier at the swimming area instead of annual hydroraking.

Herbivorous invertebrates:

- Plant-eating invertebrates, usually insects, have been tested over the years in relation to a variety of target species. See attached primer from the Practical Guide to Lake Management in Massachusetts. Some, like the loosestrife beetle *Galerucella*, have achieved some distinct success. Others, like the milfoil weevil *Euhrychiopsis*, have yielded mixed results and are not yet reliable for control. Still others, like the milfoil moth and milfoil midge, have yet to be used in active control programs, but have potential to control target plants on their own under the right (but largely unknown) circumstances. The potential exists for biological controls over targeted rooted plants, but the actual application of techniques suffers from inadequate research and inherent variability that goes hand in hand with most biological systems.
- For MP, the only plants for which there are known, manageable invertebrate herbivores are purple loosestrife and Eurasian watermilfoil. Other problem species, like water chestnut, variable milfoil, fanwort and naiad, have no such invertebrate control agents.
- Control of purple loosestrife around MP would make an excellent civic project, as the beetles are usually raised and then distributed by small groups like schools, Scouts, or clubs to make this approach affordable. The Association of Wetland Scientists runs a volunteer program that can guide any interested group.
- Control of Eurasian watermilfoil with the milfoil weevil has potential, but not much reliability at this time. The best evidence to date suggests a need for several stockings over 3-5 years before lakewide results can be expected. At a cost of $1/weevil and a desired density of 3000/ac, the cost is also significant. The presence of substantial sunfish populations can greatly interfere with results, as they readily consume the weevils, thereby jeopardizing the investment.
- The presence of multiple nuisance and invasive species in MP and the absence of an overall invertebrate plant herbivore that could control them all limits the utility of this approach.

Herbivorous fish:

- The primary fish agent of plant control is the grass carp, *Ctenopharyngodon idella*, which is not currently legal for stocking in Massachusetts waters. See attached primer from the Practical Guide to Lake Management in Massachusetts.
- Recent studies suggest that plants can be controlled without promoting excessive algal blooms, but an increase in algae is generally expected when lakes shift away from rooted plant dominance.
- Prevention of emigration is a major concern when stocking herbivorous fish, both from the perspective of gaining control in the target waterbody and for preventing impacts in upstream or downstream lakes.
- As this approach is not permitted in Massachusetts, it warrants no further consideration for MP at this time.

Plant competition:

- A healthy native plant community has a greater ability to resist invasion than the absence of plants, and there is some evidence that plant invasions have been greatly slowed by dense native assemblages. By promoting a desirable assemblage of plants, it may be possible to reduce the level of invasive plant abundance. See attached primer from the Practical Guide to Lake Management in Massachusetts.
- However, invasive species are by nature superior competitors, and may gradually become dominant even with a healthy plant assemblage. They will surely colonize areas opened by management techniques intended to simply remove existing plants.
- Since much of MP is shallow and has a hospitable substrate, it is expected that plants will grow over much of its bottom area. To minimize the effort put into invasive species control over time, it would be desirable to foster a more favorable native species complex.
- The desired native assemblage can be encouraged either by selectively removing invasive species and allowing natural growth of the desired plants, or by actively planting desired species. Both approaches have been tried in some lakes, neither is completely reliable, and considerably more research is needed.

- Species of interest for MP include:

Species	Common Name	Now Present	Related Issues
Chara	Stonewart, muskgrass	No	Must have suitable water quality
Nitella	Nitella	No	Must have suitable water quality
Potamogeton robbinsii	Robbins pondweed	Yes	Spreads vegetatively and slowly
Najas flexilis	Common naiad	Yes	Can be a nuisance at high density
Najas guadalupensis	Southern naiad	No	At northern edge of range
Potamogeton amplifolius	Broadleaf pondweed	Yes	Can be a nuisance at high density
Potamogeton epihydrus	Leafy pondweed	Yes	Patchy and uncertain distribution
Elodea canadensis	Waterweed	Yes	Can be a nuisance at high density – great for Area 1
Ceratophyllum demersum	Coontail	Yes	Can be a nuisance at high density – great for Area 1
Other Potamogeton spp.	Pondweeds	No	Patchy and uncertain distribution

- Enough desirable species exist already, with the potential for others to be present as seeds or arrive on their own, that it seems preferable to control undesirable species and let nature decide which native species expand, at least on a trial basis.
- Active planting could be attempted later (after 2-3 years of observation), with the introduction of Chara and/or Nitella having the highest priority.

EVALUATION OF THE NO ACTION ALTERNATIVE IN MORSES POND

Reasons to apply this approach:
- Lack of funds.
- Inability to get project(s) permitted.
- Public concern over non-target impacts.

What constitutes "No Action":
- No management at all?
- No change from current management approach?
- Variability in past management is a factor in discerning trends and projecting changes.

