Lake Management Plan for Bowdish Reservoir

GLOCESTER, RHODE ISLAND

PREPARED FOR

Northern Rhode Island Conservation District
17 Smith Avenue
Greenville, Rhode Island 02828

PREPARED BY

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East Providence, Rhode Island 02915

Project No. N457-000

February 5, 2010

www.essgroup.com

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1.0 INTRODUCTION

ESS Group, Inc. (ESS) was contracted by the Northern Rhode Island Conservation District to conduct an investigation of Bowdish Lake (also known as Bowdish Reservoir) and its watershed for the purpose of developing a comprehensive Lake Management Plan that would address the nuisance weed growth at the lake and guide efforts to improve water quality. A major goal of this project was to provide sensible and long-term solutions for improving conditions at the lake that will benefit recreational opportunity while also protecting or improving fish and wildlife habitat quality. The project relied on a variety of existing and readily available sources of data but also included a significant amount of in-field assessment related to the aquatic plant community at the lake as well as a limited amount of field reconnaissance focused on identifying potential sources of pollutants within its watershed. The field assessment portion of the study was performed during August and September of 2009.

An added benefit of this investigation was that high quality aquatic plant community data was collected that can be reliably used to make sound management recommendations for improving conditions at the lake and to establish a set of reliable baseline data by which future improvements can be measured.

Guidance for this project was provided by an advisory committee consisting of representatives from the Rhode Island Department of Environmental Management (RIDEM), Natural Resources Conservation Service, Northern Rhode Island Conservation District, and the Bowdish Lake Association. In accordance with recommendations from the advisory committee, the Lake Management Plan provided here has been specifically designed to:

1) Control nuisance aquatic vegetation, including the exotic invasive variable-leaf milfoil (*Myriophyllum heterophyllum*) and fanwort (*Cabomba caroliniana*)

2) Provide recommendations for assessing and improving water quality, in particular non-point sources of pollution

3) Provide recommendations for long-term monitoring

4) Establish a framework for guiding future management decisions on a year-to-year basis that is based on an economical annual monitoring program

5) Provide information that can contribute to the development of permit applications related to management actions or applications for funding assistance, e.g., grants

2.0 METHODS AND APPROACH

This section of the report describes the specific protocols and procedures adopted throughout the course of the assessment study of Bowdish Lake. A project specific Quality Assurance Project Plan (QAPP) was developed by ESS and approved by the U.S. Environmental Protection Agency (ESS, 2009). A copy of this QAPP and the Standard Operating Guidelines that served as guidance for the collection and analysis of data is on file with RIDEM.

2.1 GIS Analysis of the Bowdish Lake Watershed

2.1.1 Analysis of Watershed Land Use, Soils, and Wellhead Protection Areas

U.S. Geological Survey (USGS) 7.5 minute topographic maps were obtained from the Rhode Island Geographic Information System (RIGIS) (see Section 7.0 for details) and used to delineate the watershed of Bowdish Lake. GIS layers for soils, wellhead protection areas, and current and historical (1988) land use were obtained from RIGIS (see Section 7.0 for details). These layers were used to map the distribution of these features in the Bowdish Lake watershed and to calculate acreages, as appropriate. The GIS layer containing public water supply reservoir data was also examined.

2.1.2 Characterization of Major Pollution Sources

During the aquatic plant survey, ESS visually inspected the Bowdish Lake shoreline for signs of storm water outfalls or other pollution point sources. Additionally, ESS used a combination of GIS analysis and field observation to identify potentially major sources of pollution in the watershed.

Watershed land use, orthophotography, and surface hydrology GIS layers available through RIGIS (see Section 6.0 for details) were used to identify potential non-point sources of sediment, bacteria, nutrients and other pollutants to the lake. Field reconnaissance was used to confirm and validate the sources and the potential for impact to water quality in Bowdish Lake.

ESS also reviewed data layers available from the state through RIGIS (see Section 7.0 for details) to ascertain the presence of leaking underground storage tanks (LUSTs), Rhode Island Pollutant Discharge Elimination System (RIPDES) discharges, or other documented sources of pollution and to estimate the percent impervious cover in the watershed.

2.2 Biological Assessments

2.2.1 Aquatic Plants (Macrophytes)

Aquatic plants (primarily including floating leaved and submergent species) in Bowdish Lake were mapped on August 19 and 21, 2009 following the approach outlined in the project QAPP for the creation of an aquatic plant map (ESS, 2009). The goal of the plant mapping effort was to describe species composition and estimate plant cover (the portion of the bottom sediments of the examined area covered with plants) and biovolume (the portion of the water column of the same area filled with plant material) during the period of peak development. Plant mapping was also conducted to establish a baseline extent of any nuisance infestations of invasive plant species to allow for future evaluation of the success of implemented management measures.

A number of transects were established in order to thoroughly characterize plant beds throughout the pond. Each transect was surveyed by direct observation from a boat in clear shallow areas and by grappling plants from the bottom in deeper waters. Additionally, unique habitat areas that were not located along these transects were also surveyed so that the less abundant plant species could be documented. Total macrophyte cover and total macrophyte biovolume were mapped throughout the pond. Macrophyte cover and plant biovolume were expressed as a percentage value within four pre-defined quartile ranges from 1 (1-25% cover or biovolume) to 4 (76-100% cover or biovolume). The absence of plants was recorded as zero.

2.2.2 Fish and Other Wildlife

Observations of fish and other wildlife, including waterfowl and wading birds, were noted during the aquatic plant survey. Areas with concentrations of centrarchid (primarily sunfish) nests were also recorded.

2.3 Collection and Review of Supporting Data

Although little recent water quality data for Bowdish Lake were available, data from the University of Rhode Island Watershed Watch (URIWW, 2009) and limited historical water quality for the lake were also available from USGS (USGS, 1988). URI Watershed Watch data for the years 2006 to 2008 were acquired in spreadsheet format and reviewed as the best available contemporary data. ESS also received some documentation of previous management practices at Bowdish Lake and from RIDEM (K. Degoosh, personal communication, 2009). Several other sources were also consulted to complete ESS's collection and review of supporting data (see Section 7.0 for more details).

3.0 WATERSHED AND LAKE CHARACTERISTICS

The Bowdish Lake watershed is approximately 1,912 acres in size and spans the towns of Glocester and Burrillville, Rhode Island. At the Hydrologic Unit Code (HUC) 12 level, the Bowdish Lake watershed is located in the Lower Fivemile River subbasin, which drains in a southwesterly direction toward the Fivemile River in Connecticut.

Although a relatively shallow (maximum depth of just over 10 feet) impoundment, Bowdish Lake is approximately 233 acres in size and the total shoreline perimeter is approximately 5.05 miles. The entire lake is located within the town of Glocester, Rhode Island. The state of Rhode Island owns much of the land on the eastern side of the lake and public access is provided by a state maintained boat ramp in this area. Private residences occupy much of the western and southwestern shoreline while the Bowdish Lake Campground provides private access to visitors along much of the lake's northern shoreline.

Bowdish Lake has been classified as an oligotrophic water body by URIWW. The state of Rhode Island has classified Bowdish Lake as a class B water body with designated uses that include fish and wildlife habitat, fish consumption, and swimming (primary and secondary recreation). Although it was listed as impaired for non-native plants (Category 4C) in 2008 by the state of Rhode Island, water quality in Bowdish Lake is supportive of both primary and secondary recreation. Bowdish Lake has not been assessed for fish consumption.

3.1 Watershed Characteristics

3.1.1 GIS Analysis

3.1.1.1 Current, Historical, and Future Land Use

Watershed land use provides an important source of information about potential non-point source pollution. This stems from the observation that different land uses typically generate different loads of nutrients and other pollutants to water bodies. As a general example, urban land uses are usually expected to produce higher pollutant loadings than most natural land uses (e.g., forest). Consequently, land use is important as a tool for lake managers, to help them understand and address pollution issues in the watershed, as well as municipal planning officials, who regulate land use in the watershed.

The total watershed area of Bowdish Lake is estimated to be approximately 1,912 acres (Table 1, Figure 1) including 233 acres for Bowdish Lake itself. Impervious cover in the watershed is low (approximately 3.3%) and, reflecting its rural nature, land use is currently dominated by forest (1,355 acres or 71% of the total area). After water (including Bowdish Lake, Lake Washington, and Wilbur Pond), urban land use accounted for the third largest portion of the watershed (111 acres or 6% of the total area). Of this urban land use, only approximately six acres are commercial, while the remainder consists of low to moderately high density residential. Although this represents a relatively small proportion of overall land use in the watershed, much of this development is located along sensitive areas, including the shoreline of Lake Washington and the southern shore of Bowdish Lake. Therefore, without preventative management actions, contaminated runoff or groundwater from these properties may easily reach surface waters. Recreational land use, consisting mainly of campgrounds and swimming beaches along the northern and eastern shore of Bowdish Lake, accounts for 104 acres (5%) of the watershed area. Other land uses, including agriculture and barren land occupy less than 1% of the watershed.

Comparison of recent historical (1988) and contemporary land use indicates that no major shifts in land use appear to have occurred in the last 20 years (Table 2). Apparent shifts in forested land, water, and wetland are mostly due to a difference in way these lands were coded in the land use database. When taken together, the total decrease in wetland, water, and forested land between 1988 and 2003/2004 was approximately one acre. However, a slow increase in urbanization is apparent between the two time periods. As urbanization continues into the future, increased volumes of storm water and pollutant loading to Bowdish Lake may result.

Current zoning in the Bowdish Lake watershed (Town of Glocester, 2005) is largely agriculture-residential with 4-acre minimum lot size (884 acres) and open space (547 acres). A small area (13 acres) is zoned highway commercial. However, significant areas currently zoned as agriculture-residential are protected from development, either by wetlands setback requirements, conservation easements, or other designations. State lands, including the George Washington Memorial State Forest in the northern watershed and the Durfee Hill Management Area in the southern watershed, currently provide protection to large areas. However, pockets of land in the watershed, especially south of Route 44, may be vulnerable to future development.

3.1.1.2 Wellhead Protection Areas

A wellhead protection area is the portion of an aquifer through which groundwater moves to a well. Wellhead protection areas may be designated as “community” or “non-community.”

Community wellhead protection areas refer to areas around wells that are considered critical for the protection of source water supplies to community residents. Non-community wellhead protection areas offer protection of source water supplies to non-resident populations (schools, campgrounds, and places of employment among others). RIDEM is responsible for delineating a wellhead protection area for each of the public wells in the state.

Non-community wellhead protection areas cover a majority of the central watershed area, including most of the areas adjacent to Bowdish Lake (Figure 2). However, no community wellhead areas are known to be located within the Bowdish Lake watershed.

3.1.1.3 Soils

Soils in upland portions of the Bowdish Lake watershed are dominated by Canton and Charlton loams and Hinckley gravelly sandy loam (Table 3, Figure 3). Slopes are generally low to moderate, although a significant area (55 acres) of high slope Canton-Charlton-Rock outcrop complex is present within the watershed. Smaller areas of high slope Canton and Charlton very stony fine sandy loams (7 acres) and Hinkley gravelly sandy loam (12 acres) are also present. Additionally, according to hydrologic group, at least 66% of the watershed is underlain by moderately well- to extremely well-drained soils (hydrologic groups A and B). Soils likely to produce heaviest runoff (hydrologic groups C and D) are limited to approximately 12% of the total watershed area.

