Hickory Hills Lake
Interim Report – 2020 Recommendations

Hickory Hills Lake
Lunenburg, MA

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1.0 INTRODUCTION

Hickory Hills Lake is an approximately 314-acre water body located in Lunenburg, Massachusetts. The lake is owned and operated by the Hickory Hills Landowners Inc. (HHLI). The Board of Directors (the Board), composed of duly elected residents and shareholders, is responsible for the day to day operations of the HHLI. To better evaluate and address issues relating to the natural health of the lake, the Board approved the formation of a Lake Management Group in January of 2009. The Lake Management Group (LMG) seeks to improve environmental conditions, aesthetic value, and recreational opportunities at Hickory Hills Lake, and has reviewed and implemented a variety of techniques within the lake and watershed to manage aquatic vegetation, control erosion, and manage stormwater (see 2019 Hickory Hills Lake Management Plan, HHLI 2019). The Weed Mitigation Group, a sub-committee of the LMG focused on weed management within the lake, was formed after the discovery of an infestation of fanwort (*Cabomba caroliniana*) in Hickory Hills Lake in 2011 (date to be confirmed).

Hickory Hills Lake is generally shallow, with a maximum depth of 20 ft, and average depth of 8.9 ft (Solitude 2014). The lake shoreline is very complex, stretching for over 9 linear miles, with a multitude of coves, peninsulas, and islands. The primary inlet to Hickory Hills Lake, Mulpus Brook, is located in the northwestern extreme of the waterbody. Water depths in the Mulpus inlet area are very shallow, due to deposition of sediment from the brook. Numerous smaller inlets also flow into Hickory Hills Lake. Outflow occurs from the southeast corner of the lake and is controlled by structures including an approximately 100-foot concrete spillway, nine 6-foot wide and 18-inch deep stop-log bays, and a low-level gate valve. Pumps and siphons provide additional water level control during drawdown operations.

Hickory Hills Lake is used for a variety of recreational purposes, including boating (10 hp max), swimming, and fishing, and provides immense aesthetic value to homes along the shoreline. The Hickory Hills Lake watershed covers approximately 4,979 acres, approximately 52% of which is classified as developed land (Figure 1).

Managing the fanwort, an invasive aquatic weed species, is the primary concern of the LMG. As discussed below (see section 2.2.2) fanwort was first discovered in Hickory Hills Lake in 2011. This species grows rapidly and produces dense mats of vegetation in the water column and at the water surface, resulting in the exclusion of native species and impeding usage of the waterbody for recreation. Fanwort has spread throughout Hickory Hills Lake and continues to increase in density despite tremendous levels of volunteer and commercial harvesting efforts.

In addition to fanwort, other species of management concern include American lotus and pink water lilies, which were first observed within the lake in 2018, and purple loosestrife, which is present along areas of the lake shoreline. Nuisance levels of native vegetation, algae blooms, water quality concerns, and sedimentation due to stormwater inputs have also been identified as concerns for Hickory Hills Lake.

The HHLI is seeking an extension of their previously-issued Order of Conditions by the Lunenburg Conservation Commission (LCC) in January of 2020. This OOC allows for a wide variety of management actions, as described in the draft 2019 Hickory Hills Lake Management Plan, with the condition that HHLI consult with the LCC prior to any management actions. This interim report along with these 202 recommendations will also need to be submitted to the LCC and approved before they can be implemented.

2.0 PREVIOUS MANAGEMENT ACTIONS AND EXISTING CONDITIONS

The following sections summarize current conditions and previous management actions taken to address water quality issues and aquatic vegetation in Hickory Hills Lake.

2.1 Water Quality Management

2.1.1 Water Quality Monitoring

Surveys of Hickory Hills Lake are conducted by professionals on a biennial basis, and include testing of the following water quality parameters:

- pH
- Alkalinity
- Turbidity
- Conductivity
- Nitrate
- Ammonia
- TNK
- Total Phosphorus
- Dissolved Phosphorus
- True Color
- Apparent Color
- Total Coliform Bacteria
- Fecal Coliform Bacteria

2018 sampling results indicate that Hickory Hills Lake is within the acceptable range for most analytes tested, including pH, turbidity, conductivity, total and dissolved phosphorus, and TKN. Results of this water quality testing are now dated and some of the most critical elements of the testing appear to be less than ideal. For example, analysis for total and dissolved phosphorus in the 2019 data are shown as “ND” or non-detect, which indicates that the laboratory used was not able to analyze the samples to an appropriate level of detection. Phosphorus is a key nutrient for any freshwater system and better testing will be needed going forward.

Lake Surveys are done by professionals on a biennial basis. As part of the survey, water quality testing is conducted. Results are listed in table below.

Water Testing Results – Main Lake

Parameter	2003	2006	2008	2010	2012	2014	2016	2018
pH	7.4	6.28	6.91	7.14	6.53	6.8	6.9	7.2
Alkalinity	11	11	8.6	10.6	14.5	10	12	NS
Turbiditiy	0.61	0.75	0.43	0.48	0.49	0.64	1.1	0.49
Conductivity					117	170	190	160
Nitrate	0.22	0.12	<0.1	<0.1	ND	ND	ND	ND
Ammonia		NS	NS	<.05	ND	0.1	0.056	ND
Total Kjeldahl Nitrogen					0.2	ND	0.37	0.357
Total Phosphorus	0.013	0.007	<0.02	<.01	ND	0.012	ND	ND
Total Dissolved Phosphorus					ND	0.007	ND	ND
True Color	16	0	14	8	10	10	10	14
Apparent Color	24	34	20	10	10	10	20	17
Total Coliform Bacteria	<50	<50	<50	50				
Fecal Coliform Bacteria					10	<10	10	<1

In addition to the biennial water quality sampling described above, the Weed Mitigation Group began conducting monthly water quality testing for the following parameters at ten locations within Hickory Hills Lake in May 2019 (Table 2.1.1):

- Phosphorus
- pH
- Nitrate
- Nitrite (added in September 2019)

Table 2.1.1. 2019 Weed Mitigation Group Water Quality Sampling Locations

Site Name	Adjacent Address/ Property
Mulpus Inlet	175 Island Road
Island Road Beach	19 Island Road – Security Dock
Little Hickory Site 1	15 Crescent Road
Little Hickory Site 2	10 Cove Road
Townsend Harbor Road Site	In Front of Dam
East Side of Peninsula	437 Townsend Harbor – Boat Docks
Hemlock Beach	100 Hemlock Road
Woodlands	110 Royal Fern
Brookview Beach	16 Brookview Terrace
Proctor Cove	44 Pine Acres

2019 testing was performed using field kits that are not able to reliably measure low-level phosphorus concentrations and these results should be verified with future testing by a certified laboratory using low-level phosphorus detection methods.

ESS Group also collected water quality and sediment samples from Little Hickory on November 15, 2019 as part of a sub-study focused on this waterbody. These samples were submitted to a state-accredited lab for analysis (Phoenix Laboratories). Results of the Little Hickory sampling events are discussed in detail in the Little Hickory Algae and Aquatic Vegetation Control Plan (ESS 2020).

The Lunenburg Board of Health conducts weekly water quality testing at Hickory Hills Lake beaches during the summer months.

2.1.2 Algae Blooms

Though not harmful to human health, filamentous algae have been an issue on Hickory Hills Lake and Little Hickory. These organisms can form dense mats that are both aesthetically displeasing and can interfere with recreational use of the waterbody. The HHLMC purchased two algae skimmers in 2019, which volunteers use to remove filamentous algae mats, particularly from Little Hickory.

In addition to filamentous algae blooms, potentially toxic cyanobacteria blooms occurred on Little Hickory in 2018 and 2019. Hickory Hills Lake volunteers monitor recreational areas and use simple testing methods (jar test, stick test) to determine if a bloom is harmful. If the presence of cyanobacteria is confirmed, skimming efforts aimed at removing filamentous algae are ceased. A contract was executed with ESS group to identify potential health impacts of toxic algae blooms in Little Hickory in September 2019 but this testing found no cyanobacteria present at the time of the field collection.

2.2 Aquatic Vegetation Management

2.2.1 Aquatic Vegetation Monitoring

Biological surveys of Hickory Hills Lake have been conducted periodically since 1993. The most recent survey was conducted in 2018 by Solitude Lake Management. The results of the 2018 survey indicate that the invasive fanwort (*Cabomba caroliniana*, see section 2.2.2) was the dominant plant species in the waterbody, and was widely distributed throughout the lake. Purple bladderwort (*Utricularia purpurea*) and macroalgae (*Nitella sp.* or *Chara sp.*) were the most commonly observed native aquatic macrophytes in Hickory Hills Lake. Other native species, including tapegrass (*Vallisneria americana*), and Robbin's pondweed (*Potamogeton robbinsii*) were also commonly observed. The 2018 survey also identified an infestation of American lotus (*Nelumbo lutea*, see section 2.2.3), and the presence of pink water lilies (*Nymphaea tuberosa*, see section 2.2.4) in the lake.

2.2.1 Boat Inspections

Following the discovery of fanwort in Hickory Hills Lake, the Board of Directors adopted a protocol requiring that all boats and trailers be thoroughly inspected before launch (at specified and advertised dates/times). Boats typically enter the lake at the beginning for the season and are launched either by their owner or a local marina, and are removed from the lake by the last week of September. The boat ramp was closed during 2019 due to the infestation of fanwort in the area, so property owners utilized a flat beach area located on the Island Road beach for boat launching. This area is only accessible by vehicles during launching hours or by special appointment.

2.2.2 Fanwort (*Cabomba caroliniana*)

Fanwort was first discovered in Hickory Hills Lake in 2011. Despite extensive volunteer operations and large-scale commercial DASH activities, fanwort is now present in high densities throughout the lake (Solitude 2018). Managing the fanwort infestation is the highest priority objective for the Lake Management Board.

Fanwort is extremely difficult to eradicate, due to its rapid growth rate (stems can grow up to 1 inch per day) and ability to spread via both root growth and fragmentation. Though total eradication of fanwort is likely impossible, it is possible to manage the species with ongoing monitoring and treatment/removal efforts. An example of successful fanwort management in Massachusetts are the efforts at South Pond (a.k.a. Quacumquasit Pond) in Sturbridge, MA. The lake association and town has been effective at controlling fanwort using a combination of herbicide treatment and diver harvesting to eliminate fanwort, but the fanwort continues to be periodically re-introduced to the system from upstream sources so continued monitoring and management remains an annual priority. This adaptive approach has kept fanwort growth to less than 0.25 acres in this 225-acre waterbody for over 15 years and the annual maintenance costs remain very low compared to the initial control program.

In Hickory Hills Lake, herbicides and benthic barriers have been used to treat fanwort growth in limited areas; however, Diver Assisted Suction Harvestings (DASH) has been the primary management approach used to date. Though the HHLI has devoted a vast amount of volunteer effort and expense to address fanwort in Hickory Hills Lake, the infestation continues to expand.