Impact on Water Supply:
- The wellfield depends on the interface in the northern part of Area 7 and possibly Area 4. Accumulated organic muck could reduce hydraulic conductivity, but this has not happened over many years of limited management, so there is no reason to believe that it will change at any point in the near future.
- Water quality is somewhat variable now, and will become more variable as the capacity of Area 1 is diminished. This could affect well water quality, but only for dissolved substances not reactive with the sand that water passes through on the way to the wells. The primary concern would be taste/odor and toxic compounds from blue-green algae, which could increase in abundance and duration of dominance, but any increase in variation of DOC or pH could increase treatment needs/costs.
- The timeframe for any impacts on water supply is linked to treatment effectiveness in Area 1, which is losing detention capacity steadily, if not on an accelerating pace. The change will be gradual, and unlikely to be measurable for another decade, but possibly measurable within 20 years. It is not clear that the change will be severe enough to require a major change in supply practices, but it could be, especially in light of increased regulation of groundwater supplies.

Impact on Contact Recreation:
- Variability in water quality is a fact of life at the MP beach and throughout the lake, and will complicate definitive prediction of changes. Change should be measured as increased probability of algal blooms or bacterial standard exceedences, and these can indeed be expected to increase as treatment capacity in Area 1 declines.
- The available data do not show a distinct increase in southern basin average P level over the period of 1981-2000, but variability does increase and the expected level of change is within the measurement error for P (see attached figure).
- Activities in the watershed are not static, but there do not appear to have been major changes in loading over the last 20 years. A new load analysis is underway. It appears, however, that any change in MP water quality is largely a function of changing treatment capacity in Area 1.
- Area 1 capacity in its optimal form should result in a phosphorus reduction of about 60%; the last careful estimate of loading in 1994 suggested that the removal rate was about 46%, a decline of 14% since the last dredging of that area in the late 1970s. Tentatively, it is projected that without any increase in loading to the lake (under investigation now), removal efficiency will be cut in half in one to two decades. With about 80% of the P load passing through Area 1, this would equate to a 12% increase in the total load to the southern basin. This could be enough to cause a noticeable increase in algal bloom frequency, duration and severity, but not necessarily enough to detect within the context of current P measurement methodology.
- Water clarity vs. P is a non-linear relation (see attached figure); current and recent clarity and P levels are at a major point of inflection where changes can make a real difference in swimming conditions.
- The loss of removal efficiency is not likely to be linear; an exponential loss is more likely. The increased variability in water quality is probably the best early warning signal of changing loads.

- No clear prediction of when the lake will become "unswimmable" on a regular basis can be made, but it is probably >20 years from now.
- Impacts of rooted plants do not appear to be getting any worse, but are managed at the swimming beach. In less managed areas, conditions have been adverse for swimming for many years, and are not appreciably worse outside of Area 1 (but are also not any better, despite management attempts). If no plant management was practices, contact recreation would be prevented in most of MP within just a few years.

Impact on Flood Control:
- The water level is not changing, so available flood storage is not affected.
- The volume of the lake is declining, although not at an alarming rate. This affects detention time, and possibly downstream impacts, but not actual flood storage capacity.

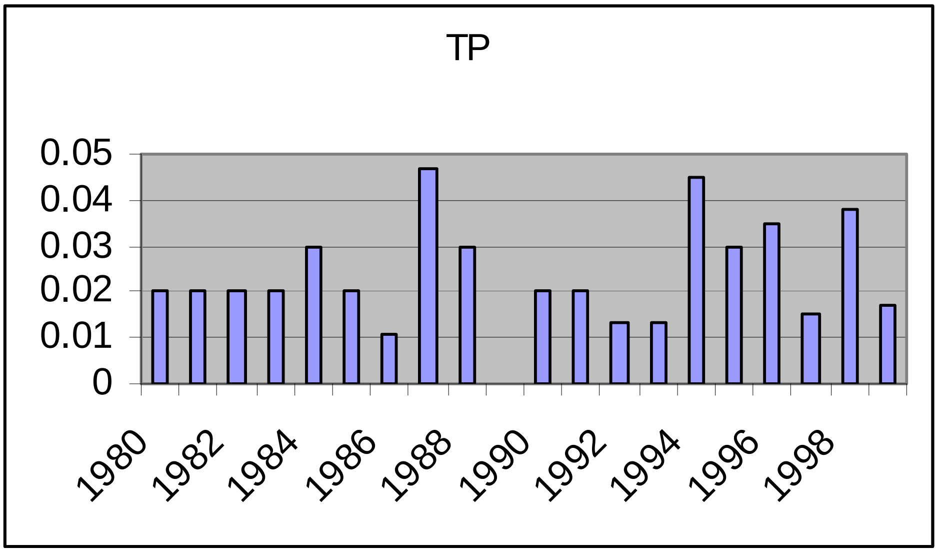
Impact on Habitat:
- The infilling of MP has impacts on habitat, but the rate is slow enough to avoid detection of changes except possibly in Area 1. Plant densities have been higher than desirable for most aquatic fauna for many years; annual fluctuations and the results of past management obscure any trend. There is no reason to expect a major change under the programs of the last 20 years, but the increased density of plants and further deterioration of habitat was evident in 2004 in the absence of harvesting anywhere but at the beach.
- Water quality does not appear to be changing at a rate detectable in terms of habitat. Key features such as oxygen, pH and clarity have not changed appreciably over a decadal scale.