3.2 In-lake and Shoreline Characteristics

3.2.1 Public Water Intakes

Public water intakes were not observed during field surveys and Bowdish Lake is not designated as a public water supply reservoir.

3.2.2 Bathymetry

Results of water depth surveys performed by the U.S. Department of Agriculture – Natural Resources Conservation Service were used to create a bathymetric map for Bowdish Lake (Figure 4). Bowdish Lake is shallow overall, with maximum depth just exceeding 10 feet (3.0 meters) in the central portion of the lake. Water depth increases quickly with distance from the shoreline, but levels out between 8 and 10 feet (2.4 and 3.0 meters) in a large portion of the central basin. Additionally, water depth is relatively shallow near the spillway of Bowdish Dam (generally less than 9 feet [2.7 meters]). Several islands, including floating bogs, are present, mainly in the western and southern portions of the lake.

3.2.3 Biological Community

Data on the biological community associated with Bowdish Lake was collected as part of this study. Particular emphasis was placed on submerged aquatic plants. However, observations on emergent plants, fish and wildlife were also noted.

3.2.3.1 Aquatic Plants (Macrophytes)

A total of 95 points along 20 transects was surveyed for aquatic plants in Bowdish Lake (Figure 5). Results of the plant survey conducted in August 2009 found an aquatic plant community consisting of a mix of exotic invasive and native species. Aquatic plant growth was observed around the perimeter of the lake to the maximum depth of 11 feet.

Aquatic plant cover was high throughout the pond with only small areas (approximately 13 acres or 6% of the lake area) where 75% or less of the bottom area was covered (Figure 6). Relatively low plant cover (1-25%) was found in the vicinity of swimming beaches, particularly along the central portion of the northern shoreline and adjacent to the public boat access. One small area with no observable plant cover was observed in the southwestern portion of the lake, just north of an island with emergent vegetative cover.

Aquatic plant biovolume (the portion of the water column filled with plant material) within the pond was 51% or greater over approximately 96 acres (41%) of the lake (Figure 7). Highest biovolumes were typically found in shallow waters relatively close to the shoreline with decreasing biovolume toward the greatest depths at the center of the pond. However, areas with low plant cover along the northern shoreline and the public beach also had low (1-25%) biovolumes.

A total of twelve vascular and non-vascular aquatic plant species were documented in Bowdish Lake during the aquatic plant survey (Figure 8). Variable-leaf milfoil was the dominant plant observed in Bowdish Lake and the highest biovolumes observed were associated with dense beds of this species. The infestation of invasive exotic variable-leaf milfoil appears to be well-established. Variable-leaf milfoil, in particular, has choked out much of the habitat available for native species and is present in densities that may interfere with swimming or other recreational uses. Additionally, invasive fanwort (*Cabomba caroliniana*) is also present in several areas of Bowdish Lake, though to a lesser degree. However, the fanwort infestation does not yet appear to be well-established. Both milfoil and fanwort reproduce mainly by fragmentation, which means that broken fragments of these plants easily take root. This allows these species to rapidly spread to multiple downstream or downcurrent locations in a single growing season. Human activities such as boating, fishing, swimming, and plant harvesting can inadvertently contribute to the spread of these plants by encouraging fragmentation.

Some native species are still present in the lake, including several bladderworts (*Utricularia* spp.), water shield (*Brasenia schreberi*), yellow and white water lilies (*Nuphar lutea variegata* and *Nymphaea odorata*, respectively), little floating heart (*Nymphoides cordata*) and muskgrass (*Chara* sp.). The submersed form of native golden hedge hyssop (*Gratiola aurea*) was especially common in shallow areas with minimal cover of variable-leaf milfoil.

3.2.3.2 Other Wildlife

Although extensive beds of dense variable-leaf milfoil are likely to reduce the amount of prime habitat for large predatory fishes, Bowdish Lake provides habitat that is generally suitable for a typical warmwater fish community. Species that are likely to be present include brown bullhead (*Ameiurus nebulosus*), bluegill (*Lepomis machrochirus*), chain pickerel (*Esox niger*), pumpkinseed (*Lepomis gibbosus*), and largemouth bass (*Micropterus salmoides*). Although the scope of this study did not include fish surveys, ESS did directly observe numerous sunfish during the aquatic plant survey, as well as evidence of bluegill and pumpkinseed nesting in shallow sandy portions of the lake. This is consistent with observations of centrarchid nests in a previous study (ESS, 2002). Bowdish Lake is a popular location for bass fishing and hosts frequent bass tournaments, the number reaching 13 in 2007 (K. DeGoosh, personal communication, 2009).

Few avian species were observed at Bowdish Lake during the aquatic plant survey. However, some waterfowl, including Mallard (*Anas platyrhynchos*) and American Black Duck (*A. rubripes*) were present in small numbers. Among wading birds, Great Blue Heron (*Ardea herodias*) was the only species observed during the field visit. Available foraging habitat for other waterfowl and wading birds was observed and it is likely that several additional species do make use of the lake. Although Canada Goose (*Branta canadensis maxima*) was not observed on or in the vicinity of Bowdish Lake during the aquatic plant survey, a resident population of 50 to 60 individuals is estimated to reside at Bowdish Lake according to members of the Bowdish Lake Association.

3.2.4 Surface Water Quality

Phosphorus and nitrogen are essential plant nutrients. Excessive concentrations of these nutrients often fuel undesirable growths of algae in the water column (phytoplankton) and accumulations of attached algae (periphyton) on the shallower bottom sediments (within the euphotic zone). In addition, excessive quantities of these nutrients can also promote rooted plant growth. Rhode Island water quality regulations stipulate that average total phosphorus shall not exceed 0.025 milligrams per liter (mg/L) in any lake, pond, kettlehole or reservoir. Total phosphorus values below 0.025 mg/L will be essential for maintaining low algal biomass and high water clarity (Canavan and Siver, 1995). Values much above this are likely to be indicative of excessive human inputs. Similar thresholds for nitrogen in freshwater systems have not been established since phosphorus is typically the limiting nutrient in most freshwater systems.

Results from prior water quality monitoring efforts are summarized in the sections below. Additional information on in-lake water quality can be found in Appendix A. It should be noted that existing water quality data was limited to point measurements of concentration. While in-lake concentrations provide useful snapshots of pollutant levels they are not sufficient for understanding actual loading to the lake from watershed sources or downstream export. In general, Bowdish Lake enjoys relatively high in-lake water quality with respect to phosphorus and other pollutants.

3.2.4.1 Phosphorus

In recent years, total phosphorus levels have ranged from 0.004 to 0.017 mg/L, which meets established state criteria while dissolved phosphorus (that portion directly available for plant or algae growth) concentrations have ranged from less than 0.003 mg/L to 0.026 mg/L (Table 4; URIWW, 2009). Historical levels of phosphorus were generally similar, although total phosphorus may have been somewhat greater, ranging from 0.02 to 0.03 mg/L in 1988 (Table 4; USGS, 1988).

3.2.4.2 Secchi Disk Depth and Chlorophyll *a*

Water clarity, as indicated by Secchi disk readings, typically ranges from 2.3 to 2.9 meters or 7.5 to 9.5 feet between the months of May and October (Table 4; URIWW, 2009). Given the shallow bathymetry of Bowdish Lake, this means that sufficient light is available for plant growth throughout most of the pond during the growing season. This combination of factors makes Bowdish Lake especially vulnerable to *widespread* growth of certain aquatic invasive plant species, despite the fact that total phosphorus levels in the water column meet state criteria,

Chlorophyll *a*, which is correlated with the density of algal populations, generally ranged from 1.7 to 5.0 micrograms per liter although levels as high as 33.9 micrograms per liter have been reported (Table 4; URIWW, 2009).

These data, in concert with phosphorus data, suggest that Bowdish Lake is a mesotrophic reservoir, although it has been classified as oligotrophic by URIWW. Nutrient and chlorophyll *a* levels are typically low to moderate and water clarity is usually acceptable but may be limited to less than the maximum depth of this shallow water body at times.

Phytoplankton (suspended algae) populations do not currently appear to be a problem in Bowdish Lake, perhaps due to competition for nutrients with the heavy growth of aquatic macrophytes in the lake. Although the zooplankton (suspended microscopic animals) community was not examined under the current scope of work, it is also possible that a healthy community of grazing zooplankters helps keep phytoplankton populations in check at Bowdish Lake.

3.2.4.3 Bacteria

Bacterial levels in Bowdish Lake are generally low and it is considered to be fully supporting for both primary and secondary recreation as a Class B water body (RIDEM, 2008). Recent data show a range in Enterococci levels from 0 to 3.1 most probable number per 100 milliliters (MPN/100mL) in Bowdish Lake (Table 4; URIWW, 2009), which do not suggest serious bacterial contamination of the lake's waters.

3.2.4.4 Supplemental Data

Waters in Bowdish Lake are somewhat acidic and poorly buffered, as evidenced by a range in pH from 5.3 to 6.3 and alkalinity from 0.8 to 3.1 mg/L $CaCO_3$ during recent years (Table 4;

URIWW, 2009). Recent historical data suggest that the acidity of the lake has not changed appreciably, with pH ranging from 5.3 to 6.4 (USGS, 1988). Although recent historical alkalinity data was not available from the USGS dataset, related measures such as hardness (7 to 8 mg/L as $CaCO_3$) and calcium (1.9 to 2.1 mg/L) were both very low in Bowdish Lake (USGS, 1988).

3.2.5 Additional Information on Ownership of Bowdish Dam

Bowdish Dam is owned and maintained by the State of Rhode Island (Governor's Task Force, 2001), although Bowdish Lake Association members coordinate with RIDEM to adjust main valve settings on the dam for annual drawdowns. It was acquired on December 28, 1984 and repaired in 2001-2002 (RIDEM, 2001).

Small portions of the land under Bowdish Lake appear to be privately owned (Town of Glocester, 2009), including two parcels completely underwater and three parcels that extend into the water from shore. Additional details on these parcels can be found in Appendix C.

3.3 Identification of Inlets, Outlets, Spillways and Major Water Bodies

Based on an analysis of the 7.5 minute USGS topographic maps for the area, the principal water bodies in the Bowdish Lake watershed are Wilbur Pond and Lake Washington and their respective unnamed outlet streams that flow into Bowdish Lake (Table 5). At least five other unnamed tributaries drain into Bowdish Lake and the adjacent impounded area on the southern side of Route 44. Of these water bodies, Lake Washington is listed as impaired for aquatic invasive species (RIDEM, 2008) and likely serves as a major source of variable leaf milfoil to Bowdish Lake.

Bowdish Lake itself represents a potential source of nutrients and invasive species to downstream waterbodies. Likewise, management actions taken in Bowdish Lake must also take into account downstream impacts. Water from Bowdish Lake drains west through the Bowdish Dam spillway into Sawmilll Pond, which is unnamed on USGS topographic maps. From Sawmill Pond, flow continues through a series of impoundments and stream segments, including (in downstream sequence) Clarkville Pond, Hawkins Pond, Mary Brown Brook, and Mary Brown Pond, finally joining the Fivemile River in Connecticut.

3.4 Local and Watershed Pollution Sources

Non-point source pollution inputs to lakes often include both local (i.e., shoreline) and watershed sources. The potential sources of non-point source pollution are numerous and may include roads, roofs, lawns, agricultural fields, septic systems, construction sites, and mining operations among other things.