2.2.2.1 Fanwort Survey Team

A volunteer survey team of Hickory Hills residents was formed in 2012 to identify fanwort locations within the Lake to help direct DASH operations. Each member of the survey team is assigned one of 23 zones within the Lake to survey and are asked to patrol their zone in a boat, kayak, paddle board, of other watercraft, once per week. Some Survey team members also conduct surveys by snorkeling or scuba diving. Currently, survey team members deploy orange and yellow buoys to mark the location of fanwort plants. These buoys are then removed by the DASH teams after the plants have been harvested.

2.2.2.2 Diver Assisted Suction Harvesting

DASH has been the primary fanwort management approach utilized at Hickory Hills Lake to date. This technique involves the hand removal of invasive plants (including root systems) by a trained diver. Plant material is then fed into a suction hose and transported to a specially constructed barge for dewatering and transport to an off-site disposal location. This technique is faster and may result in less fragmentation of nuisance plants than hand harvesting and has been in use for decades.

Volunteer DASH Program

Hickory Hills has conducted a volunteer DASH program since 2012 and owns a DASH vessel (the original DASH vessel, obtained in 2012, was replaced in 2016). The volunteer DASH program relies on certified divers and trained deckhands, operating in teams of 3 to 4 people, depending on water depth. Hickory Hills Lake has adopted a diver certification program, and currently have three DASH teams in place. In 2019, volunteer DASH teams conducted 21 days (averaging 6 hours a day) of fanwort removal efforts.

Commercial DASH Program

In 2017, the HHLMC hired AB Aquatics to augment the volunteer DASH program. AB Aquatics deployed for two weeks in 2017 (60 hours of dive time) and was able to remove more than three times the amount of fanwort material than was typically harvested by the volunteer DASH program during the entire season. Due to the efficiency of the commercial operation, the HHLMC elected to hire AB Aquatics for 6 and 12 weeks of fanwort removal work in 2018 and 2019, respectively. Through 2018, nearly 18,000 gallons of fanwort have been removed from Hickory Hills Lake during commercial DASH operations and substantially more was removed during the 2019 season's efforts (tally not yet available to ESS).

2.2.2.3 Wader Assisted Suction Harvesting

In 2018, HHLMC volunteers constructed a mobile suction harvester for use in shallow water, named the Muck Suck 1 (MS1). This device operates like a typical DASH vessel but does not require a diver. Trained volunteers access shallow areas within coves by wading and hand pull fanwort plants from the targeted area. Plants are moved to the MS1 via suction hose, where material is dewatered before transportation to a disposal location.

The MS1 was used to harvest over 738 gallons of fanwort in 2018 but was not able to operate in 2019 due to mechanical issues. Upgraded components (new motor, floating hose) were obtained in 2019 and the MS1 is anticipated to be available for operation during the 2020 season.

2.2.2.4 Herbicides and Benthic Barrier Treatment - Boat Cove

The initial infestation of fanwort in Hickory Hills Lake was identified in the Boat Cove (adjacent to the Island Road office) during the summer of 2011. In response to this infestation, during the winter of 2015 the Weed Mitigation Group sought and received approval from the Board of Directors and the Town of Lunenburg Conservation Commission to implement a multi-phase treatment plan within the Cove. This plan involved the application of Clipper (Flumioxazin, see section 3.2.2.6) within the Cove on June 10, 2016, and the application of Sonar (Fluridone, see section 3.2.2.1) pellets along the shore within the Cove (from 39 Island Road to the mouth of the Cove) on July 5, 2016. Forty-foot log rolls of burlap benthic barriers were placed over the Sonar pellets to assure that the fanwort root systems were exposed to a concentrated dose of the herbicide. This treatment approach proved to be successful, as fanwort growth within the Boat Cove was non-existent in August of 2016. However, fanwort was once again present within the Cove in June of 2018.

2.2.3 American Lotus (*Nelumbo lutea*)

American lotus was observed in Hickory Hills Lake for the first time during the 2018 vegetation management survey conducted by Solitude Lake Management. This species was found growing in a moderate to dense patch covering approximately 4,000 square feet in the cove to the east of Hemlock Terrace.

Though American lotus is classified as native to Massachusetts (according to USDA), it can outcompete native species and rapidly take over shoreline areas and wetland habitats. Infestations can limit species diversity and interfere with recreational uses of the area, including swimming, boating, and fishing. American lotus rhizomes can grow several feet beneath the surface of muddy substrates, making physical removal difficult. Control of American lotus requires multiple years of treatment and monitoring, as lotus seeds can remain viable in bottom sediments for several years.

In an effort to decrease the extent of the lotus bed in the cove east of Hemlock Terrace, a backhoe was used to remove lake sediments and lotus rhizomes exposed during the winter drawdown in December 2019. This action is expected to reduce but not eradicate the lotus infestation, as approximately 1/3 of the bed remained submerged during lake drawdown and could not be removed.

2.2.4 Pink Water Lily (*Nymphaea tuberosa*)

Pink water lilies were identified for the first time in Hickory Hills Lake during the 2018 vegetation management survey conducted by Solitude Lake Management. This species was found growing near the Mulpus inlet. Pink water lily is considered by some to be a subspecies variation of the very common and native white water lily (*Nymphaea odorata*). Although pink water lily is not native to Massachusetts (according to USDA), it is not generally considered to be invasive. In Connecticut, for instance, the subspecies is classified as a threated species of special concern and is protected. Management of pink water lily should not be a priority unless it is found to be growing in areas where it impacts use of the lake.

2.2.5 Nuisance Native Vegetation

Though of less concern than fanwort and other invasive species within the lake, nuisance levels of native aquatic vegetation have been an issued at Hickory Hills Lake in the past. Prior to the discovery of fanwort within Hickory Hills lake in 2011, a mechanical harvester owned by HHLI was used to remove nuisance native aquatic vegetation from high use recreational areas within the waterbody. This practice was discontinued after 2011, as mechanical harvesting of fanwort promotes the spread of this species through fragmentation.

Based upon the 2018 Aquatic Vegetation survey conducted by Solitude Lake Management, plant coverage exceeds 75% within large areas of Hickory Hills Lake. Such dense coverage reduces the amount of open water habitat within the waterbody, which can deplete oxygen levels, lead to increased sediment depth, and hinder recreational activities. Management goals seeking to promote native plant growth within the lake to levels between 25% and 50% coverage are considered appropriate for Hickory Hills Lake and would provide the ideal balance of native vegetation cover for the benefit of fish and wildlife populations while not negatively impacting the ecology of the lake system or most of its recreational users.

3.0 MANAGEMENT RECOMMENDATIONS FOR 2020

There are a wide range of management options to be considered for implementation at Hickory Hills Lake and at Little Hickory. The range of options considered for aquatic weed management in 2020 includes several of the more proven approaches such as herbicides, harvesting, diver assisted suction harvesting (DASH), winter drawdown, bottom barriers and dredging. ESS will consider these more proven approaches along with several non-traditional and emerging approaches after we have fully assessed the lake during the summer of 2020. Other approached worth considering for rooted weed management may include insect herbivores, aeration, shading, sediment augmentation, P-pod bottom phosphorus extraction, barley straw and enzyme/bacterial additions to name a few.

In addition to the various approaches to address rooted plants, there are a range of approaches to be considered for improving water clarity and reducing algal blooms. More traditional approaches evaluated in this recommended program for 2020 include the use of a low-dose phosphorus binding agent (alum) and algaecides primarily recommended for Little Hickory as this is the only system we have assessed to date. Alternative algal management options we will evaluate for potential use in the future years may include alum treatment, lanthanum clay treatment, innovative stormwater solutions for the watershed, the algae skimming A-pod approach, aeration/circulation technologies, sonic disruption and biomanipulation of the plankton community.

A summary of recommended management actions for Hickory Hills Lake in 2020 is presented in Table 3.0. These management options are described in detail in the following sections.

Table 3.0. Recommended Management Actions for Hickory Hills Lake in 2020

Management Approach		Management Concern				
		Fanwort	American Lotus	Pink Water Lily	Nuisance Native Vegetation	Algae Blooms
Chemical Controls	Phosphorus Binding	-	-	-	-	✓L
	Algaecides	-	-	-	-	-
	Fluridone (Sonar)	✓+	-	-	-	-
	Glyphosate	-	✓H	-	-	-
	Imazamox (Clearcast)	-	-	-	✓L	-
	2,4-D	-	-	-	-	-
	Diquat Dibromide	-	-	-	✓+	-
	Flumioxazin (Clipper)	-	-	-	-	-
Physical Controls	Mechanical Harvesting	-	-	-	-	-
	DASH	-	-	-	-	-
	Wader Assisted Suction Harvesting (Muck Suck 1)	-	-	-	-	-
	Dredging	-	-	-	-	-

Management Approach		Management Concern				
		Fanwort	American Lotus	Pink Water Lily	Nuisance Native Vegetation	Algae Blooms
	Water Level Control (Drawdown)	✓H	-	-	-	-

✓H = Recommended for Hickory Hills Lake only, ✓L = recommended for Little Hickory only, ✓+ = recommended for both Hickory Hills Lake and Little Hickory, **-** = not recommended for use in 2020

3.1 Water Quality Management

3.1.1 Water Quality Monitoring for 2020

Although water quality monitoring is not a management action, per se, given the relationship between water quality and lake biology, it is recommended as part of the management plan for Hickory Hills Lake in 2020. Monitoring provides continuous data for the purpose of detecting changes in lake conditions that might encourage algae blooms, as well as tracking the effectiveness of any future management practices that may be implemented. Additionally, water quality monitoring is required under the current OOC for the Hickory Hills Lake drawdown.

ESS recommends that the HHLI implement a water quality monitoring program to track in-lake conditions during the growing season in 2020. This could be used to identify any emerging negative trends in water quality before they become more problematic as well as to document any improvements in water quality that may be realized through pond management actions. Phosphorus and chlorophyll-*a* levels would be important in this regard, along with easily measured field parameters (pH, dissolved oxygen, temperature, specific conductance, and clarity [Secchi depth]). At a minimum, samples should be collected during the spring, summer and fall at the surface and bottom of the lake at its deepest location. Samples should be sent to a certified laboratory that can achieve a phosphorus detection limit of 0.01 mg/L or better. Additionally, detailed lab analysis of the algal community by a taxonomic algal lab, Aquatic Analysts, Inc., is recommended for three samples taken from the surface of the deepest location during Spring, Summer and Fall.

In 2019, the Lunenburg Conservation Commission required the collection of monthly water quality samples at 10 locations within Hickory Hills Lake to monitor the effects of drawdown (Table 2.1.1). Testing for phosphorus, nitrate, and nitrite was performed using field kits that are not able to reliably measure low-level concentrations of these nutrients. For 2020, ESS recommends that the HHLI collect water quality samples during August from the 10 sampling locations established in 2019 and submit these samples to a certified laboratory for analysis of total and dissolved phosphorus using low-level detection methods as well as nitrate nitrogen and Total Kjeldahl nitrogen. Once these results can be analyzed, a more refined and focused program can be developed.