Impact on Fishing:
- Lack of plant management will virtually prevent enjoyable fishing anywhere but Area 7 during summer and early fall.
- With plant management at the level of the past 20 years, no major change in fishing conditions is expected, but conditions appear suboptimal.
- Water quality does not appear to be changing at a rate that would yield a measurable change in fishing quality.

Impact on Boating:
- Lack of plant management will virtually prevent enjoyable boating anywhere but Area 7 during summer and early fall.
- With plant management at the level of the past 20 years, no major change in boating conditions is expected, but conditions appear suboptimal.
- Water quality does not appear to be changing at a rate that would yield a measurable change in boating quality.

Impact on Aesthetics:
- Aesthetics are somewhat subjective, but plant densities and water appearance cause unaesthetic conditions by virtually any standard for much of the summer and early fall.
- Plant conditions cannot get much worse than observed in 2004 in the absence of active management except at the beach.
- Water clarity will decline over time in the absence of management, either in the watershed or Area 1, but the rate of decline is difficult to predict in light of high variability. Variability is likely to measurably increase, and may be the best indicator. A change was noted over the last decade, and appears detectable on about that scale (10 years of data).

Economic impact:
- While not explicit examined in this evaluation, the loss of tax base has been documented in studies of both changing water quality and plant communities.
- The cost to the tax base is typically in excess of recommended management cost.


TP
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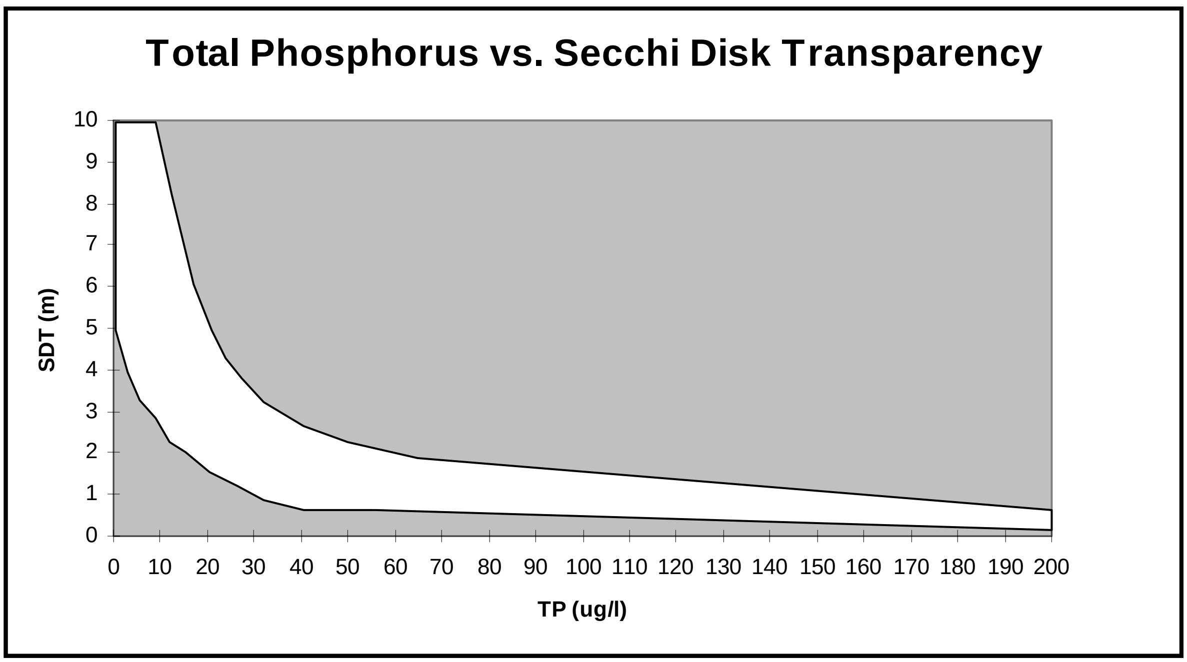
Total Phosphorus vs. Secchi Disk Transparency
SDT (m)
10
9
8
7
6
5
4
3
2
1
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
TP (ug/l)