Watershed sources of pollution are unlikely to be significant, as most of the Bowdish Lake watershed area is forested and has relatively low road densities. Therefore, outside of direct runoff from roads and developed properties abutting Bowdish Lake, non-point source pollution in the watershed is most likely limited to those shoreline properties and roads abutting Lake Washington.

Review of the town of Glocester's storm water GIS data layer (R. Goff, personal communication, 2009) did not indicate the presence of storm water outfalls at Bowdish Lake. However, storm water structures have not been completely inventoried for the entirety of the town. Therefore, this does not guarantee that storm water outfalls are not present. Direct shoreline observations of Bowdish Lake resulted in identification of a high density polyethylene pipe, located in the vicinity of the public boat launch on Bowdish Lake. This pipe was not flowing at the time of observation but appears to provide culvert drainage from a low-lying area on the opposite side of the boat ramp access road.

No additional outfalls were identified in the Bowdish Lake watershed during the brief visual survey, although runoff from area roads and adjacent shoreline properties is likely to enter Bowdish Lake directly as sheet flow or via non-structural drainage conveyances. One example of this is visible where an extension of the paved area abutting Route 44 (Putnam Pike) directs highway runoff directly into the southern arm of the lake (Appendix B).

Data on leaking or failed septic systems near Bowdish Lake was not available from the town of Glocester. However, the Glocester Town Planner was not aware of any particular problems from properties around the lake (R. Goff, personal communication, 2009). A search of the state On-site Wastewater Treatment Systems (OWTS) online database, which displays records back to 1992, indicates that most OWTS in the vicinity of the lake were installed or last upgraded prior to 1992. Older OWTS, if not properly maintained, are likely to fail and could result in additional loading of pathogens and nutrients to Bowdish Lake. RIDEM maintains records pre-1992 OWTS in its archives. These records could be searched to obtain additional details on individual systems.

Additional review of GIS data files available from the state (see Section 6.0) was conducted to identify other known or potential sources of pollution within the watershed. Locations of leaking underground storage tanks (LUSTs) and Rhode Island Pollutant Discharge Elimination System (RIPDES) discharges (direct discharges of wastewater including industrial discharges) were mapped to evaluate their potential to impact Bowdish Lake, although none were identified within the Bowdish Lake watershed.

3.5 Summary of Previous Studies, Management Actions and Current Problems

No comprehensive limnological studies of Bowdish Lake were found during ESS's review of available information. Based on this review it is clear that a new study and a well-defined management plan were needed to address ongoing issues. In general, management techniques have been gradually adapted over the years to address short term issues in Bowdish Lake. Problems with aquatic weeds and water quality have been dealt with as they arise, only to return after a short time. This Lake Management Plan should serves as a significant first step in solving systemic issues in Bowdish Lake.

3.6 Quality Assurance/Quality Control

With a few minor exceptions, no deviations were made from the methodology described in the QAPP (ESS, 2009). Modifications in methodology at Bowdish Lake included the following:

- Aquatic plant mapping was conducted along 20 transects (rather than the 21 proposed) on Bowdish Lake. The final transect was located south of Route 44. As Route 44 is a causeway with no bridge crossing, transect 21 was not accessible by boat from Bowdish Lake. However, visual surveys of the water surface from the highway suggest that variable-leaf milfoil is also the dominant plant throughout this area.

- Although aquatic plant surveys were conducted over two days, these days were not consecutive, due to survey timing and weather conditions. However, both days of the survey were conducted during the month of August and within a relatively short period of time (August 19 and 21, 2009). Therefore, it is unlikely that aquatic plant cover, biovolume, or composition changed significantly during this period.

No other deviations from the QAPP were noted. Validations of aquatic plant determinations were conducted by a second ESS staff member in the lab using voucher specimens collected from Bowdish Lake.

4.0 ASSESSMENT OF MANAGEMENT OPTIONS AND RECOMMENDATIONS

4.1 Management Concerns

Future management of Bowdish Lake will be dependent upon its intended uses as determined by the Town of Glocester, the Bowdish Lake Association, local residents, the State of Rhode Island (as the dam owner), and other stakeholders in the watershed. Bowdish Lake was created by impoundment of a bog system (Matheson, 2004) and the water body which was created is well-suited to serving a variety of human purposes, including swimming, winter skating, fishing (including ice fishing), nature observation, small-craft boating, and passive aesthetic enjoyment. However, the present-day Bowdish Lake is not ideally suited for swimming in many areas due to the potential safety hazard posed by excessive weed growth throughout much of the basin, particularly in areas with greater than 75% biovolume (Figure 7). In recent years, incidences of swimmers becoming entangled in certain aquatic weeds (primarily large milfoils and fanwort) have been reported from across the nation. Although children may be most sensitive, adults (even experienced swimmers) may also succumb to entanglement. For example, in an article dated August 27, 2007, *The Seattle Times* reported a drowning of a 22-year old man that was likely due to entanglement in invasive milfoil beds. Likewise, *The County Press* (Lapeer, Michigan) reported in an August 19, 2009 article that a 42-year old man drowned when he became entangled in dense lake weeds after jumping into the water from a pontoon boat.

The weedy condition may pose a threat to those swimmers who accidentally fall from a boat where they could become entangled in the weeds. Despite the nuisance and potential safety threat posed by the weeds, Bowdish Lake remains a popular swimming destination as evidenced by the swimming areas maintained at the state's beach at George Washington State Park and Campground, the private Bowdish Lake Campground, and the numerous local lake residents along their own shorelines.

Excessive weed growth is not only a potential safety risk but it can also be detrimental to the health of fish and other aquatic organisms. Exotic species such as the milfoil and fanwort present in Bowdish Lake typically grow up to and along the water surface creating a canopy that may shade out native plant species. The native species provide superb habitat for juvenile fish by providing cover from predation while still affording access to their principle forage base of aquatic insects and worms that live in the bottom sediments. The canopy formed by the exotic species competes with native species for resources (such as light, space, and nutrients) and may actually leave bottom sediments more exposed, allowing for easy predation on juvenile fish. In addition, dense weed growth can result in significant oxygen depletion during night time hours when photosynthesis is not occurring and oxygen production has ceased. This condition may result in a stunting of the fish population (limiting fish growth potential) or, in severe cases, can cause massive fish kills. The extent of impacts on native plants and fish in Bowdish Lake is not currently known. However, inclusion of plant mapping and fish sampling in a long term monitoring plan would provide site specific information on the relationship of exotic aquatic plant cover with native plants and fish populations.

Although the Bowdish Lake Association has been actively engaged in the implementation of a winter lake drawdown during recent years to aid in managing the rooted aquatic plant problems at the lake, weed problems were still evident throughout most of the basin in 2009.

Other potential threats to human health that should also be addressed as part of a comprehensive Lake Management Plan are bacteria loading and algal blooms. Bowdish Lake is not threatened by either of these poor water quality conditions at present, however, at a minimum education, watershed planning, and limited watershed management actions should be considered to prevent future water quality issues.

Significant residential development in the lake’s watershed exists along the southern shoreline of Bowdish Lake and along the perimeter of Lake Washington while the state forest has successfully preserved a relatively undeveloped condition along much of the lake’s northern shoreline. Furthermore, the George Washington Management Area established in the northern third of the watershed and the Durfee Hill Management Area in the southern portion of the watershed provide a significant amount of additional protection against the threat of development which would ultimately lead to deteriorating water quality. There still remains an area of unprotected and undeveloped land within the watershed that should be proactively managed to minimize potential impacts from future development.

The selection of management actions for Bowdish Lake should be guided by the long-term management objectives.

4.2 Management Objectives

As a Class B water body, state designated uses in Bowdish Lake include swimming and other recreational contact, aquatic life support and fish consumption. Management for recreation is believed to be appropriate for Bowdish Lake at this time, as this water body is a community asset that could be significantly enhanced if given the appropriate level of attention. This also makes sense given the abundance of state park land within the watershed. Protecting water quality and controlling aquatic invasive weeds in Bowdish Lake will also help meet the goal of removing the lake from the state’s list of impaired waters. These points of consideration should benefit the Town and the Bowdish Lake Association in their pursuit of state and federal funding support for future management actions.

Management goals for Bowdish Lake should include the following:

1. Protect water quality in the lake;
2. Reduce the impairment caused by nuisance and exotic plant growth;
3. Ensure lake conditions support valued recreational uses including swimming, boating and fishing;
4. Improve aquatic habitat, including fish habitat;
5. Protect unique habitat within the lake, specifically the floating islands; and
6. Maintain and restore habitat for *migratory* waterfowl, wading birds, reptiles and amphibians within the lake and within hydrologically connected wetlands and waterways.

More specifically, physical features of the lake are to be managed to maintain appropriate fish habitat, maximize safety and enjoyment for human users, minimize shoreline erosion, and prevent excessive plant growth or other abnormal biological nuisances. Short-term management effort is needed with regard to controlling exotic weed growth (milfoil and fanwort) in the lake while long-term management should be directed toward planning for future growth and development within the watershed. Exotic weed growth is a long-term management challenge. Even if complete eradication of variable-leaf milfoil and fanwort were achieved in Bowdish Lake, other sources of these and additional invasive exotic species exist in nearby waterways. Therefore, regular ongoing monitoring and management will be needed over the long term to prevent the establishment of future infestations.

Monitoring of Bowdish Lake will also be needed to measure the progress of management actions taken and to document that these actions are environmentally protective. The nature and extent of monitoring will depend on the management actions undertaken. A monitoring program for Bowdish Lake is proposed in Section 5.0.

4.3 Management Options and Recommendations

Although a range of options may be considered for managing Bowdish Lake, the current extent of nuisance variable-leaf milfoil growth in Bowdish Lake means that fewer strategies are likely to be viable compared to an otherwise similar water body in earlier stages of infestation. However, with each of the specific management objectives outlined above in mind, management methodologies can be examined to determine the applicability and feasibility of options for meeting that objective. Prior to selecting management options, it is important to examine the benefits and disadvantages of each management action, including an evaluation of the likelihood for success, cost-effectiveness, sustainability and potential ecological consequences. A review of potential management options for each suggested management objective is presented below.

4.3.1 Recommended Management Options for Water Quality Protection and Improvement – Watershed Level

The watershed management actions discussed below are based on our understanding of watershed characteristics and historical water quality data. Water quality data for one in-lake location at Bowdish Lake were available through University of Rhode Island Watershed Watch and continued participation in the URI-WW program is recommended at a cost of about $600 per year. However, no watershed water quality data were available and no additional site-specific water quality data were collected by ESS in support of our analysis.

Although Bowdish Lake benefits from having a watershed with sizable amounts of preserved open space and limited development, it is very likely that the lake's water quality is still impacted by septic systems, storm water runoff, waterfowl (geese), and other land use practices to one degree or another. However, which of these sources is the most critical or relevant source cannot be determined without additional water quality investigation and the development of a nutrient loading budget for the lake. In order to understand this pollutant loading, water quality sampling would need to be conducted in the watershed. It should also be clearly stated that watershed management actions designed to reduce nutrients such as phosphorus or nitrogen will not have a measurable impact on reducing or controlling nuisance aquatic rooted plants in Bowdish Lake. Although Bowdish Lake is likely to be a phosphorus limited system, the additional phosphorus loading from its watershed is not needed by the rooted plant community established in the lake because the lake's sediments have significantly more than the necessary nutrient for supporting the rooted plant growth. Subsequently, this nutrient is returned to the sediment at the end of each growing season when the plants senesce and when phytoplankton within the water column die off and settle to the lake bottom. Managing water quality from the watershed will still benefit in-lake water quality by limiting the duration and intensity of algal blooms and therefore is still encouraged.