Table 4. Recommended Water Quality Monitoring Program for 2020

Parameter	Location	Timing for 2020	Notes
Total Phosphorus, Dissolved Phosphorus, Nitrate Nitrogen, and Total Kjeldahl Nitrogen	a. Surface and Bottom at Deepest Location b. From 10 routine in-lake locations once	a. Spring, Summer and Fall b. Only once - August	Will need a Van Dorn style sampler for bottom grab. Phos. detection limit <0.01 mg/L – by a lab Phoenix Labs preferred
Chlorophyll a and algal community	Surface of Deep location	Spring, Summer and Fall	Lab analysis by Phoenix Labs and Aquatic Analysts
Dissolved Oxygen/ Conductivity/ Temperature	a. Deep Location – as profile All locations as spot measurement	a. Spring, Summer and Fall b. Only once - August	Wil require purchase of new meter (~$1,000)
pH	All locations	All events	Will require purchase of new pH pen (~$75)

Prior to the initiation of the 2020 water quality sampling program, it is recommended that volunteers be trained in proper sample collection and handling procedures by ESS staff. Techniques for sample collection and handling are presented in Appendix A. Water quality monitoring at Hickory Hills Lake in 2020 by volunteers, including the purchase of a quality dissolved oxygen meter, a pH pen, and submission or relevant samples to an appropriate analytical laboratory, would cost less than $5,000.

The program recommended above will be modified by ESS for 2021 and beyond based on the results of the 2020 testing and the budget available for annual water quality monitoring. We anticipate crafting an annual monitoring program with a cost of $2,500 - $3,000 per year assuming volunteer collection and laboratory analysis.

3.1.2 Resident Education (Recommended)

Although not likely to make a significant improvement in water quality on its own, an education program can increase awareness of easy, low cost actions that residents can take to improve lake water quality by reducing nutrient runoff from their property. These actions include minimizing the impact of yard care (particularly fertilization), managing pet waste, developing rain gardens, and maintaining or planting buffers at lake and stream margins. A brochure to raise awareness among residents could be made available by HHLI and distributed to watershed residents at minimal cost by mailing out with regular correspondence (e.g., dues or bills) or electronically. The cost for the resident education program depends on the programs undertaken but will likely cost less than $3,000 to have a professional brochure developed, printed and distributed. If developed by volunteers, the cost could be essentially zero to develop and distribute electronically.

3.1.3 Stormwater Infrastructure (Recommended)

The HHLI can also help maintain water quality by committing to proper maintenance of stormwater infrastructure including catch basin cleaning and installation of modern BMPs. Modern BMPs include grassed swales, bio-infiltration designs, and created wetland systems for management runoff or peak runoff. The addition of stormwater detention and infiltration facilities at key runoff locations could greatly reduce phosphorus loading.

The recently installed stormwater outfall structures may be adequate if maintained properly. These should be monitored at least annually to assess them for removal efficiency to determine if these are adequate in achieving the goal of removing 20% of the phosphorus load from the watershed. To do such testing, the streams would be sampled upstream and downstream of each BMP for total and dissolved phosphorus. The lab costs for this testing to be performed annually would be less than $100 per site if collections were made by HHLI volunteers. This cost has not been included in recommended costs for 2020.

3.1.4 Phosphorus Binding (Recommended for Little Hickory)

Nutrient inactivation typically involves the addition of aluminum (alum or aluminum sulfate) to surface water or sediment, with the intention of binding available phosphorus, thereby effectively “inactivating” it. Alternatives to alum, such as polyaluminum chloride, various ferric compounds, and a lanthanum-based proprietary agent called Phoslock are also available on the market. During treatment, bound phosphorus precipitates out of solution and settles into sediments, where it remains unavailable for biological activity. Inactivation agent that does not immediately bind with available phosphorus settles into the sediments, helping to capture additional phosphorus that may be released from sediments over time.

An in-lake low-dose alum treatment could be applied as needed to prevent or control an incipient algae bloom. This approach is the most appropriate for addressing occasional algae blooms and, due to the low dosage applied, can be implemented with minimal risk of undesired impact. Although low-dose alum treatments carry a higher cost than algaecide treatments, they provide an added benefit of removing phosphorus from the water column and may provide control over a longer period than algaecides. Algaecides target the algae, while alum targets the cause of the excessive algae. Low-dose alum treatments should be preceded, accompanied and followed by sampling of the water body targeted for treatment. Sampling should minimally include analysis of dissolved phosphorus, aluminum, pH, and alkalinity and the locations sampled should be representative of all areas to be treated.

ESS has not fully evaluated Hickory Hills Lake, but we do not envision a need for low-dose alum applications in Hickory Hills Lake in 2020 based on prior reports of in-lake water clarity and conditions. Little Hickory, which was assessed by ESS in the fall of 2019, would be a candidate to receive a low-dose alum treatment to address algal blooms that are reported to have occurred in recent years.

Costs for treatment vary significantly depending on the type of inactivation agent used, the necessary dosage of the selected agent, and commodity prices at the time. A typical low-dose alum treatment was previously recommended for Little Hickory (ESS 2020). Costs for this treatment should be on the order of $4,000 to $5,000 per treatment and would be expected to be effective at controlling blooms in the water column for at least two months based on the pond’s flushing rate. ESS recommends the application of a low-dose alum treatment at Little Hickory in 2020, if needed, to control algae and improve water clarity. Such treatment would most likely be needed in July. Additional costs would be likely if the treatment were to be repeated in a single season and to cover necessary monitoring costs. A budget of $5,000 to $8,000 for a pilot program to assess its benefits is envisioned.

Nutrient inactivation requires an Order of Conditions issued under the Wetlands Protection Act. Therefore, a Notice of Intent (NOI) must be filed with the Lunenburg Conservation Commission, and in the case of Hickory Hills Lake, the existing OOC may only need to be modified to include the alum treatment to the existing program. In addition, the applicator must possess obtain a License to Apply Chemical from the state in order to treat the waterbody.

3.1.5 Algaecides (Not Recommended at This Time)

Algal blooms can be associated with aquatic vegetation control due to the reduced competition for light in managed areas. Registered algaecides are primarily copper-based and result in almost immediate control of a broad spectrum of planktonic and filamentous algae. Algaecide treatments can be expected to cost on the order of $250 to $500/acre for most formulations, although some specialty formulations may exceed this cost.

Algaecides are only recommended if algal growth were to reach nuisance levels (>20,000 cells/mL), and ESS does not recommend the use of algicides at Hickory Hills Lake or at Little Hickory in 2020. Algaecide application requires an Order of Conditions issued under the Wetlands Protection Act. Therefore, a NOI must be filed with the Lunenburg Conservation Commission. In addition, the applicator must possess a Commercial Applicator License and obtain a water body-specific “license to apply” prior to treatment.

3.2 Aquatic Vegetation Management

There are quite a few options for managing rooted aquatic plants and many of these have been tried to varying degrees at Hickory Hills Lake in the past. ESS is making our recommendations for 2020 based on recent studies and reports by others of the plant community at the lake and the assessment by others of the relative effectiveness or lack of effectiveness in the various approaches that have been tried to date. Once we are able to fully assess the lake in 2020, ESS will refine the management program to tailor the recommendations to the conditions we observe at the lake and to specific areas of the lake that may need more attention than others based on recreational access, navigation needs, type and distribution of weed species, and the degree of weed growth observed.

It should be noted that the approaches that have been implemented at the lake since 2011, when fanwort was first observed, have been herculean in scale and scope and are to be commended. The work involved, the commitment to the efforts, and the dedication and organization of all the various components from volunteers and equipment development through hiring and tracking of contractors is truly impressive. When fanwort was first discovered in 2011, the tools available to combat the weed essentially consisted of the herbicide fluridone (tradename Sonar) and hand harvesting or DASH. Since this time, new herbicides (e.g. flumioxazin) have become available for use in Massachusetts that are able to “spot” treat fanwort beds and the formulations of Sonar have advanced to maximize the required contact time at the correct dose with targeted plant beds.

Generally speaking, ESS is recommending an approach for 2020 that diverges significantly from the work performed in recent years in order to re-set the plant community in the lake using a lake-wide herbicide treatment in 2020 and to allow the efforts by volunteers going forward in subsequent years (2021 through

2024) to be much more targeted and focused at combating small fanwort infestations or weed beds that can be effectively managed with DASH or diver harvesting. Details of the approach we are recommending for 2020 are described below.

3.2.1 Aquatic Vegetation Monitoring and Boat Inspection

Although monitoring and boat inspections are not management actions, per se, they are recommended as part of the management plan for Hickory Hills Lake in 2020. The key monitoring element associated with any vegetation management action program would be the mapping of aquatic plant species distribution, cover, and biovolume with focus on the distribution of exotic plant species. Monitoring provides continuous data for the purpose of detecting new infestations, as well as tracking the effectiveness of any management practices that may be implemented. Monitoring is essential if management efforts are to be cost efficient since early detection and control of any future infestation can save tens of thousands of dollars in management costs. Monitoring plant cover in the lake should be performed on at least an annual basis to track changes in beds of existing exotic species and identify any emerging infestations before they spread. Plant monitoring also allows evaluations of implemented management actions to be made and strategies adjusted, as necessary.

Aquatic Plant Survey by ESS in 2020

ESS recommends that aquatic vegetation surveys of Hickory Hills Lake be performed in early summer (June) every year to assess re-growth of fanwort and any other potentially threatening exotic species. For 2020, ESS is already under contract to perform a full mapping of Hickory Hills Lake, but in subsequent years, the efforts should be able to be performed much more efficiently with a focus on mapping just the beds of fanwort regrowth to allow for focused removal through DASH.

In 2020, ESS will assess the lake at numerous points (between 200 and 300 points anticipated) along appropriately spaced transects. At each sampling point, ESS will identify each submergent, floating, and emergent aquatic plant species; record the presence of any aquatic invasive/non-native plant species; assess which plant species are dominant in the community; and estimate plant cover (the percent aerial coverage of the lake bottom) and biovolume (the percent of space in the water column taken up by plants based on density and height of plants). In addition, ESS will collect water depth and sediment type data at all points. Plant surveys will be conducted using aquatic plant rakes or underwater video camera, and the location of each data point will be recorded using a sub-meter accurate handheld GPS unit (Trimble Geo7X DGPS).

Costs for the aquatic plant surveys of Hickory Hills Lake in 2020 are included in the ESS Study. Typically, a thorough assessment of the lake would require two days to complete at a cost of approximately $3,500.

Fanwort Surveys by Hickory Hills Lake Volunteers

Given that ESS will be conducting a complete assessment of Hickory Hills Lake in 2020, ESS recommends that volunteer fanwort surveys in 2020 be suspended. Going forward, these volunteer surveys could be greatly improved using hand-held GPS units for recording the locations of fanwort beds or individual plants. If volunteers are to map the fanwort beds in future years, ESS recommends using a hand-held GPS units with sub 3-meter accuracy to collect points along the perimeter of each bed or to collect a point at the location of a single or small cluster of plants. This approach will allow for quickly mapping and sharing map info with other volunteers performing the DASH or to share with contractors being hired to perform the removals. A hand-held GPS unit with WAAS (Wide Area Augmentation System) will be sufficiently accurate for mapping weed beds and these units can be purchased for between $100 and $250 depending upon the options desired.