Given this, the following considerations for future management of the watershed are provided to improve or protect water quality.

4.3.1.1 Behavioral Modifications – Recommended

Behavioral modifications include alteration of individual or group practices that lead to increased runoff and pollutant loading. Actions relating to lawn and garden care, yard waste disposal, automotive cleaning and maintenance, and pavement deicing or sanding would be likely targets for this approach. Modifications are usually attained by a combination of education and regulation, but there can be practical limits in residential settings. Most behavioral controls are best implemented on a voluntary basis, but are unlikely to provide more than a 5% to 10% reduction in total pollutant load. Mandatory controls are better suited to situations of clear non-compliance, as with illegal hook-ups or dumping to the storm drainage system, but these conveyance systems are not present in the Bowdish Lake watershed.

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There are typically no permits or significant costs associated with most behavioral modifications, but compliance is difficult to measure.

4.3.1.2 Low Impact Development and Stormwater Management Improvements – Recommended

Assuming the guidelines in the draft Stormwater Design and Installation Standards Manual (2009) are adopted, Low Impact Development (LID) is likely to soon be mandatory for all new development and redevelopment projects in Rhode Island. LID techniques emphasize on-site measures to avoid, if possible, negative water quality or quantity impacts on surface waters. Impacts that cannot be effectively mitigated on site may be addressed with structural best management practices (BMPs) to treat and detain storm water.

A number of options are available to treat stormwater and each option has its own set of advantages and disadvantages and costs may vary widely for design and installation.

Wet Vegetated Treatment Systems (WVTS): Aims to delay the time it takes for storm water runoff to reach streams and ponds but may not significantly reduce the total volume of runoff. Depending on the design, they may also remove stormwater pollutants. They must be maintained in order to function properly. Maintenance may include repair of discharge structures, mowing, and cleaning out accumulated sediments.

Treatment Swales (Open Channels): There are two main kinds of treatment swales – dry and wet. Dry swales are designed to dry out between storm events and tend to retain only a minimal portion of the storm water pollutants. Wet swales retain a permanent pool of water, which allows a longer period of time for the removal of pollutants. Both types of treatment swales must be maintained in order to function properly.

Infiltration Basins: Infiltration basins are designed to reduce runoff volumes by infiltrating storm water into the ground. Under most circumstances, they also provide improved removal of pollutants, particularly phosphorus, over detention basins and may contribute to groundwater recharge. Maintenance usually consists of cleaning out accumulated sediments to prevent clogging of the basin.

Although infiltration basins may take up a significant amount of space when used to control runoff from large developments, compact structural designs may be used to treat storm water in areas that are already densely developed or along roadways.

A catch basin sump and leaching dry well system combines principals of detention (sump) with infiltration (leaching dry well) in a relatively compact area. Outflow or overflow pipes from these systems can be tied into existing storm drains. These types of designs could provide much improved treatment of storm water along paved roads.

Filtering Systems: It may also be beneficial to consider other decentralized approaches to reducing runoff and infiltrating storm water at its source based on the principles of LID, which encourage the use of filtering systems such as sand or organic filters, green roofs and rain gardens (bioretention) among town residents and particularly for new developments. By reducing the volume of runoff from individual properties, these types of storm water BMPs reduce peak storm water flows and can also prevent many contaminants from entering the storm drainage system. Rain gardens are often very efficient at removing suspended solids and heavy metals (90% is not uncommon for total suspended solids and metals such as copper, zinc, and lead) but removal rates for nutrients, and nitrate in particular, are lower (usually 30-40%) and less consistent. Most structures can be retrofitted with green roofs and although the initial investment cost is high, green roofs easily extend the life of a traditional roof by 20 or more years. Rain gardens typically require much less capital investment and can be constructed in all but the smallest yards. In order to be noticeably effective, porous pavement, green roofs and rain gardens would need to be implemented over a significant portion of the currently developed area. However, updated regulatory ordinances in town could be developed to encourage or require these techniques.

Although implementation of any of the above recommendations could begin at any time, successful implementation of these approaches on a watershed-wide basis will most likely occur once the state's Storm water Design and Installation Standards Manual (2009) are adopted. This would impact future development, but additional efforts could also be performed to retrofit currently developed properties. Costs for evaluating the watershed to identify the sites that may be superior candidates for retrofitting with LID or other storm water management techniques would be on the order of $15,000 to $20,000.

4.3.1.3 Maintenance and Upgrade of On-site Wastewater Treatment Systems – Recommended

OWTS provide on-site treatment of sewage for homes and businesses that are not connected to a sanitary sewer. Since Glocester does not have a municipal sewer system or treatment plant, OWTS use is expected to be the principal sewage disposal approach. OWTS failures may result in ponded or flowing wastewater at the ground surface or into surface waters, which presents a potentially serious public health issue. Additionally, failed systems may also contribute nutrients (primarily nitrogen) to surface waters, which can fuel excessive aquatic plant or algal growth.

Septic system repairs and improvements could help reduce the nutrient load associated with failing systems or improperly designed or sized systems in the watershed. Additionally, education on proper maintenance of existing systems would be of some value for optimizing system performance and preventing future failures.

The current study did not include an evaluation of the lake's water quality budget or sampling of shallow groundwater – therefore it has not been determined whether contamination from improperly sited or failing OWTS is a primary source of nutrient or bacterial loading to the lake. However, since the area immediately surrounding the lake is not sewered, a program focusing on identification of faulty or failing OWTS as well as on providing maintenance or upgrades may provide measurable improvements to in-lake water quality. Although such a program is unlikely to directly reduce nuisance weed growth in Bowdish Lake, it would help prevent future nutrient and pathogen loading to the lake.

A comprehensive program would need to focus both on maintenance as well as identification and repair or upgrade of improperly sited or failing OWTS. Development of a public education program about good housekeeping measures (proper maintenance) could help prevent OWTS failure and degradation of water quality within Bowdish Lake. This could be incorporated into a more general public education program to address multiple issues at Smith and Sayles Reservoir.

Additionally, for regular maintenance of OWTS, homeowners would likely be able to negotiate a 10% to 30% discount by requesting service as a group (street or neighborhood level). If more extensive repairs or upgrades are necessary, the Town of Glocester currently participates in the Community Septic System Loan Program. This program offers low interest loans to homeowners for repair and replacement of substandard OWTS. As with maintenance, groups of homeowners wishing to upgrade their systems might be able to negotiate a discount from contractors.

4.3.1.4 Wildlife Control – Recommended

Canada goose populations in Rhode Island can be broken into two broad groups: migratory and resident. Migratory Canada goose populations are generally not considered to be a problem in Rhode Island since they do not nest locally and experience significant hunting pressure across much of their migratory routes. However, resident Canada goose populations have increased greatly over the last 50 years in southern New England where local hunting-related ordinances and feeding by the public reduce pressures on goose populations.

Resident Canada goose populations may increase the nutrient loads to Bowdish Lake and pose a potential public health issue to swimmers through bacterial loading. Additionally, geese may become aggressive toward children and even adults that approach too closely. Given the reports of a resident Canada goose population at Bowdish Lake, management actions specifically addressing control of this population may be worth consideration.

ESS recommends initiating a study to determine resident Canada goose flock size and primary nesting and grazing areas at Bowdish Lake and in nearby areas accessible from shore. The study should also include observation of the effectiveness of existing deterrents already in use, such as vegetative buffers, decoys, fencing, and general landscape management. Results of the study could be used to evaluate and management options and locations for implementation. Both passive (e.g., fencing) and active (e.g., egg addling) management options could be evaluated. Costs for a single-season study would be approximately $6,000.

General public education in the form of a brochure or workshop series would be beneficial either within the context of a study or as a stand-alone program. This would be useful for increasing awareness of the resident Canada goose problem. Education on behavioral modifications to prevent expansion of the resident goose populations would also benefit the lake in general. These could also be included in the educational effort for little additional cost. Costs for developing and implementing such an education program would be on the order of $3,000.

4.3.2 Recommended Management Options for Weed Management or Water Quality Improvement – In-lake Level

4.3.2.1 Bottom Sealing – Recommended on Limited Basis

Benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants. They have such positive side effects as creating more edge habitat within dense plant assemblages and minimizing turbidity generation from fine bottom sediments. Barrier materials have been commercially available for decade and a variety of solid and porous are available. However, deployment and maintenance of benthic barriers continues to be difficult and this limits their utility over the full range of weed bed sizes.

Plants under the barrier will usually die completely after about a month, with solid barriers more effective than porous ones in killing the whole plant. Barriers of sufficient tensile strength can then be moved to a new location, although continued presence of at least solid barriers restricts recolonization. Benthic barriers are best used for providing control of milfoil and other nuisance growth on a localized basis. They are likely to be of most use in heavily used areas near shore and in the vicinity of docks or other shoreline structures.

The ability of vegetative fragments to recolonize porous benthic barriers such as fiberglass screening has made them less useful for combating infestations by milfoil on any but the smallest scale, as sheets must be removed and cleaned at least yearly. Solid barriers have been more useful, although the gas released during decomposition in the sediments below can cause the barrier to billow, necessitating the use of anchors or vents that can reduce the lifespan of the barrier.

Problems associated with benthic barriers include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Benthic barriers are also non-selective, which means all plants in the treatment area are killed, including desirable native plants. By smothering bottom sediments, barriers can also impact the benthic macroinvertebrate community within the treatment area, which may locally reduce food sources for some fish. Another drawback of benthic barriers is that recolonization from adjacent plant beds can occur quickly, once the barrier has been removed. Additional effort, such as hand harvesting, might be necessary for two growing seasons or more.

One final problem is the tendency of products to come and go without much stability in the market. Few of the barrier materials on the market at any time continue to be available for more than 5-10 years; most need to be made in bulk to keep costs down, yet costs remain high enough to hinder demand and reduce bulk use.

Cost and labor are the main factors limiting the use of benthic barriers in most lakes, and would be prime deterrents in Bowdish Lake. The cost per installed square foot is on the order of $2.00, leading to an expense of nearly $90,000 per acre. Bulk purchase and use of volunteer labor can greatly decrease costs, but use over large areas of nuisance vegetation is highly unlikely. Benthic barriers could be useful for addressing nuisance plant growth at the public beaches, where deployment and any subsequent maintenance would be relatively simple. The use of benthic barriers by individual property owners could also be a good approach to local weed control, as necessary.

4.3.2.2 Chemical Treatment (Herbicides) – Recommended

Herbicides remain a controversial aquatic weed control measure in many communities because of their association with pesticides, which is generally perceived to be negative. However, as we learn more about the various negative impacts that can be associated with alternative physical and biological management options, chemical control measures continue to be used as part of many balanced lake management plans.