Boat Inspections

ESS strongly recommends that the HHLI continue to implement their boat inspection policy in 2020 to help prevent the introduction of new species to Hickory Hills Lake. This will help to prevent introductions of new aquatic invasive species.

3.2.2 Herbicides

It is understood by ESS that the Order of Conditions issued by the Town of Lunenburg Conservation Commission allows for the application of various herbicides to Hickory Hills Lake, after consultation. Options for chemical control of invasive aquatic plants are presented in Table 3.0 and are detailed individually in the following sections.

Herbicide treatment is usually the most cost-effective means by which to rapidly achieve the goal of reducing aquatic biomass over a large area. Herbicides may also be used over the long-term as part of a comprehensive management plan to treat areas of recurring infestations that are not readily controllable through other means. Over time, as control of the target species is achieved, management may be re-focused on other non-chemical methods, if desired.

The six herbicide options with potential to be useful for aquatic plant control at Hickory Hills Lake are fluridone, glyphosate, Imazamox, 2,4-D, diquat dibromide, and flumioxazin. Information about each herbicide and its specific applicability is presented in the sections below.

Given the widespread high density of fanwort within Hickory Hills Lake and Little Hickory, ESS recommends lake-wide treatment with fluridone (Sonar) in May of 2020. Foliar application of glyphosate is recommended to treat the American lotus infestation in Hickory Hills Lake in July/August. Spot-treatment of nuisance native emergent vegetation (lilies, etc.) using Imazamox in Little Hickory (in June/July) as needed and diquat for control of native plant species in Hickory Hills Lake (July) is also recommended for use in 2020.

3.2.2.1 Fluridone – Systemic Herbicide (Recommended for Hickory Hills Lake and Little Hickory in 2020)

Fluridone (trade name Sonar) is a systemic herbicide that reduces photosynthesis in affected plants (by inhibiting the formation of the plant pigment carotene which causes the rapid degradation of chlorophyll by sunlight in the plan), leading to eventual starvation of the entire plant. Fluridone is the only systemic herbicide that is highly effective on fanwort. A systemic herbicide is one that can kill the plant and its roots whereas a contact herbicide only controls the exposed surface growth of the plant and thus the roots survive to regenerate stems and leaves later in the season or during the following year.

Fluridone can also be used in the control of Eurasian milfoil and variable-leaf milfoil (should these ever be introduced to Hickory Hills Lake) and can be used to manage the native large-leaf pondweed (*Potomogeton amplifolius*) and some other native pond weeds. Fluridone may also help to control American lotus growth below the water surface and thus prevent regrowth from seeds during the treatment period.

Fluridone may be applied as a liquid formulation or as a slow-release pellet formulation. Fluridone concentrations must be maintained at treatment levels (5 to 20 ppb) for as long as 90 days to achieve effective treatment. This treatment is most effective when applied in late spring or early summer, when targeted fanwort plants are expected to be rapidly maturing. Fluridone will be absorbed by the targeted plants, providing complete control of the vegetation and root structures after two to three months of exposure.

The primary advantages of fluridone include the following:

- As a systemic herbicide, fluridone should result in multiple seasons of control.
- Due to the slow action of this herbicide, plant dieback is gradual and dissolved oxygen sags are rarely problematic.
- Label restrictions are minimal.

The primary limitations of fluridone include the following:

- Concentrations must be maintained at treatment levels for as long as 90 days to achieve effective treatment. This can be difficult in water bodies with rapid flushing rates, although use of granular formulations or advanced liquid formulations (e.g., Sonar Genesis) may significantly improve treatment success.

Fluridone is one of the more expensive herbicides on the market and treatments are typically cost $700 to more than $1,000/acre, depending on the formulation used and the need for "booster" treatments to maintain the concentration of the herbicide at an effective level over the treatment period. ESS recommends the use of fluridone for Hickory Hills Lake and Little Hickory in 2020 as an effective means for achieving control of fanwort. Whole-lake Sonar treatment in 2020 is expected to cost on the order of $200,000 - $225,000 for Hickory Hills Lake, and $5,000 - $8,000 for Little Hickory. This treatment is only being recommended for 2020 and it is expected that no treatment will be required in 2021 or 2022 and the need for any further treatments after 2022 will depend upon the level of diligence by volunteer monitors and DASH boat operators to map and remove any regrowth or new infestations of fanwort.

A few notes on the fluridone treatment:

1. Fluridone treatment is likely to be at a dose of between 5 and 20 ppb. The USEPA allows for fluridone to be safely applied to aquatic systems at a dose up to 150 ppb.

2. Fluridone impacts carotene and thus has shown few impacts to animals at tested levels as high as 1,000 ppb to 10,000 ppb.

3. Fluridone has been extensively tested and found to not be a carcinogen or mutagen.

4. Using fluridone to manage the fanwort will result in a very prolonged die off and decay of the plants and will thus not result in a spike in phosphorus being released from the plans that might otherwise lead to algal blooms or drops in oxygen levels.

5. Fluridone use will kill the rooted plants as well as any floating fragments within the water column.

6. DASH harvesting during the fluridone treatment is not necessary and in fact may be counterproductive as the goal of the fluridone treatment is to allow the plants to take up the herbicide and slowly die off thus killing the root system. If the plants are picked, it will stimulate the root systems to re-sprout new stems and leaves.

7. Swimming and boating and other recreational used will not be allowed during the day of the initial application or on days in which a booster treatment is required. Use of lake water for irrigation will not be allowed for up to 14 days post application.

8. A study by the Ramsey-Washington Metro Watershed District in 2014 found that aquatic plants contain approximately 0.0313% phosphorus or 36 lbs. of phosphorus in 115,000 lbs. of aquatic vegetation harvested. This amount of phosphorus is not insignificant, but it is also not so large that HHLI should worry about the lack of plant biomass removal during this single year of lake-wide herbicide treatment. Much of the nutrient being released during the decay of the plant enters the water column slowly and passes downstream with outflowing water.

9. Fluridone has been used in several locations in Massachusetts to eliminate a target weed for extended periods of time. Ashmere Lake in Hinsdale, MA was successful in keeping milfoil growth at bay using furidone alone for over 10 years while South Pond in Sturbridge, MA was able to treat fanwort and milfoil once using fluridone once and then kept in check for over 15 years with continued follow-up using hand-pulling and spot herbicide treatments.

3.2.2.2 Glyphosate – Systemic Herbicide (Recommended for Hickory Hills Lake Annually Until Lotus is Eliminated)

Glyphosate is a widely used systemic herbicide in both upland and aquatic environments. Special formulations are available for use in aquatic treatments and marketed under the tradename Rodeo (among other names). At Hickory Hills Lake, glyphosate is recommended as the preferred option for the control of emergent beds of American lotus. Glyphosate has a well-established track record of effectiveness and has been used to successfully control American lotus recently in a small pond in Concord, MA.

Although glyphosate is a broad-spectrum herbicide, careful application as a foliar spray could effectively allow it to be selective for floating-leaved or emergent plants in the immediate treatment area with reduced impact on submerged native plants or other aquatic life.

A foliar spray is likely to be the most cost-effective application method. More than one treatment per year may be required, at least during initial years when the American lotus seed bank is still healthy. Five to ten years of repeated treatment may be required to bring established beds under control. The estimated cost to treat up to one acre of American lotus in Hickory Hills Lake with glyphosate in 2020 is $3,000 with similar cost expectations for subsequent years of treatment until the seed bank is exhausted.

3.2.2.3 Imazamox - Systemic Herbicide (Recommended for Little Hickory in 2020)

Imazamox is a relatively new herbicide with very low toxicity to animals or humans. Imazamox is the common name of the active ingredient ammonium salt of Imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethl)-3-pyridinecarboxylic acid. It was registered with the EPA in 2008 and is a systemic herbicide currently marketed for aquatic use under the brand name Clearcast. Imazamox moves throughout plant tissue and prevents target species from producing a necessary enzyme, acetolactate synthase (ALS), which is not found in animals. Susceptible plants will stop growing soon after treatment, but plant death and decomposition will occur over several weeks.

The primary advantages of Imazamox include the following:

- Very favorable environmental profile with extremely low toxicity risk.
- Is a systemic herbicide that is ideally suited to control emergent plants such as phragmites and water chestnut, but also effective against many emergent pondweeds, water lilies and watershield.
- Imazamox is relatively slow acting which minimizes the potential for low oxygen levels following treatment that could result from the decay of the plants.

The primary limitations of Imazamox include:

- It is not effective against fanwort.
- Imazamox is a newer product and is one of the more costly herbicide options.

The cost of Imazamox is significantly higher than most other herbicides, ranging up to $1,000/acre for treatment. This herbicide is ideal for control of lilies and watershed in areas of Little Hickory that are impacted by nuisance levels of these native species. These species do not have to be controlled but having this herbicide as an option under the permit will allow for it to be applied as appropriate based on the need of the lake users. Its use would be most appropriate as a spot treatment, after whole-lake treatment of Little Hickory with fluridone (since the fluridone will not do much to impact floating leaved plants). Using Imazamox as a spot treatment on selected lily beds in targeted areas of Hickory Hills Lake or at Little Hickory in 2020 would cost a minimum of $1,500, plus $1,000 per acre.

3.2.2.4 2,4-D – Systemic Herbicide (Not Recommended)

2,4-D is a systemic herbicide that prevents affected plants from being able generate new tissue, resulting in eventual death of the plant. This herbicide is not effective on fanwort, pondweeds, or watershield but would impact milfoil should this plant be introduced to Hickory Hills Lake in the future. Various formulations of 2,4-D are approved for aquatic use under multiple tradenames (e.g., Navigate) in Massachusetts.

The primary advantages of 2,4-D include the following:

- As a systemic herbicide that can achieve multiple seasons of control for some species such as milfoil.
- 2,4-D is selective for dicots, which means that it is effective on milfoil while having less impact or no impact on desirable plant species such as most native pondweeds.
- The required contact time for 2,4-D is significantly less than fluridone. Therefore, it may be easier to achieve effective control of target species in waterbodies with high flushing rates.

The primary limitations of 2,4-D include the following:

- The potential for migration through soils means 2,4-D cannot be used in Interim or Zone II Wellhead Protection Areas without significant additional hydrologic or hydrogeologic assessments. Additionally, setbacks from private wells are required to minimize the potential for 2,4-D treated water to be drawn into these wells. Setbacks vary from 25 to 200 feet, depending on geology. This would likely be an issue at Little Hickory.
- The fanwort, pondweeds, and watershield would not be impacted for multi-year control as these are not impacted by 2,4-D.

ESS does not recommend 2,4-D over other herbicide options given its lack of impact on the plants of primary concern in Hickory Hills Lake, and the potential for this herbicide to impact groundwater.

3.2.2.5 Diquat Dibromide – Contact Herbicide (Recommended for Hickory Hills Lake)

Diquat dibromide, also known as diquat or by its tradename Reward, works quickly by interrupting the photosynthetic process, resulting in the dieback of leaf and stem cells. It offers immediate control of pondweed but is not effective against fanwort or watershield.

The primary advantages of diquat include the following:

- Provides rapid control of targeted plants.
- Minimal contact time is required for diquat to be effective.

The primary limitations of diquat include the following:

- Diquat is not effective against all species of concern in Hickory Hills Lake.

- As a contact herbicide, diquat only kills the exposed parts of the plant (leaves and stem). The seeds, roots, and crowns typically survive and put out another flush of growth in the following year (or even later in the same season). Long-term control requires consistent reapplication over several years.

- Application should be limited to no more than one-half of total lake area per label restrictions. This is required to prevent impacts to aquatic life due to rapid dieback of treated plants, which could result in temporary reductions in dissolved oxygen levels.

Diquat will be useful for control of pondweeds and other species in areas of Hickory Hills Lake where native vegetation has reached nuisance levels. Diquat is one of the least expensive herbicides on the market on a per-treatment basis but would need to be used on an annual basis to be effective. In 2020, use of diquat would be most appropriate as a spot treatment for nuisance native plants in high priority areas (boat lunches, marines, etc.) in Hickory Hills Lake. Dense native plant beds may not be well managed using just the whole-lake Sonar treatment as it is difficult to achieve the concentration needed in some near-shore and dense plant beds. Treatment of up to 20 acres of high-density nuisance native plants in Hickory Hills Lake with diquat in 2020 would cost about $5,000 (minimum of 20 acres, additional acres priced at $350 per acre) if such efforts are deemed necessary.

3.2.2.6 Flumioxazin – Contact Herbicide (Not Recommended at This Time)

Flumioxazin (trade name Clipper) works by inhibiting protoporphyrinogen oxidase (PPO), an enzyme necessary for photosynthesis. Inhibition of PPO causes destruction of plant cell plasma membranes in the presence of sunlight, resulting in rapid dieback of plant tissues. Treatment is most successful when applied in late spring or early summer, when targeted fanwort plants are expected to be rapidly maturing

The primary advantages of flumioxazin include the following:

- Flumioxazin is the only contact herbicide that provides rapid control of both fanwort and exotic milfoils (which may at some point be introduced to Hickory Hills Lake).

- Minimal contact time is required for flumioxazin to be effective.

The primary limitations of flumioxazin include the following:

- As a contact herbicide, flumioxazin only kills the exposed parts of the plant (leaves and stem). The roots and crowns typically survive and put out another flush of growth in the following year (or even later in the same season). Long-term control requires consistent reapplication to the same beds over several years.

- Because flumioxazin requires sunlight to work, it is less effective once a significant vegetative canopy has developed in the water column, due to the shading that develops.

- Flumioxazin degrades rapidly in water, so it may result in poor control if not precisely applied to the targeted beds.

- Application is limited to no more than one-quarter of total lake area in Massachusetts. Additionally, the treatment cannot be reapplied to the same area for at least three consecutive years. This is required to protect non-target species populations and prevent the development of resistant plant populations. Flumioxazin was applied in the boat cove of Hickory Hills Lake in June 2016 and has not been used in the lake since.

The cost of flumioxazin is significantly higher than most other contact herbicides, ranging up to $1,000/acre for treatment. Treatment costs can sometimes be reduced if flumioxazin is used in combination with diquat. In Hickory Hills Lake, flumioxazin may be potentially useful for spot or partial-lake control of fanwort following whole-lake treatment with fluridone but is not currently recommended for use in 2020. Our preferred approach would be to address any fanwort regrowth in years following 2020 using non-herbicide approaches such as DASH or diver harvesting. However, should beds become too large to manage through DASH but not yet spread to an area greater than ¼ of the lake, the use of flumioxazin would be appropriate.

3.2.2.7 Permitting

Herbicide application requires an Order of Conditions (OOC) issued under the Massachusetts Wetlands Protection Act. Therefore, a Notice of Intent (NOI) must be filed with the Lunenburg Conservation Commission (LCC).

The current OOC is effective until January 2021 and has previously allowed for the treatment of Hickory Hills Lake with the following herbicides:

- Fluridone (Sonar)
- Diquat dibromide
- Flumioxazin (Clipper)

The HHLMC will notify the LCC of all planned herbicide applications prior to initiation of any actions. Additionally, the herbicide applicator must possess a Commercial Applicator License and obtain a water body-specific License to Apply Herbicides prior to treatment.

3.2.3 Mechanical Harvesting (Not Recommended)

Mechanical harvesting, which involves cutting and pulling aquatic plants from a specially equipped watercraft, is an effective short-term approach to control plant biomass. As mechanical harvesting simply sets plants back for the season and may allow plant fragments to break free and colonize new locations, its use should be reserved for scenarios where there is an immediate but temporary need for widespread reduction of nuisance macrophyte cover. This may include reservoir areas near water intakes or locations where seed-propagated nuisance species (e.g., water chestnut) have spread beyond the scale of hand harvesting methods. Harvesting of these species should be completed when the plants are large enough to be efficiently cut but *before* the seeds have matured.

Mechanical harvesting typically results in only single season control. Due to physical limitations of the harvester, this method is also typically most effective on plants growing in less than ten feet, but more than two feet, of water. These limitations should be carefully considered before proceeding with a mechanical harvesting program.

This technique has a secondary benefit of depleting nutrients from the sediments over time. However, this usually occurs very slowly and, in some cases, may not keep up with nutrient loading from the watershed. Therefore, ESS would not recommend the use of mechanical harvesting specifically to address nutrients.

Mechanical harvesting may encourage the spread of fanwort and other macrophyte species that spread by fragmentation (e.g. milfoils). Therefore, this approach should not be considered as a means for controlling nuisance native vegetation within Hickory Hills Lake in 2020 (or likely ever) due to the abundance of fanwort in the waterbody.

3.2.4 Diver Assisted Suction Harvesting (Not Recommended for 2020, but Annually Thereafter)

Diver assisted suction harvesting (DASH) technology has been around for decades but has been refined in recent years to make it more efficient and accessible. An advantage of DASH over other mechanical harvesting methods is that divers can directly confirm removal of entire individual plants.

Costs for implementing a DASH program can vary substantially dependent upon such factors as plant bed density, visibility, water current, availability of dewatering locations, and disposal. Particularly dense and extensive weed beds are likely to require multiple rounds of harvesting per season over several years to exhaust the beds.

Commercial DASH rates are typically in the range of $2,250 to $2,750 per day for small efforts. However, DASH rates were approximately $1,050 per day at Hickory Hills Lake in 2019, due to the extended length of the commercial deployment. A DASH team may clear more than an acre per day, but the actual rate achieved depends on diver expertise and the density of the weed beds. Under difficult conditions, the clearance rate may be as little as 0.1 acre per day. Particularly dense and extensive infestations may require two harvesting passes per year to maximize effectiveness.

DASH operations have removed thousands of gallons of fanwort from Hickory Hills Lake and have slowed the spread of this invasive species within the waterbody. However, fanwort is now widely distributed and established throughout the lake. It is estimated that removal of a subset of large fanwort beds remaining within the lake after the end of the 2019 season would require well over 60 days of commercial DASH activities plus volunteer DASH efforts. Therefore, it is no longer feasible to manage the fanwort infestation in Hickory Hills Lake through DASH alone.

ESS recommends that DASH operations be suspended for the 2020 season to maximize the effectiveness of the whole-lake fluridone treatment. The break in harvesting will allow for rapidly-growing fanwort plants to uptake sufficient dosages of Sonar to result in starvation of the entire plant. Use of the HHLI-owned DASH vessel would be ideally suited to maintenance of the lake in the years following the 2020 fluridone treatment, targeting specific areas that were not susceptible to the herbicide (such as at the Mulpus inlet where flushing may minimize the effects of a fluridone treatment), or to target early infestations of fanwort regrowth or new invasive species. Controlling small targeted beds using DASH can extend the length of time between the larger and more expensive fluridone herbicide treatments.

3.2.5 Wader Assisted Suction Harvesting (Not Recommended for 2020)

The HHLI-owned mobile suction harvester, the Muck Suck 1 (MS1) allows for suction harvesting in shallow waters without the use of divers. Utilizing the MS1 in shallow, wadeable, areas is more efficient than traditional hand harvesting, as plants are transported to the barge via suction hose. However, the slow and intensive nature of this work makes practical implementation most feasible for limited areas.

The MS1 is manned by trained Hickory Hills Lake volunteers, but operational costs include fuel and replacement parts.

Similar to DASH, ESS does not recommend use of the MS1 in 2020. This vessel is best used at Hickory Hills Lake once fanwort density has decreased, in the years following treatment of the lake with herbicides. In future years, the MS1 could be used to control isolated beds of fanwort in shallow areas, or target early infestations of new invasive species.

3.2.6 Water Level Control – Drawdown (Recommended Annually)

Drawdown involves lowering the water level to expose shallow bottom sediments and associated plants to drying and/or freezing. It has the distinct advantage of being relatively inexpensive to implement but must be conducted carefully and sometimes needs to be repeated over multiple years to be effective. Drawdown is also a useful technique for addressing aquatic invasive plants in submerged riprap or otherwise inaccessible areas that would not otherwise be susceptible to harvesting.

As a management tool, drawdown is most effective against species that reproduce mainly by vegetative means, including Eurasian and variable-leaf milfoils and fanwort. Drawdown is less effective on species that reproduce primarily by seed (e.g., pondweeds) and/or turion (e.g., curly-leaf pondweed) and may actually expand beds of these species.

Timing of drawdown is also important. Although it can be conducted at any time, the interaction of drying and freezing that occurs with winter drawdown is usually most effective. In southern New England, winters are often variable in their intensity and the ideal condition of at least two weeks of very cold weather with limited snow cover (which would otherwise insulate the plants) may not be achieved every year. In addition to the need for exposure of sediments to freezing, refill of the lake should be completed as early as possible after a prolonged thaw period has begun. Otherwise, shallow water conditions in the littoral zone could actually enhance germination and growth of problem species by allowing more light to penetrate to the lake bottom.

In addition to these potential drawbacks, drawdowns may also impact non-target species, including fish, reptiles, amphibians, invertebrates, and native plants. Drawdown typically reduces fish habitat volume, access to spawning areas, and availability of dissolved oxygen, among other parameters, each of which should be considered prior to drawdown implementation. Native plants in exposed sediments are likely to be killed or set back by winter drawdown. However, many desirable native species reproduce through seeds, turions or other means that allow them to quickly repopulate areas exposed by drawdown. Typically, this would be expected to favor native species over the target invasives and improve aquatic habitat.

In most cases, undesired impacts can be mitigated through careful planning, operation, and monitoring. Guidance on timing and rate of winter drawdown to be protective of non-target resources is provided in the Final Generic Environmental Impact Report for Eutrophication and Aquatic Plant Management in Massachusetts (Mattson et al. 2004). If possible, drawdown should be initiated in early November and completed by December 1, although this may be difficult to achieve in practice during wet years. Ideally, the drawdown rate should not exceed 0.25 feet per day or result in flows exceeding 4 cubic feet per second per square mile (cfsm). Refill of the water body should be complete by April 1.