Although no herbicide is completely safe or harmless, a premise of federal pesticide regulation is that the potential benefits derived from use outweigh the risks when registered herbicides are applied according to label recommendations and restrictions. Current herbicide registration procedures are far more rigorous than in the past and the ability of qualified and licensed applicators to target applications of herbicides further improves the relative safety of using these chemicals for nuisance aquatic plant control. However, each of the herbicides evaluated in this Lake Management Plan present some degree of risk with regard to potential toxicity to non-target organisms and temporary recreation restrictions would be needed for herbicide applications at Bowdish Lake.

Where exotic aquatic plants infestations have become extensive and well-established (as with variable-leaf milfoil in Bowdish Lake), lakewide herbicide treatment is usually the most effective initial control option. Chemical treatment will also be the most cost effective means by which to immediately achieve the goal of reducing aquatic weed biomass in Bowdish Lake.

However, as herbicides can only be applied by state licensed herbicide applicators, this is not an option that lake residents can undertake themselves. It should also be noted that herbicide treatment alone would not provide for long term, sustainable control of nuisance aquatic plant growth. However, when integrated with other management strategies as part of a comprehensive plan which includes watershed and in-lake level approaches, herbicides can play a valuable role in managing nuisance growth.

There are only a few herbicides currently approved for use in aquatic ecosystems. The three most effective herbicides for targeting variable leaf milfoil in Bowdish Lake are presented below.

***Diquat dibromide – Contact Herbicide*:** For Bowdish Lake one of the most immediate approaches for controlling weed growth would be to target variable-leaf milfoil with the contact herbicide known as diquat (trade name Reward). As a contact herbicide, diquat can clear large areas of weeds in a very short time. Treatment of the entire lake (in excess of 200 acres of treatment) could be performed at a cost of approximately $35,000 to $40,000 per treatment (including permitting) and would clear the lake of most milfoil. However, since diquat is a contact herbicide, it does not typically kill rooted portions of aquatic vegetation and follow-up applications would be needed to control growth each year. Additionally, diquat is not selective and would also likely reduce the biovolume of native plants. A lake-wide diquat program would likely need to be phased in at least three partial-lake treatments in order to avoid excessive nutrient release and oxygen demand due to the decaying plant material.

Although mechanical harvesting may be used post-herbicide treatment with the objective of removing biomass (and the phosphorus stored in plant tissues) from a lake, there are many potential drawbacks to this kind of operation. First, it is difficult to harvest biomass that is decaying. Harvesting is unlikely to be efficient because decaying plant tissues may easily break into finer and finer segments or particles. This makes it hard for most mechanical devices to collect the decaying plant material. Additionally, aquatic plants treated with herbicide rapidly release phosphorus to the water column as they die. The amount lost varies but tends to be proportional to the concentration of phosphorus originally in the plant tissues (Carpenter and Adams, 1978), so that plants with higher concentrations of phosphorus tend to release higher amounts of phosphorus during decay. This means that even if harvesting could efficiently recover all of the decaying plant material it would only be able to remove a portion of the phosphorus contained by the plants when they were alive. Lastly, mechanical harvesting adds significantly to the cost of management (approximately $2,000 per acre).

Even without harvesting, the use of the contact herbicide diquat is likely to be cost prohibitive since the costs would not decrease significantly on an annual basis. This approach would not be recommended as anything more than a very short-term solution to the problem at hand. If other techniques to control the milfoil on a lake-wide basis prove to be ineffective or difficult to permit, a diquat treatment program targeting 20 to 25 acre areas along critical recreational shorelines or in key habitat areas could be performed at an annual cost of about $6,000.

***Triclopyr – Systemic Herbicide*:** The dicot selective systemic herbicide known as Tricolpyr (Renovate OTF) is a growth regulating herbicide that would be an option for achieving longer term control of the variable leaf milfoil problem since systemic herbicides are able to kill the roots of the plants as well. A joint study by the U.S. Army Corps of Engineers (USACE) and the state of New Hampshire showed Triclopyr to be very effective in controlling variable leaf milfoil when the targeted dose was maintained for a period of at least 12 hrs (Getsinger et al., 2003). One of the most recent and comprehensive investigations on the effects of Triclopyr on variable leaf milfoil showed that it provided “good” control across a broad range of concentrations (Netherland and Glomski, 2008). However, in a recent Rhode Island application in Lake Mishnock in 2007 and 2008 (Aquatic Control Technology, 2008), Triclopyr did not prove to be as effective at lower doses and although control at higher doses was achieved, the additional cost to attain these higher concentration levels resulted in a treatment program that was not cost effective.

One of the major benefits of using an herbicide such as Triclopyr as compared to diquat is the ability to be selective for dicots such as milfoil while having much less to no impact on most natives such as lilies and pond weed (*Potamogeton*) species. This represents a much more sustainable solution and is protective of the necessary native plant species and habitat they afford to lake biota.

One drawback of Triclopyr is the long (two to four days) contact period required for maximum effect. A poorly planned or executed treatment might not achieve appreciable improvement over large areas of the lake. Additionally, Triclopyr treatments are relatively expensive. Costs to treat Bowdish Lake with Triclopyr are likely to be on the order of $1,000 per acre. A treatment program targeting variable milfoil beds that most conflict with recreation use or habitat quality in the lake would be expected to require a minimum treatment area of 100 acres at a cost of approximately $100,000. Treatment should be expected to last for at least two years, perhaps even three, but additional efforts would also be required to address milfoil growth in non-treatment areas. Alternatively, the costs for a whole lake treatment using Triclopyr would be expected to exceed $200,000.

Given that Triclopyr is relatively fast acting the treatments would need to be performed in a phased approach with no more than 50 acres of the lake being treated at a given time to minimize the potential for nuisance algal blooms or fish kills. As with diquat, mechanical harvesting of decaying biomass would not be recommended as a feasible option.

2,4-D – Systemic Herbicide: The granular form of the systemic herbicide known as 2,4-D (trade name Navigate) is likely to be the most effective herbicide to combat variable leaf milfoil (Netherland and Glomski, 2008) and is also the most economical given its ability to achieve multiple years of control. Like Triclopyr, 2,4-D is a growth regulating herbicide that is selective for dicots, which means that it will be effective on milfoil while having less impact or no impact on desirable plant species such as the native pond weeds and water lilies. The real advantage of using 2,4-D over Triclopyr is that it has been shown to be the most effective herbicide at controlling variable leaf milfoil and it can be applied at about half the cost of Triclopyr (assuming an application rate of 100 lbs/acre or $500/acre). Therefore, using 2,4-D will achieve two to three years of variable milfoil control in Bowdish Lake for a cost of about $100,000 for the entire lake, or about half of this cost to target the most critical recreational and/or habitat areas.

Of the three herbicide treatment options discussed above, the one that makes the most sense from an economic perspective is the use of 2,4-D since the cost per acre is relatively modest and the effects are more specific to the target plant and will last for more than one year. A major drawback to this herbicide is the potential for the herbicide to migrate through soils and negatively impact wells adjacent to the lake. Given the known presence of public supply wells around the perimeter of the lake, it will likely be necessary to establish setbacks from the lake shore for treatment to minimize the potential for treated water to be drawn into these wells. No specific setback distance has been established for Rhode Island; however, the setbacks in various states range from as low as 75 feet in Michigan to as much as 1,500 feet in Maine, depending on the nature of the wells. ESS recommends that the nature of the wells that could potentially be drawing water from Bowdish Lake first be investigated by a qualified hydrogeologist and, if necessary, by a human health and environmental risk assessor, to assist in determining the fate and transport potential of 2,4-D so that specific setbacks, if any, can be recommended and included as part of the permitting conditions. Costs for this critical step are likely to be on the order of $10,000 to $12,000 for Bowdish Lake. In areas where a setback is required but milfoil control is still required, diquat may be used as long as this option has been included in the permitting application and approved.

The Rhode Island Division of Agriculture administers the permit program applicable to aquatic herbicide applications. The application form is available on the DEM website: http://www.dem.ri.gov/programs/bnatres/agricult/pdf/aquanuis.pdf. A permit to apply herbicides can typically be obtained by the herbicide applicator for a cost of around $250 including the filing fee.

The RIDEM Office of Water Resources does not require wetland alteration applications for projects that solely involve herbicide treatments. If herbicides are applied in conjunction with other mechanical management activities, such as hand-pulling large areas or mechanical harvesting, then RIDEM approval and a permit are likely to be needed. Exempt activities related to the removal of invasive plants are described in Rule 6.0 of the RIDEM Freshwater Wetland regulations.[†]

Total costs for an herbicide program which included a full lake treatment with 2,4-D along with the necessary investigations, permitting, and monitoring would be on the order of $120,000 for up to three years of control. Costs could escalate if there is any significant opposition to herbicide treatment by watershed stakeholders. Permits could be denied, appealed, or rigorously conditioned, the last of which could add cost both through constraints on the treatment process and pre- and post-treatment monitoring expenses. However, given the fact that herbicides, particularly the use of the recommended 2,4-D, have not been contested heavily in Rhode Island, successful permitting of an herbicide application to control the invasive species variable leaf milfoil is not likely to present a problem.

4.3.2.3 Macrophyte Harvesting – Recommended for Fanwort Only

Aquatic plant (or macrophyte) harvesting covers a wide range of techniques, including mechanical harvesting, hand pulling, and suction harvesting.

[†] For those waterbodies located within the jurisdiction of the RI Coastal Resources Management Council (CRMC), an application for an assent to conduct the herbicide treatment is currently required. Bowdish Lake is not located within the jurisdiction of CRMC.

Mechanical Harvesting

Mechanical harvesting, which involves cutting and pulling aquatic plants from a specially-equipped watercraft, is most effective in the short term. 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 plant cover.

Mechanical harvesting is not a recommended management option for Bowdish Lake because it is relatively expensive, typically results in only single season control, and may actually encourage the spread of invasive variable leaf milfoil or fanwort (which can both spread by fragmentation) to other areas within Bowdish Lake and downstream. However, hand pulling or diver assisted suction harvesting of the limited areas of fanwort in Bowdish Lake will likely be essential to preventing its spread to other areas of the lake.

Hand Pulling

The simplest form of harvesting is hand pulling of selected plants. Depending on the depth of the water at the targeted site, hand pulling may involve wading, snorkeling, or SCUBA diving. Hand pulling involves collection of pulled plants (with associated root systems) and fragments in a mesh bag. In deeper water, frequent trips to the surface are necessary to dispose of full bags. Depending on the experience and ability of the individual, fragments of the removed plants may occasionally escape collection and could result in colonization of new areas of the lake; however, given the widespread milfoil colonization in Bowdish Lake, this is not a major concern. The intensive nature of this work limits its application to small areas of shallow water, typically less than one acre in size.

Permits are not currently required for hand harvesting of aquatic invasive species in small areas around docks and private shorelines.

Diver Assisted Suction Harvesting

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. Additionally, because DASH uses suction to bring harvested plants to the surface, it is faster and may result in less fragmentation of nuisance plants than hand harvesting.

Fanwort is currently becoming established in the immediate vicinity of the lake's floating wetland and in a small patch along its northern shoreline in the vicinity of the Bowdish Lake Campground (Figure 8). It cannot be stressed enough how important it will be to address this outbreak immediately. In its current distribution the fanwort is not more than an acre in total area and is only sparse to moderately dense. This condition lends itself quite readily to hand harvesting or DASH techniques.