For Hickory Hills Lake, drawdown is controlled by the release of water through seven 8-inch diameter siphons and one 6-inch siphon pipe at the lake outlet to the west of Townsend Harbor Road. Prior to 2019, drawdown of Hickory Hills Lake was limited to a maximum of 36”. However, after consultation with the Lunenburg Conservation Commission, and the Massachusetts Department of Fish and Game, the HHLI received permission to drawdown the lake by 4 feet during the 2019, 2020, and 2021 winter seasons. If monitoring indicates no ill effects of this increased drawdown, the Lunenburg Conservation Commission has indicated that drawdown to 4.5 feet or 5 feet could be permitted in future.

It is estimated that approximately 10% of fanwort within Hickory Hills Lake is located within the drawdown zone. Therefore, it is clear that the amount of drawdown being achieved is insufficient to achieve the desired level of fanwort control. Though deeper drawdown might allow for the exposure, and control, of a greater percentage of fanwort within the lake, this species is distributed throughout the waterbody, including deep areas which could not be dewatered. Even if a permit for more extensive drawdown could be secured, the effects on fanwort plants occurring in deeper waters would be negligible and their growth could even be enhanced by the increased availability of light at the bottom during the period of drawdown and refill.

The costs associated with drawdown are very low compared to most other macrophyte management options and are primarily associated with operation and monitoring of the drawdown itself. Post-drawdown monitoring costs vary depending on how the extent and nature of any work required to evaluate impact to target species and non-target resources (see section 3.1.1 for water quality monitoring recommendations).

3.2.7 Dredging (Not Recommended)

Dredging works as a plant control technique when either a light limitation is imposed through increased water depth or when enough soft sediment is removed to reveal a less hospitable substrate for plant growth (e.g. hard bottom or other nutrient-poor substrate). Light limitation through increased depth is possible in Little Hickory, but only in the central portions of the pond since water clarity is relatively good and it would not be feasible to create very steeply sloped sides along the shoreline.

The amount of material to be removed and the type of disposal or reuse will also have a significant impact on the cost of dredging. Environmental permitting for dredging projects is moderately complex and will require up to a year before the project could receive all required approvals. Federal (U.S. Army Corps of Engineers 404), state (Massachusetts Environmental Protection Act Certificate and 401 Water Quality Certificate), and local permits (Notice of Intent filed for Order of Conditions from the Department of Natural Resources) are all required, and would necessitate considerable advance information and review time.

Dredging of Hickory Hills Lake would not be feasible given the size and the amount of sediment that would be required to be removed to deepen the lake to a depth to preclude plant growth. However, with an estimated soft sediment volume of approximately 25,000 cubic yards in Little Hickory, the cost of a dry or hydraulic dredging project for the entire pond would likely run between $600,000 and $1,000,000 (including permitting and design) for removal of all of the soft sediments, although not all sediments would necessarily need to be removed to achieve light limitation throughout the pond. Costs could increase if sediment cannot be reused or disposed of in the immediate vicinity of the pond. It is feasible to dredge Little Hickory, but it is not the best or most economical approach for plant control.

4.0 SUMMARY OF MANAGEMENT RECOMMENDATIONS

Though Hickory Hills Lake and Little Hickory continue to provide shoreline residents with immense recreational and aesthetic value, conditions within the waterbodies have deteriorated in recent years due to the infestation of invasive fanwort. The primary management goals for Hickory Hills Lake in 2020 is to reduce the abundance and density of fanwort, treat the American lotus bed, and control nuisance native vegetation in select areas of the lake. Recommended management of Little Hickory includes reducing the abundance and density of fanwort, treatment of nuisance native vegetation, and algae control. Recommended management actions for 2020, and associated costs, are summarized and presented in Table 5.0.

Table 5.0. Recommended Management Actions and Associated Costs for Hickory Hills Lake and Little Hickory, 2020

Management Action	Approximate Timeframe	Estimated 2020 Cost
Little Hickory		
• Whole-lake Sonar (fluridone) application to control fanwort, pondweed and bladderwort (sub-surface growing plants). Sonar is most effective against fanwort and less effective against pondweeds unless used at higher concentrations	May	$5,000 - $8,000 (depending on dose)
• Spot treatment of lilies (emergent plant) using Imazamox, as desired, in targeted areas. Not all lilies should be targeted as these are good fish habitat.	June/July	$1,500 minimum cost plus $1,000/ac.
• Spot Treatment of submergent plant regrowth using diquat herbicide - only needed in years following initial sonar treatment	Not needed in 2020	$1,500 minimum cost plus $350/ac.
• Low-dose alum treatment for algae control and water clarity improvement	If needed - likely July	$4,000 - $5,000 plus $2,500 for monitoring and report
Hickory Hills Lake		
• Whole-lake Sonar (fluridone) application to control fanwort	May	$200,000 - $225,000
• Aquatic vegetation mapping by ESS	Summer	Included in ESS Study
• Training of HHLA water quality monitoring volunteers by ESS staff	Spring	Included in ESS Study
• Water quality monitoring by HHLA volunteers at up to 10 sites	Seasonally – 3 times	< $5,000 using quality lab
• Spot treatment of up to 20 acres of high-density nuisance plants with diquat at high priority areas (e.g. marinas, boat launch, etc.). Needed since whole lake treatment will not be at a dose high enough to significantly impact species other than fanwort	July	$5,000 minimum for 20 acres with additional acres at $350/ac.
• Treatment of up to 1 acre American lotus bed with glyphosate	July/August	$3,000
• Drawdown of Hickory Hills Lake	November	No cost
• Physical removal of American Lotus roots during drawdown	November/ December	No cost if volunteer effort

There are a range of options available for improving the lake. The simplest, most economical and quickest option would be to control the fanwort infestation with a whole-lake treatment of the systemic herbicide fluridone (Sonar). Costs for this treatment would be on the order of $200,000 - $225,000 for Hickory Hills Lake, and $5,000 - $8,000 for Little Hickory, in 2020. This treatment is expected to last for at least two years and possibly as many as five years following the treatment, but this duration will be highly dependent upon how effective the initial treatment is and how diligent the monitoring and subsequent spot control efforts are carried out in the form of DASH or sport herbicide control using flumioxazin.

ESS recommends treatment of the American lotus infestation in Hickory Hills Lake with glyphosate in 2020. The American lotus bed is still relatively limited in size, and quick action to address this issue will save thousands of dollars in future management costs (treatment of up to 1 acre in 2020 will cost approximately $3,000). Aquatic vegetation mapping should occur before and after herbicide treatment, to allow for the evaluation of treatment effectiveness. Additionally, monitoring of water quality within the lake, in support of drawdown requirements, should occur in 2020, following training of Hickory Hills Lake volunteers (estimated cost of $5,000 for analysis of samples by a certified analytical laboratory).

Because Fluridone treatment will not do much to control nuisance native vegetation, spot treatment of high priority areas (e.g. boat launches, marinas, etc.) in Hickory Hills Lake with diquat is recommended for 2020 ($5,000 minimum for 20 acres with additional acres priced at $350/acre). Similarly, spot treatment of nuisance lily beds in Little Hickory with Imazamox is recommended as an option in 2020 ($1,500 minimum cost plus $1,000/acre). If algae blooms occur in Little Hickory in 2020, the application of low-dose alum, at a cost of $4,000 - $5,000, would be recommended.

Though drawdown is not an effective means to control fanwort in Hickory Hills Lake, this management action does allow for the physical removal of American lotus during drawdown and may limit fanwort growth in shoreline areas. Therefore, ESS recommends that lake drawdown (to 4 ft) occur in the winter of 2020. To prevent the introduction of new invasive species into Hickory Hills Lake, ESS recommends that the HHLI continue the boat inspection program indefinitely.

5.0 REFERENCES

[ESS] ESS Group, Inc. (2020). Little Hickory Algae and Aquatic Vegetation Control Plan.

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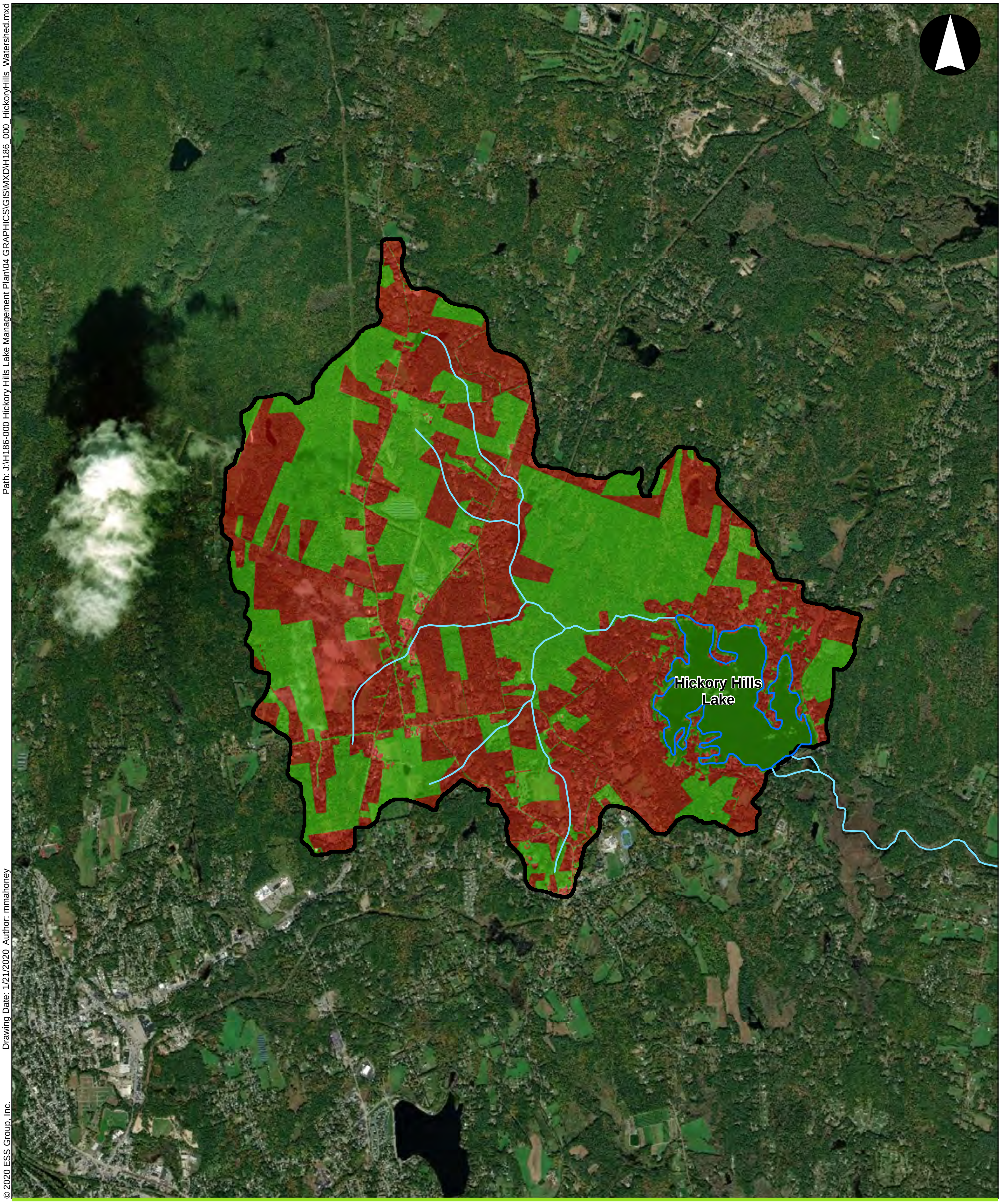
Figures



Path: J:\H186-000 Hickory Hills Lake Management Plan\04 GRAPHICS\GIS\MXD\H186_000_HickoryHills_Watershed.mxd

Drawing Date: 1/21/2020 Author: mmahoney

ess group
environmental consulting & engineering services

Hickory Hills Management Plan

Lunenberg, Massachusetts

Source: 1) ESRI, World Imagery, 2018
2) USGS, StreamStats, 2019
3) MassGIS, Land Use, 2016

0 0.5 1 Miles

Hickory Hills Lake (293.4 acres)

Hickory Hills Lake Watershed (4,978 acres)

Land use (% of Watershed)

Developed (52 %)

Not Developed (48 %)

Watershed

Figure 1

Appendix A

Surface Water Sampling Guidelines

GUIDELINES FOR COLLECTION OF SURFACE WATER SAMPLES

1.0 INTRODUCTION

These guidelines provide basic instructions for the routine acquisition of surface water from lakes, ponds, and streams. The methods outlined below are intended to (1) standardize water sample collection methods used by Hickory Hills Lake volunteers; (2) ensure that samples delivered to the laboratory represent field conditions as accurately as possible; (3) assure proper documentation of sample collection; and (4) minimize cross contamination between sampling sites.

2.0 REQUIRED MATERIALS

The following materials are necessary for the acquisition of surface water samples:

- Nitrile gloves
- Labeled sample bottles provided by contracted laboratory (appropriately sanitized and containing the necessary preservative for desired analyses, see Table 2.0 for examples)
- Field data sheets or logbooks, including list of sites or locations to be sampled, and pencil
- Cooler with ice packs for sample storage
- Integrated depth sampler (if collecting algae sample)
- Secchi disk (if collecting algae samples)
- Chain of Custody (see examples attached)

Table 2.0 Example Container Types, Preservative Requirements, and Hold Times for Water Quality Samples.

Analysis	Bottle Type	Preservative	Hold Time
Total Phosphorus	plastic	H_2SO_4	28 days
Dissolved Phosphorus	plastic	As Is	analyze immediately*
Total Suspended Solids (TSS)	plastic	As Is	7 days
Nitrate/Nitrite	plastic	As Is	48 hrs
Total Kjeldahl Nitrogen (TKN)	plastic	H_2SO_4	28 days
Metals - Total	plastic	HNO_3	6 months**
Metals - Dissolved	plastic	As Is	6 months**
Algae	opaque plastic	Lugol's iodine	>1 year
Chlorophyll-a	opaque plastic	As Is	analyze immediately
Bacteria	sterile plastic	As Is	6 hrs

* = 24 hrs with field filtration, ** = 28 days for mercury

3.0 METHODS

3.1 General Sampling Instructions

- Testing methods, sample containers, preservation techniques, and sample volumes should be selected in consultation with the laboratory to ensure that samples obtained will provide the desired results.
- Hold times vary considerably between different analytes and must be taken into consideration when planning field sampling efforts and lab courier pickups to assure the validity of analytical results.
- Field filtration of certain samples (dissolved phosphorus) is recommended. The laboratory can supply syringes and filters for use in the field.

Using a pre-cleaned (as is) bottle to fill a sample bottle containing preservative.

- In general, surface water samples should be collected via direct grab methods.
- Sample collection should precede the measurement of physical field parameters (including pH, apparent color, turbidity, conductivity, and dissolved oxygen) in order to minimize the risk of sediment disturbance and/or sample contamination.
- Clean rubber gloves should be worn at each sampling location. When sampling multiple sites on the same day, gloves may be rinsed in the immediate area of the waterbody to be sampled (downstream at flowing sites).
- Approximately 1-inch of air space should be left when filling sample bottles (except for dissolved oxygen, alkalinity, and BOD samples), so that bottles may be shaken (if needed) before analyses (EPA, 1997; Simpson 1991).
- Sample containers with preservatives should not be used to collect water samples. If using containers with preservatives, a pre-cleaned container of similar type (an as is bottle) should be used to collect and subsequently transfer the sample to the preserved container.
- Ensure that all sample bottles are correctly and completely labeled before storage. Sample bottles should be stored in a cooler with ice packs (it is best to avoid ice, as meltwater could potentially contaminate samples) or in a refrigerator until they are submitted to a lab courier.

3.1.1. Lake and Pond Sampling

- Grab samples from lakes and ponds should be collected at approximately 8 to 12 inches beneath the water surface or mid-way between the surface and the bottom if the waterbody is shallow (EPA 1997). Samples should not be collected in close proximity to the lake shoreline or submerged obstacles

- To collect water samples, hold an as is bottle near the base, remove the lid, and plunge it into the water with the opening facing downward. Invert the bottle and allow it to fill before bringing it to the surface. Decant sufficient water from the bottle to allow for the required headspace and replace the cover, or carefully pour the contents into a bottle containing preservative. Repeat the above process to refill the as is bottle as many times as necessary.

Algae Samples

- Algae samples should be stored in opaque bottles with a small amount of Lugol's iodine for preservative (~1-2 drops in a 250 mL bottle). Algal taxonomy labs can provide opaque plastic bottles, but standard plastic as is bottles covered in aluminum foil can also be used.

- Algae samples should be collected using an integrated depth sampler. An integrated depth sampler consists of a length of tubing (~1in diameter, at least 2 m long) with a weight attached to one end. Sample collection procedures using the depth sampler should proceeds as follows (procedure adapted from EPA 2012):

Integrated depth sampler for collection of algae samples.

    - Determine the euphotic zone:
        - Lower the secchi disk over the shaded side of the boat until it disappears. Lower the disk a bit further, then slowly raise the disk until it reappears. Record the reappearance depth. The euphotic zone is calculated by multiplying the reappearance depth by 2.
    - Holding onto the non-weighted end of the sampler, lower the tube into the water column. Rinse the sampler by submerging it three times.
    - Lower the sampler so that it is submerged to the depth of the euphotic zone, or fully submerged if the euphotic zone is deeper than the length of the sampler. Cover the opening at the non-weighted end with a gloved thumb.

- Lift the sampler completely out of the water and cover the opening at the weighted end with a gloved thumb (both ends should be covered). Repeatedly lift each end of the sampler to mix the water sample within the tube.
- Fill the algae sample bottle with the required volume of water from the sampler (the bottle will contain Lugol's solution as preservative so be careful not to over-fill).
- Unlike samples for most other analytes, preserved algae samples can be stored at room temperature before submission to a lab.

3.1.2. Stream Sampling

- Samples should be collected from the center of small streams (i.e., 10-20 feet wide with a maximum depth of less than 2 feet), and at a location where water depth is 2-3 feet in larger streams.
- Volunteers should always approach a sampling location from downstream, traveling so as to minimize the disturbance of bottom sediments and upstream waters.
- Volunteers should stand downstream of the desired sampling location, hold the sample bottle near its base and plunge it below the water surface with the opening (mouth) downward. The opening of sample bottles should always be directed away from the volunteer in an upstream direction.
- To inform investigations about nutrient inputs, stream flow should be measured whenever water quality samples are collected (see Guidelines for Measuring Stream Flow)

4.0 DOCUMENTATION

Volunteers should report surface water field data on sheets or in notebooks. Any unanticipated site-specific information, which requires volunteers to deviate from the above guidelines, should be recorded. Field notes for surface water sampling should include a minimum of the following:

- Name or initials of person collecting the samples
- Sample identification/station location
- Date and time of sample collection
- Environmental conditions (e.g. wind, weather)
- Other comments or observations about water quality and site conditions (e.g. visible algae bloom, dead fish nearby, sample has noticeable odor or color, etc.)

Photographic evidence of any notable conditions is also desirable.

5.0 REFERENCES

EPA, 1997. Volunteer Stream Monitoring: A Methods Manual. United States Environmental Protection Agency. Office of Water. EPA 841-B-97-003. Accessed January 23, 2020 at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100MRC3.PDF?Dockey=P100MRC3.PDF

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Appendix B

Streamflow Measurement Guidelines

GUIDELINES FOR MEASURING STREAMFLOW

1.0 INTRODUCTION

These guidelines provide basic instructions for the measurement of flow rate in bodies of running water. The technique described below, called the time of travel method, is simple and does not require expensive or specialized equipment.

This method of calculating streamflow involves determining the cross-sectional area of the stream and measuring the average time it takes for a neutrally buoyant object to travel a known distance.

2.0 REQUIRED MATERIALS

The following materials are necessary for the measuring streamflow using the time to travel method:

- Yard-stick to measure stream depth (folding plastic yard stick is recommended)
- Flexible tape measure (longer than the width of the stream)
- A neutrally buoyant float (see Section 3.2)
- Twine or other heavy-duty string material (only required when using tethered float, see Section 3.2)
- Stopwatch or time-keeping device (e.g. timer function on phone)
- Field data sheet or logbook

3.0 METHODS

3.1 Choosing a Sampling Reach

- Select an appropriate stream cross section. The location selected should be straight (no bends), and free of obstructions or slow areas of water (no pools). Unobstructed runs or riffles, ideally with a water depth of at least 6 inches, are ideal.

- To assure consistency of measurements and allow for easier comparison of data across time, flow should be measured in the same reach of the stream during all visits. Include descriptions of site landmarks in field notes, and/or take photos of measurement locations.

Measuring stream depth using a folding yard stick.

- If a staff gauge is present near the stream measurement location, make sure to record the staff gauge depth.

3.2. Measuring Average Cross-Sectional Area

- Establish a transect by stretching the measuring tape across the stream, perpendicular to the shoreline. The tape can be secured to the stream banks with stakes, or by wrapping the ends around vegetation, rocks, or other structures.

- Record the total width of the stream, and measure stream depth at a minimum of 3 locations within the steam channel. Recommended depth measurement locations are ¼, ½, and ¾ of the distance across the stream.

- The average stream depth along the transect will be the sum of the measured depths divided by the number of locations where depth was measured plus one (to account for the 0 depths that occur at the stream shorelines).