Small DASH projects targeting aquatic invasive species may be granted an exemption from the necessity to file a Request for a Preliminary Determination or Wetlands Alteration Permit. Exempt activities related to the removal of invasive plants are described in Rule 6.0 of the RIDEM Freshwater Wetland regulations.[†] However, prior to implementing a DASH program, the proponent should consult with RIDEM for confirmation that the proposed program does not require additional permitting.

Costs for immediately implementing a hand harvesting or DASH program will be minimal compared with the potential costs should fanwort be left to overtake the lake. Fanwort is one of the more resistant plants when it comes to herbicide control, with the only option currently available for use being the herbicide fluridone (trade name Sonar), and not much else. If fanwort is allowed to grow unchecked, the cost to treat Bowdish Lake at a later date with fluridone is likely to be on the order of $200,000, and may need to be repeated within 2 years. Fluridone also has only a marginal success rate on variable milfoil, so both plants cannot be addressed successfully with the same herbicide treatment. In contrast, the recommended approach of immediately implementing a hand or diver assisted harvesting program for fanwort, as discussed here, will likely be less than $15,000 to complete.

4.2.3.4 Water Level Control (Drawdown) – Recommended

Drawdown involves lowering the water level of a lake to expose shallow bottom sediments and associated plants (both native and non-native) to drying and/or freezing. It is most effective against species that reproduce mainly by vegetative means, including variable-leaf milfoil. Drawdown is less effective on species that reproduce primarily by seed (such as the invasive exotic species water chestnut and curly-leaf pondweed) and may actually expand beds of these species.

Lakes with rapid drop-offs to great depths tend to benefit most from drawdown. Due to the shallow bathymetry of Bowdish Lake, drawdown is only likely to provide limited control of aquatic invasive plant growth. Although drawdown can be conducted at any time, the interaction of drying and freezing that occurs with winter drawdown is usually most effective. Environmental restrictions and recreational uses also limit the appropriate window for drawdown to the winter period. In Rhode Island, winters are often variable in their intensity and the ideal winter condition of very cold weather with limited snow cover (which insulates the plants) is not likely to be achieved any more frequently than every other year.

“Ice rip” is a drawdown technique that focuses on physical removal of rooted aquatic plants by managing ice cover to literally “rip” the plants, including roots, from shallow areas. This technique is not recommended for Bowdish Lake as variable-leaf milfoil and fanwort spread primarily by fragments (not roots) and it is unlikely to be more effective than a standard drawdown program. Additionally, the rapid induced fluctuation of water levels and ice cover may exacerbate shoreline or downstream erosion, suspend bottom sediments and associated

[†] For those waterbodies located within the jurisdiction of the RI Coastal Resources Management Council (CRMC), an application for an assent to conduct the herbicide treatment is currently required. Bowdish Lake is not located within the jurisdiction of CRMC.

nutrients that are lifted with the ice, negatively impact bottom-dwelling fauna, disrupt hibernating reptiles and amphibians along the margins of the lake, reduce the safety of winter recreation activities on the ice, or compromise a weak dam.

In order to effectively drawdown a lake, there must be an adjustable discharge structure that allows the water level to be safely controlled. The water level must be drawn down to a sufficient depth (typically at least 4 feet [1.25 meters]) and for a long enough period of time to allow bottom sediments to at least partially de-water. Aside from the practical feasibility of performing a drawdown, the potential impacts on winter recreation (primarily ice fishing and skating) should also be considered.

Any manipulation of the water level in Bowdish Lake would need to be approved by and coordinated with the state, which currently owns the dam. For the previous five year period water levels have been managed by the Bowdish Lake Association under a cooperative memorandum of understanding agreement between the lake association and the RIDEM Division of Forest Environment (RIDEM Division of Forest Environment, 2004). Water level management under this agreement has resulted in a targeted winter drawdown of approximately 4.5 feet that begins in late September and refills by February. These drawdowns have specifically targeted aquatic plant control but as evidenced by our plant survey results, do not appear to be contributing significantly to the control of nuisance aquatic species in the lake. According to a letter authored by the Bowdish Lake Association (Bowdish Lake Association, 2003), the long-time residents around the lake have stated “extreme” drawdowns kept the lake “weed-free for many years”, however these extreme drawdowns ceased upon state control of the dam due to safety concerns and “a possible lack of knowledge pertaining to historical lake management practice”. The letter also states that a prior consultant recommended drawdown as a preferred method for variable leaf milfoil control and that the association “unanimously endorses this method because it is economical and chemical free”.

If drawdown is pursued as a management strategy, a drawdown feasibility study would first need to be developed that would identify potentially sensitive habitats or biota that may be present within the lake, its downstream waters, or within hydrologically connected wetlands. The drawdown feasibility study would also examine the feasibility of drawdown with regard to controlling hydraulics (related to the amount of water Bowdish Lake can hold, how much would be lost during the drawdown, and limitations concerning where the water goes downstream), flooding, and impacts to downstream and hydrologically connected wetland resources (e.g., drying) and would be used to establish a current baseline condition as well as to support permitting. In addition, there would be a need to develop a Drawdown Operations Plan, inclusive of all hydrologic calculations, that will serve to guide dam operators on methods for managing the drawdown timing, the release rate, and the magnitude of drawdown. The Drawdown Operations Plan will also provide protocols for monitoring the system to ensure protection of biota within lake and associated waters while also achieving a better level of control on the targeted milfoil. Given the data already collected under the current study, the costs for performing the drawdown feasibility study and preparing the Drawdown Operations Plan are likely to be on the order of $8,000.

Once this information has been determined and the Drawdown Operations Plan is developed, it will then be necessary to file an application for a Request for Preliminary Determination to determine whether the drawdown, as proposed, represents a *significant alteration* to a freshwater wetland. A Preliminary Determination typically costs between $1,000 and $3,000 to prepare and file, including a $600 application fee (which will be reduced to half when based on a Lake Management Plan). If it is determined by RIDEM that the proposed drawdown represent an *insignificant alteration*, then they may grant a permit for a period of up to four years. It may also be that with minor modifications to the Drawdown Operations Plan, the program could be altered to achieve a determination of being insignificant.

However, if the drawdown that is necessary to achieve satisfactory control of the milfoil is deemed to be a *significant alteration*, based upon the nature of potential impacts to non-target organisms and wetland habitat, then a submission for an “Application to Alter a Freshwater Wetland” will be necessary. Assuming that a Drawdown Operations Plan is made available, an Application to Alter a Freshwater Wetland for drawdown at Bowdish Lake is likely to cost between $6,000 and $10,000 to prepare and file based upon the nature of the impacts and the supporting studies and pre-drawdown monitoring that are likely to be required. The permitting fee for an Application to Alter a Freshwater Wetland is currently $1,500 for aquatic plant control projects, but this fee is also cut in half when the application is based on a valid Lake Management Plan (such as this). The issued permit will be valid for a one year period, but can be renewed annually for up to four years by filing an “Application for Permit Renewal” (along with the annual $200 renewal fee) if drawdowns are to be performed annually.

Given that Bowdish Lake has a recently improved outlet control structure and has historically used drawdowns of 4.5 feet or more to manage aquatic vegetation, it seems that drawdown should not be difficult to permit going forward. The effectiveness of the 4.5 foot drawdown program implemented over the previous five years is concerning and indicates that an effective drawdown program designed to manage milfoil at Bowdish Lake is likely to require a greater target drawdown depth. A greater target depth would be more likely to control weed growth in the eastern cove where the state beach and boating facility exists, as well as within the southern cove east of Hutter Drive. However, gradual drawdowns would likely be favored, in order to reduce impacts to fish, amphibians, and invertebrates such as freshwater mussels. Drawdown typically reduces habitat volume, access to spawning areas, and availability of dissolved oxygen, among other parameters, each of which is an important factor in the success of fish populations and should be considered prior to drawdown implementation. Overwintering amphibians may also be sensitive to fluctuating water levels during drawdown if it exposes them to dry or freezing conditions. Additionally, invertebrate species, especially those that are slower moving, may be desiccated or frozen if drawdown occurs too rapidly. Therefore, ESS would not recommend a drawdown greater than 4.5 feet without additional study, in light of concerns over potential impacts to fish and wildlife.

If drawdown were determined to be feasible and could be successfully permitted, the town or Bowdish Lake Association would likely be required to hire a qualified consultant to monitor impacts to aquatic resources in the lake annually as a permit condition, which could cost $5,000/year. Monitoring for potential impacts due to drawdown should focus on the mollusk population, water quality, and changes to hydrologically connected wetland plant communities.

4.3.1 Other Management Options for Water Quality Protection and Improvement – Watershed Level

4.3.1.1 Agricultural Best Management Practices – No Recommended Actions Identified

Agricultural land use currently makes up less than 1% of the total watershed area for Bowdish Lake (Figure 1). Therefore, agricultural BMPs are unlikely to significantly benefit water quality in Bowdish Lake.

4.3.1.2 Bank and Slope Stabilization – No Recommended Actions Identified

Bank and slope erosion appear to be contributing little to sedimentation in Bowdish Lake, although an evaluation during the period of the annual drawdown, when localized erosion may be heaviest, was not included in our assessment. The watershed itself is predominantly forested and as such erosion in these areas is likely to be limited. In areas of the watershed where erosion may be occurring due to higher slopes, most of the sediment that might mobilized is expected to be intercepted by either Wilbur Pond, the basin south of the Route 44 road crossing, or one of the several wetland systems within the watershed. A better option for controlling sedimentation to the lake would be implementation of select storm water BMPs along Route 44 at high runoff locations around the southern portion of the lake. Additional discussion on appropriate BMPs for Bowdish Lake are discussed under section 4.2.1.4.

4.3.1.3 Increased Street Sweeping and Catch Basin Cleaning – No Recommended Actions Identified

By increasing the frequency of street sweeping and catch basin cleaning on paved roads within the watershed some additional runoff pollutants could be removed, particularly sediments and associated phosphorus. Since much of the watershed is not currently equipped with storm drainage structures or even paved roads, the potential benefits are expected to be limited. Increased street sweeping, particularly along Route 44, would be expected to have some incremental value as part of a comprehensive watershed pollution reduction program.

4.3.1.4 Provision of Sanitary Sewers – No Recommended Actions Identified

The Town of Glocester currently does not provide sanitary sewer service to any of its residences or businesses. Developing a sanitary sewer system in this town would be extremely costly, particularly since extending the sanitary sewer system from the town center to residences and businesses in the more remote area of Bowdish Lake would not be practical. Encouraging the upgrade or repair of on-site disposal systems, as described in the previous section, is likely to be a less costly and reasonably effective option. Therefore, development of a sanitary sewer solely for the purpose of managing water quality at Bowdish Lake is not recommended at this time.

4.3.1.5 Storm Water or Wastewater Diversion – No Recommended Actions Identified

The diversion of storm water or wastewater involves diverting these sources to discharge outside of the Bowdish Lake watershed, essentially bypassing the lake. This option does not provide significant treatment of storm water or wastewater. Rather, it would simply shift the problems associated with contaminated storm water or wastewater to areas outside the Bowdish Lake watershed. Therefore, this option is not recommended at this time.

4.3.1.6 Zoning and Land Use Planning – No Recommended Actions Identified

The perimeter of much of Bowdish Lake is either already developed or is protected as State Management Areas. However, portions of the watershed outside of these areas remain largely unprotected and could be developed in the future.