3.2. Measuring Travel Time

- To measure travel time, volunteers will time how long it takes for a neutrally buoyant object (a float) to travel a known distance. Suitable objects should float, but sit very low in the water, and can be untethered or tethered (methods adapted from EPA, 2012a described below). Suitable floats include:
  - citrus fruits or pieces of citrus peel
  - cheese puffs
  - small sponge rubber balls
  - small sticks or bits of vegetation

- Volunteers should measure travel times at a minimum of 3 locations within the stream channel, at different distances from the stream bank, to adequately characterize variations in flow speed. Recommended travel time measurement locations are ¼, ½, and ¾ of the distance across the stream.

- Surface velocity is generally greater than depth-averaged velocity, so a correction factor (0.8 for rocky-bottom streams, 0.9 for muddy-bottom streams) is applied to float travel times (see Section 3.3, EPA 2012b)

Using an Untethered Float

- Untethered floats should be biodegradable, or a second volunteer equipped with a net should be stationed downstream of the sampling reach to retrieve the float(s).

- Hold the folding yard stick above the water surface, parallel to the direction of flow. Release the untethered float somewhat upstream of the end of the yard stick to allow the float to reach full flow velocity. Time how long it takes for the float to travel a known distance (3 ft is recommended). Repeat this process three times to obtain an average time to travel at one stream location (e.g. ¼ distance across the stream) before proceeding to the next location (e.g. ½ distance across the stream).

Using a Tethered Float

- Securely attach a known length (3 ft is recommended) of string to a float (sponge rubber ball, citrus fruit).

- Release the tethered floating object in the water and activate the timer. Record the time from when the floating object is released to when the string goes taught, indicating that the tethered float has traveled 3 ft. Repeat this process three times to obtain an average time to travel at one stream location (e.g. ¼ distance across the stream) before proceeding to the next location (e.g. ½ distance across the stream).

3.3. Calculating Flow

- The following equation is used to calculate flow (typically reported in feet per second):

Flow = (A*L*C)/T

  - A = cross sectional area of the stream at the established transect
  - L = distance of float travel (standardly 3 ft)
  - C = correction factor (0.8 for rocky-bottom streams, 0.9 for muddy-bottom streams)
  - T = average time of travel (seconds)

4.0 DOCUMENTATION

Volunteers should record streamflow data on field sheets or in field notebooks. Any unanticipated site-specific information, which requires volunteers to deviate from the above guidelines, should be reported on field sheets or in a field notebook. Field notes for streamflow measurement should include a minimum of the following:

- Name or initials of person conducting the measurement
- Sample identification/station location
- Date and time of streamflow measurement
- Environmental conditions (e.g. wind, weather)
- Other comments or observations about water quality and site conditions (e.g., water has a surface sheen, noticeable odor or color present, visible erosion observed due to recent storm event, etc.)

Photographic evidence of streamflow and measurement locations are also desirable, and can ensure that volunteers are able to relocate sampling sites on subsequent visits.

5.0 REFERENCES

EPA, 2012a. Water: Monitoring and Assessment. 5.1 Stream Flow. United States Environmental Protection Agency. Office of Water. EPA 841-B-97-003. Accessed January 27, 2020 at https://archive.epa.gov/water/archive/web/html/vms51.html

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Appendix C

Stormwater Sampling Guidelines

GUIDELINES FOR STORMWATER SAMPLING

1.0 INTRODUCTION

These guidelines provide basic instructions for the acquisition of storm water samples. The methods outlined below are intended to (1) standardize stormwater sample collection methods used by Hickory Hills Lake volunteers; (2) ensure that samples delivered to the laboratory represent field conditions as accurately as possible; (3) assure proper documentation of sample collection; and (4) minimize cross contamination between sampling sites

2.0 REQUIRED MATERIALS

The following materials are necessary for the acquisition of stormwater samples:

- Nitrile gloves
- Labeled sample bottles provided by contracted laboratory (appropriately sanitized and containing the necessary preservative for desired analyses, see Table 2.0 for examples)
- Clear, colorless glass or plastic container for examining stormwater sample characteristics
- Weatherproof field data sheets or field books (e.g. Rite in the Rain), and pencil or weatherproof pen
- List of sites and locations to be sampled and site location information. Location data can be provided in the form of a sketch, map, or data layer for viewing on a smartphone (.kml file)

The following additional equipment may be necessary, depending on site conditions and sampling objectives:

- Extendible grab sampler. This could be something as simple as a bottle taped to the end of a broom stick or length of PVC pipe
- Cut off bottle or cup for collecting overland runoff samples (a cutoff gallon water jug with the handle left intact works well)
- Loppers or other pruning tools (for clearing vegetation)
- Waders or hip boots
- High Visibility gear if working near or on a road or sampling in wooded areas during hunting season. It is very important the passing vehicles, or nearby hunters, are able to see you from afar.
- Necessary equipment for measuring streamflow (see Streamflow Sampling Guidelines)

Table 2.0 Example Bottle Types, Required Preservatives, and Hold Times for Stormwater Samples.

Analysis	Bottle Type	Preservative	Hold Time
Total Phosphorus	plastic	H_2SO_4	28 days
Nitrate/Nitrite	plastic	As Is	48 hrs
Ammonia	plastic	H_2SO_4	28 days
Total Kjeldahl Nitrogen (TKN)	plastic	H_2SO_4	28 days
Total Suspended Solids (TSS)	plastic	As Is	7 days
Oil and Grease	amber glass	H_2SO_4	28 days
Chemical Oxygen Demand (COD)	plastic	H_2SO_4	28 days
Bacteria	sterile plastic	As Is	6 hrs

3.0 METHODS

3.1 Selecting a Storm Event

- The target of storm water sampling is typically the “first flush” of a storm event. To obtain a sample representative of this first flush, sampling should only be conducted after a significant dry period, typically 72 hours. Dry weather is usually defined as a period of 0.1 inch of precipitation or less and no measurable snow cover. Storm water sampling events may require a minimum storm event size of at least 0.5 inches of precipitation.

Storm event selection and timing of sample collection is important, as samples should capture the “first flush” of the storm event, and outfalls of interest may not flow during all storm events.

- Storms should be screened for a high probability of producing a sufficient amount of rain over the entire watershed area. Storms that meet this criterion should be tracked on a daily basis until the day of the storm. On the day of the storm, volunteers should use radar, precipitation total maps, forecast discussions, and any other evidence that is available and useful to track the storm. Forecast and radar trends are at least as important as the latest forecast or radar map. Declining probabilities of precipitation or forecasted storm amounts are generally signs of a storm that is not likely to produce satisfactory results. It is important to check the scientific forecaster discussion (available as a link from most weather websites), which provides background information on the forecast reasoning. Changes to the forecast may emerge in this discussion several hours before the daily or hourly forecasts for individual locations are altered.

- The volunteer project manager should track storm systems to assess the potential of each storm to produce conditions adequate for stormwater sampling and communicate expectations to the volunteers who will be performing the sampling. To reduce the number of missed storm events, volunteers should be notified as far in advance as possible (preferably two to five days) that sampling may be necessary.

- Volunteers should have all equipment and materials (including sample bottles) prepared well in advance of the targeted storm event. Prior to leaving for the sampling site, field volunteers should confirm with the volunteer project manager that storm water sampling is authorized. This will minimize the number of false starts. Field volunteers or the volunteer project manager should also notify the analytical laboratory of the sampling schedule for the day to ensure that samples will be received within holding times and that lab personnel will be available to log samples in a timely manner. This is particularly important when collecting samples with short hold times, such as bacteria.

3.2. General Water Sampling Instructions

- Testing methods, sample containers, preservation techniques, and sample volumes should be selected in consultation with the laboratory to ensure that samples obtained will provide the desired results.

- Hold times vary considerably between different analytes and must be taken into consideration when planning field sampling efforts and lab courier pickups to assure the validity of analytical results.

- Field filtration of certain samples (dissolved phosphorus) is recommended. The laboratory can supply syringes and filters for use in the field.

- Sample collection should precede the measurement of physical field parameters (including pH, apparent color, turbidity, conductivity, and dissolved oxygen) in order to minimize the risk of sediment disturbance and/or sample contamination.

- Clean rubber gloves should be worn at each sampling location. When sampling multiple sites on the same day, gloves may be rinsed immediately downstream of the sampling sites.

- Approximately 1-inch of air space should be left when filling sample bottles (except for dissolved oxygen, alkalinity, and BOD samples), so that bottles may be shaken (if needed) before analyses (EPA, 1997; Simpson 1991).

- Sample containers with preservatives should not be used to collect water samples. If using containers with preservatives, a pre-cleaned container of similar type (an as is bottle) should be used to collect and subsequently transfer the sample to the preserved container.

- Ensure that all sample bottles are correctly and completely labeled before storage. Sample bottles should be stored in a cooler with ice packs (it is best to avoid ice, as meltwater could potentially contaminate samples) or in a refrigerator until they are submitted to a lab courier.

3.2. Stormwater Sampling Instructions

- Sample once the duration and amount of rain is sufficient to produce runoff.
- Samples should be collected from the center of small streams (i.e., 10-20 feet wide with a maximum depth of less than 2 feet), and at a location where water depth is 2-3 feet in larger streams.

- Volunteers should always approach a sampling location from downstream, traveling so as to minimize the disturbance of bottom sediments and upstream waters.

- If water depth at the sampling location is sufficiently deep, volunteers should stand downstream of the desired sampling location, hold the sample bottle near its base and plunge it below the water surface with the opening (mouth) downward. The opening of sample bottles should always be directed away from the volunteer in an upstream direction.

- If water depth is insufficient to allow for submersion of the sample bottle, an as is bottle or a cut-off gallon jug can be used to collect the sample. Volunteers should minimize disturbance to bottom sediments or vegetation when collecting samples in shallow streambeds, and should collect stormwater directly from outfall pipes if possible.

4.0 DOCUMENTATION

Volunteers should record stormwater data on field sheets or in field notebooks. Any unanticipated site-specific information, which requires volunteers to deviate from the above guidelines, should be reported on field sheets or in a field notebook. Field notes for stormwater sampling should include a minimum of the following:

- Name or initials of person collecting the samples
- Sample identification/station location
- Date and time of sample collection
- Environmental conditions at time of sample collection (e.g. heavy rain, light rain after downpour, etc.)
- Other comments or observations about water quality or site conditions. Examples of sample characteristics to note include:
    - o Suspended, floating, or settled solids
    - o Cloudiness
    - o Noticeable odor or color
    - o Foam or sheen on water surface
- Describe any readily identifiable probably sources of the water quality and site conditions noted. For example, a soil stockpile located upstream of a storm drain might be a likely source of cloudiness, brownish color, and settled solids, in a stormwater sample.
- Duration between previous storm event and storm event sampled
- Total precipitation and duration of storm event sampled (can be obtained via weather websites after storm event has ended)

Visual observation of stormwater samples should be conducted using a clear, colorless glass or plastic container.

Photographic evidence of stormwater flows and sampling locations are also desirable and can ensure that volunteers are able to relocate sampling sites on subsequent visits.

5.0 REFERENCES

EPA, 2012a. Water: Monitoring and Assessment. 5.1 Stream Flow. United States Environmental Protection Agency. Office of Water. EPA 841-B-97-003. Accessed January 27, 2020 at https://archive.epa.gov/water/archive/web/html/vms51.html

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