It is recommended that efforts be made to preserve natural areas not subject to protection, especially in areas adjacent to stream corridors and wetlands, and encourage best management practices for construction and storm water management. Costs for such actions are highly variable and unpredictable, but could be minimal with thoughtful use of existing regulations and programs. Although, land use planning would have no immediate effect on the water quality or nuisance aquatic plant growth in Bowdish Lake, advanced planning for future development can be a critical step toward preventing future problems.

Conducting a watershed build-out analysis along with a projection of the ramifications on future nutrient loading in the Bowdish Lake watershed would be beneficial toward determining how water quality might change if all available sites within the watershed were developed. However, given that much of the watershed is already developed or has been protected through designation as Town Parklands, a build-out analysis for the Bowdish Lake watershed is not being recommended as a high priority. Costs for performing a build out analysis along with the associated nutrient load modeling would be on the order of $6,000 and could be used toward justifying future changes to zoning regulations or updating the storm water management ordinances.

4.3.1.7 Treatment of Runoff or Stream Flows – No Recommended Actions Identified

Runoff may be chemically treated in order to remove or inactivate target pollutants. Chemical treatment of nutrients typically targets dissolved phosphorous (the form most readily available to plants and algae) and involves the proportional injection of alum (aluminum sulfate) or similar compounds into storm water sources so that phosphorous is inactivated

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prior to entering the lake. This approach to nutrient management can be costly and does not address the actual sources of nutrients to the lake. Therefore, given the other options available with regard to providing long-term permanent improvements to the storm water infrastructure, phosphorus inactivation is not being recommended.

4.3.2 Other Management Options for Weed Management or Water Quality Improvement – In-lake Level

4.2.2.1 Aeration and/or Destratification – No Recommended Actions Identified

Aeration and/or destratification (or circulation) is used to treat problems with algal growth and low oxygen concentrations that may occur in smaller ponds. Air diffusers, aerating fountains, and water pumps are typical types of equipment that may be installed to increase circulation in a pond. The cost of purchasing, installing, and maintaining pond circulation equipment becomes substantial as pond size increases. Likewise, the effectiveness of the equipment tends to decline with pond size as it is difficult to achieve sufficient circulation in large ponds. Systems such as the Solar Bee® circulation system have recently been promoted as being capable of reducing aquatic weed growth, but definitive scientific studies have yet to confirm these claims.

This approach is not currently recommended for Bowdish Lake since nuisance aquatic plant growth (rather than algal growth) is the targeted impairment at the lake and nuisance aquatic plant growth has not been definitively shown to be controlled by aeration or circulation systems. If such a system were to be tried in Bowdish Lake, considerable advance work would be expected to be necessary to support permit applications such as fishery studies, sediment quality studies, addition water quality studies, and user conflict assessments.

4.2.2.4 Dilution and/or Flushing – No Recommended Actions Identified

Dilution and flushing involve increasing the flow rate so as to dilute or remove concentrations of nutrients or other pollutants in the lake. It requires an appropriate outlet structure and must take into account the potential downstream impacts of increased flow and “flushing” of nutrients. This approach is unlikely to be effective in Bowdish Lake because the volume of the lake is large compared to the magnitude of any relatively “clean” diluting flows that could be diverted into the lake. Additionally, lake sediments are believed to hold a large amount of nutrient that would sustain aquatic plant growth well into the future even if significant dilution or flushing could be achieved. Therefore, dilution and flushing are not recommended.

4.2.2.5 Dredging – No Recommended Actions Identified

Dredging can only work as a long-term 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. This means that any dredging to control rooted plants must remove all soft sediment in the target area or achieve a water depth in excess of 2.9 meters (9.5 feet) which is the maximum Secchi depth observed in Bowdish Lake.

Although permitting and implementation of a dredging project requires significant time and expense, this technique has recently been used to successfully manage nuisance aquatic plants in other New England lakes. Dredging in Bowdish Lake could be an effective long-term control technique for nuisance aquatic plants in key areas, but would be extremely expensive to perform on a lake-wide basis given the lake's size. Even if the area of dredging was reduced to cover only select areas, a program of up to 20 acres could be easily envisioned. Assuming an average dredging depth of only 2 feet over the 20 acre area would yield a dredge volume of over 65,000 cubic yards. Costs for this limited dredge program, including design, permitting, and construction would be on the order of $30/cubic yard or nearly $2,000,000. Furthermore, given the high fixed costs to initiate a dredging project, only a modest additional reduction in price would be expected for smaller dredging projects.

The challenges of a project of this type and magnitude are likely to be significant at any scale. Chemical content of the material to be dredged is an important consideration in determining the feasibility of reuse or disposal and no assessment was performed as part of this study. Research on the proposed upland containment area and disposal sites would also be essential to a complete evaluation. Hydraulic dredging is likely to be the most cost effective approach, but does require a larger and more sophisticated containment area or the use of advanced dewatering techniques such as the use of Geotubes (geotextile fabric for dewatering) or a belt-filter press machine that can extract water from the sediments while using a relatively confined work area.

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 complex and will require at least one year before the project could receive all required approvals. Federal (USACE 404) and state (Application to Alter Wetlands and 401 Water Quality Certificate) permits are all required for most projects and would necessitate considerable advance information and review time.

Given the high costs involved and the fact that dredging a limited area of Bowdish Lake would not ultimately achieve the stated objective of controlling nuisance weed growth throughout much of the remainder of the lake, dredging is not recommended as a realistic or appropriate option of rooted plant control.

4.2.2.6 Dye Addition – No Recommended Actions Identified

Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow. In essence, they mimic the effect of light inhibition that might be expected during periods of high turbidity or prolonged ice and snow cover. Dyes are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which time the plant could reach the euphotic zone). Dyes tend to reduce the maximum depth of plant growth, but are relatively ineffective in shallow water (less than 6 feet or 1.8 meters deep). Dyes are unlikely to make a significant difference in plant growth within shallow bodies of water like Bowdish Lake and would be extremely expensive if implemented in a system as large as Bowdish Lake. The application of dyes to Bowdish Lake would also require approval from RIDEM. Therefore, their use is not recommended for weed control in this system.

4.2.2.8 Hydroraking and Rotovation – No Recommended Actions Identified

Hydroraking uses a backhoe-like machine mounted on a barge to remove plants directly from lake sediments. Depending on the attachment used, plants are scooped, scraped, or raked from the bottom and deposited on shore for disposal. Hydroraking could be somewhat useful for control of milfoil in small areas of Bowdish Lake, although it has the potential to spread milfoil to downstream areas through fragmentation. Hydroraking may be more useful for local control of water lilies, as it can physically remove their large rhizomes (roots). Costs associated with hydroraking in Bowdish Lake would depend upon the area to be raked. Hydroraking generally costs $160/hour and may take between 12 to 24 hours of time per acre. Hydroraking all of the 220 acres with greater than 75% plant cover would range between approximately $420,000 and $840,000. In addition, trucking costs for removal of this amount of plant material will range from $80,000 to $140,000 if a contracted company is hired. Given other possible alternatives, hydroraking is not a cost-effective option for overall control of aquatic vegetation within Bowdish Lake. If used in combination with herbicides to control nuisance aquatic vegetation in problem spots or in high priority areas, hydroraking could be a useful and less complex management technique than dredging. However, prior to implementation, hydroraking would require a wetlands alteration permit.

Rotovation is essentially underwater rototilling of lake sediments. Rotating blades cut through roots, shoots, and tubers, dislodging and expelling them from their growing locations. Some operations are also outfitted to collect some or most of the rotovated plant materials. However, complete collection of these materials is often not possible. Although rotovation typically results in longer control of nuisance plant beds than mechanical harvesting, the risk of dispersing plant fragments remains relatively high. In this way, rotovation may actually be counterproductive in the long term, resulting in new areas of aquatic weed growth. Rotovation is not a recommended management option for Bowdish Lake because it is relatively expensive and is not a long-term solution for management of variable milfoil which can rapidly re-colonize from fragmentation.

4.2.2.9 Hypolimnetic Withdrawal – No Recommended Actions Identified

Hypolimnetic withdrawal involves the removal of oxygen-depleted waters from a lake bottom, typically by siphoning or pumping these waters through a specially constructed pipe or by releasing these from a hypolimnetic release on the dam structure. The selective withdrawal of these waters may help prevent phosphorous in the sediments from becoming available to phytoplankton (suspended algae) in a lake.

Although dissolved oxygen levels are likely to drop to very low levels within Bowdish Lake, the thickness of this oxygen-depleted layer is limited by the shallowness of the lake and at most times it would be impractical to selectively remove this layer. Hypolimnetic withdrawal may also require treatment of the removed water (with alum compounds) before it is returned to the downstream waterway in order to prevent causing water quality problems downstream. Additionally, this management option tends to have a very limited effective on the nuisance growth of aquatic plants since rooted plants derive most of their nutrients from the sediments and not from the water column. Therefore, hypolimnetic withdrawal is not recommended as a water quality or plant management option at Bowdish Lake.

4.2.2.10 Nutrient Inactivation – No Recommended Actions Identified

Nutrient inactivation typically targets dissolved phosphorous (the form most readily available to plants and algae) and involves the addition of alum (aluminum sulfate) or similar compounds to sequester this phosphorous in pond sediments. In its simplest form, nutrient inactivation is conducted by applying alum directly to a lake as a single dose. More sophisticated nutrient inactivation programs involve proportional injection of alum into storm water sources so that phosphorous is inactivated before it even enters the system.

Nutrient inactivation is typically used to control algae blooms and improve water clarity. These are not considered to be high priority issues for Bowdish Lake, where nuisance growth of aquatic plants is the primary problem and phosphorus levels meet state criteria. Therefore, nutrient inactivation is not recommended.

4.2.3.11 Biological Controls

Biological control involves the introduction of any parasite, predator, pathogen or other organism by humans to a lake as a method of managing invasive aquatic plants or algal blooms. Several different biological control techniques including food web manipulation, herbivorous fish stocking, insect stocking, pathogen release, barley straw deposition and plant competition enhancement have been used to control target invasive plants with varying degrees of success. Biological control functions as a suppression technology that in most cases reduces population growth and stresses target plants rather than eliminating the species (Grodowitz, 1998). Unlike physical and chemical control which have well defined outcomes, the results of biological controls are often less predictable with outcomes that have greater uncertainty (Mattson et al., 2004). Biological controls are more effective as a long-term approach to plant management because their use alone often takes several years before effective results are observed in a lake (Aquatic Ecosystem Restoration Foundation, 2005). Therefore, biological controls are most useful as part of an integrated approach to invasive plant management which may include the use of other techniques as well.

Several broad biological treatment approaches are currently recognized. These include a classical approach, inundative approach, use of general feeders and native species augmentation. Using a classical approach, a host-specific organism from the target plant’s native home range is introduced into the non-native environment the target plant has invaded. In essence, another exotic species is introduced to control an exotic species which has already invaded a new environment (Washington State Department of Ecology 2008). Extensive research is usually conducted ahead of time to ensure the newly introduced species does not become a nuisance in itself.

A mass release of either a native or exotic species which targets a nuisance invasive species is the basis of an inundative biological control approach. This method is used when the natural reproduction of the controlling species is not high enough to limit the spread of the target species.

A general feeder approach involves the introduction of an agent which is not species-specific and will target both native as well as the exotic target species of interest. The introduction of exotic grass carp (*Ctenopharyngodon idella*) which feed on a wide variety of plant species represents a general feeder approach to biological control.

Last, native species augmentation seeks to improve the natural capacity of a native controlling agent to target an invasive species. The use of native milfoil weevils (*Euhrychiopsis lecontei*) to control Eurasian milfoil provides an example of native species augmentation. Weevils are reared and then stocked in select lakes to supplement the existing in-lake weevil population.

A variety of bio-control methods which use these different general approaches was researched for potential use in Bowdish Lake. These methods and their applicability for use are discussed in the sections below.

Food Web Manipulation for Water Quality – No Recommended Actions Identified

Food web manipulation is a method typically used to manage algal populations in a lake, not rooted plant populations. The method relies on native species augmentation that works to alter the fish community structure by favoring larger, piscivorous fish over smaller planktivorous fish. By introducing or augmenting piscivorous fish such as largemouth bass, the population of planktivorous fish in the lake is reduced through predation by the piscivorous fish, thus allowing the population of algae-eating zooplankton to increase (Mattson et al., 2004). In theory, the increased zooplankton population will graze on algae and improve water clarity and quality. An alternate method of reducing the planktivorous fish population without having to stock larger fish is to remove planktivorous fish through electro-shocking, netting and recreational fishing.

The advantage of food web manipulation is it is relatively inexpensive, does not rely on chemicals to treat algae and does not involve the release of any exotic species. This approach may require only limited follow-up work once fish are introduced and natural processes are set in motion. The major disadvantages are variability and lack of predictability in results.

Food web manipulation would be likely to require submission of a Request for Preliminary Determination to Alter Freshwater Wetlands, at a minimum, and would likely to be reviewed very closely by the Rhode Island Division of Fisheries and Wildlife for fish stocking. Estimates of costs are variable and range from $500 to $1,500/acre for piscivorous fish stocking and $1,000 to $5,000/acre for planktivorous fish removal (Wagner, 2004). Food web manipulation is not recommended for Bowdish Lake as the primary nuisance aquatic species are rooted macrophytes rather than algae blooms. It is unlikely that food web manipulation would have any significant impact on reducing invasive macrophytes.

Herbivorous Fish Stocking for Macrophyte Control – Not Allowed

The introduction of herbivorous fish employs a generalist approach to aquatic invasive species management. The most commonly used species are grass carp which have been introduced into lakes in other states and have successfully controlled exotic plant growth as well native growth. Although there other fish species which consume macrophytes, grass carp appear to be the only actively used species which can survive the cold waters of the northeast during the winter. Grass carp are not currently permitted to be introduced into Massachusetts waters so they are not an option for Hopedale Pond. However, the following discussion is included to cover this commonly used technique which has been used in neighboring states.

The grass carp is an exotic species which typically grows up to 15 to 20 pounds in North America and tolerates a wide range of water conditions (Jordan, 2003). They display a wide range in dietary preference and feed vociferously, with the ability to consume more than their own body weight in fresh vegetation in a single day (Whetstone and Watson, 2004). Because of concern of the spread of this exotic species, biologists artificially created a sterile, triploid grass carp for use as a plant control agent in the 1980’s, and only a few states allow for stocking of anything but the sterile fish. Alaska, Oregon, Montana, North Dakota, Minnesota, Wisconsin, Michigan, Massachusetts, Vermont, Maine, Maryland and Rhode Island all prohibit introduction of any form of grass carp.

When introduced, grass carp will selectively feed on preferred species before targeting other less preferred species (Whetstone and Watson, 2004). Grass carp are reported to preferentially feed on fanwort and other nuisance species but not preferentially on variable leaf milfoil or Eurasian milfoil (Jordan, 2003). One source reviewed noted that most submerged aquatic weeds can be controlled with a stocking rate of 20-25 grass carp per acre (Whetstone and Watson, 2004). However, appropriate stocking rates appear to vary, with other sources citing ranges from 80 to 100 fish/acre, 12 fish/acre in Virginia and New York and 9 to 25 fish/acre in Washington (Wagner, 2004; Helfrich et al., 2004; Washington State Department of Ecology, 2008). Costs of grass carp range from $4 to $13 per fish depending on the source. At a stocking rate of 7 to 15 fish per acre, this would lead to a cost of $28 to $195 per acre with treatment effectiveness lasting for approximately five years (Wagner, 2004).

There are many challenges and concerns regarding the use of grass carp which explain why their use is not permitted in Rhode Island. In addition to controlling some exotic plants, grass carp can have serious impacts on native aquatic vegetation as well. Their introduction often leads to decreases in water quality and they are known to carry fish diseases which can be transmitted to local fish. Once released, grass carp are extremely difficult to catch. Finally, they are highly migratory and can easily escape over spillways and dams. Although they can be effective in controlling invasive plants, any use of grass carp in Bowdish Lake would need to be done with a great deal of caution even if their release were to be permitted in Rhode Island in the future.

Insect Stocking (Weevils) – No Recommended Actions Identified

The milfoil weevil (*Euhrychiopsis lecontei*) is a native invertebrate which typically feeds on northern watermilfoil (*Myriophyllum sibericum*) a native milfoil species which has been replaced by the spread of the invasive Eurasian milfoil (Wagner, 2004). The weevil does not feed on non-milfoil species. Adults feed on the milfoil and the larvae burrow into the stems of the plant, consuming the plant tissue within the stem, which ultimately results in the collapse of the plant to the lake bottom. As a control technique, the weevil larvae are introduced to a lake by placing larvae infested water milfoil strands within the targeted water milfoil beds of the lake. The best results are usually achieved in controlling water milfoil in lakes with dense, monotypic stands of water milfoil with several years required to measure a positive effect. As outlined by Grodowitz (1998), it may also be possible to improve results of weevil and other insect introductions by taking an active approach which includes yearly follow-up studies to evaluate populations, supplementing the insect population if necessary and integrating with other plant control techniques.

The weevils were first associated with the decline of Eurasian milfoil in nine lakes in Vermont and there have been signs of success of weevil introductions at two test lakes in Massachusetts. The weevils are now marketed commercially with a recommended stocking of up to 3,000 weevils per acre (Wagner, 2004). Costs of the weevils are generally $1 per insect though the insects can generally be raised by interested parties on their own at a reduced price (Washington State Department of Ecology, 2008). An introduction of weevils to Bowdish Lake is likely to require submission of a Request for Preliminary Determination to Alter Freshwater Wetlands, at a minimum, and will require review by RIDEM Division of Fisheries and Wildlife in order to introduce the weevils to any Rhode Island body of water.

Given that the primary invasive plant observed in Bowdish Lake is variable leaf milfoil, which is not targeted by the weevil, the opportunity to use milfoil weevils is not even relevant to Bowdish Lake's plant problem at this time. If Eurasian milfoil ever became a problem in Bowdish Lake, use of the weevils might be reconsidered.

Pathogen Introduction – No Recommended Actions Identified

The release of pathogens (disease causing organisms) into a lake to suppress target invasive aquatic species remains largely experimental, though considerable research has been done on the subject (Mattson, 2004). Pathogens hold promise for invasive species control for several reasons: they have a high abundance and diversity, are often host-specific, are usually harmless to non-target organisms, are easily disseminated, are self-maintaining and have to the ability to limit the host population without elimination (Mattson, 2004).

The most commonly used plant pathogens have been fungi with results of their use evaluated extensively. Specific pathogen examples include the fungi species *Mycoleptodiscus terrestris* which has been under research for use against Eurasian milfoil and hydrilla (Aquatic Ecosystem Restoration Foundation, 2005). Existing research has yielded inconsistent results and problems isolating specific pathogens. In addition, many host plants have shown resistance to pathogens.

Viral, bacterial and fungal pathogens have also been explored to control algae populations as well (Mattson, 2004). Lakes could potentially be inoculated with a pathogen to suppress the growth of a variety of algae populations. Experimental results using pathogens to target algae have shown that this method has not proven effective to date.

The introduction of any pathogen to Bowdish Lake would likely require submission of a Request for Preliminary Determination to Alter Freshwater Wetlands. Costs of existing pathogens are not well known; however, bacterial additives are relatively inexpensive for the small scale at which they have been used (Wagner, 2004). Because the use of pathogens is still largely experimental with unpredictable results, it is not recommended for use in Bowdish Lake.

Barley Straw – No Recommended Actions Identified

The use of barley straw as a method to control algae blooms in lakes began in England in the early 1990s. As the barley straw rots, a chemical is believed to be released which acts as an algaecide. The chemical which is actually responsible for the algae control has not yet been identified and it is not clear whether it is exuded from the barley straw itself or whether it is a metabolic byproduct produced by decomposers (Lembi, 2002).

Existing research suggests that barley straw acts to prevent new algae growth rather than kill existing algae, and is not effective against all types of algae (Lembi, 2002). In addition, results of use of barley straw in both the laboratory and in the field have varied widely from success to failure. Overall, the use of barley straw appears to have very unreliable results (Wagner, 2004).

When it is used, the suggested application rate is 255 pounds of barley straw per surface acre of lake (Lembi, 2002). When applied, the bales of barley straw first need to be broken apart, then packed into some form of loose netting before being placed in the lake using floats. The barley straw needs to remain in the upper three to four feet of the lake in order to remain effective. Costs of barley straw and labor to install are largely unknown however commercial operations do exist to perform this service.

Barley straw would most likely require is likely to require submission of a Request for Preliminary Determination to Alter Freshwater Wetlands before being applied. The use of barley straw also raises an issue in regards to permitting. Because of its algaecidal properties, barley straw is currently regarded as an unregistered herbicide by the US Environmental Protection Agency. As such, it cannot be covered by a permit to apply herbicides by the Rhode Island Division of Agriculture and licensed herbicide applicators cannot apply it to a lake (Wagner, 2004).

Because of its unreliability, the large size of Bowdish Lake which would require over 50,000 pounds of barley straw and the associated permitting issues, barley straw is not recommended for use in Bowdish Lake.

Plant Competition – No Recommended Actions Identified

The presence of a healthy, native plant community can often suppress the spread of invasive aquatic species. A plant competition biocontrol technique seeks to supplement native species through seeding and planting disturbed or bare areas before they can be colonized by invasives. The overall goal of the technique is to maximize spatial resource use by desirable species to keep out undesirable invasive species (Wagner, 2004).

The advantages of this approach are that it uses natural processes to control aquatic invasives, may be self-perpetuating after an initial establishment period of several years and can be easily integrated with other approaches. It is likely to be most effective after elimination of an invasive plant community through an initial herbicide treatment or mechanical removal (suction harvesting or hydroraking) followed by native species plantings.

There are several challenges associated with the plant competition approach which makes its long-term effectiveness uncertain. Periodic natural disturbances within a plant community provide continual opportunities for recolonization by invasives, which would require ongoing effort with supplemental native plantings (Wagner, 2004). The use of seeding or planting native vegetation is also still experimental and these native species may not become established quickly enough to prevent invasion by exotics.

A Request for Preliminary Determination to Alter Freshwater Wetlands will be required in order to implement a plant competition approach in Bowdish Lake, although if this approach is used in combination with other plant management approaches as part of a long-term solution, the required permitting efforts should be easily combined at little additional cost. Costs for implementing this approach will vary depending on the species and area being planted and are largely unknown, but estimates of more than $5,000 per acre would not be unexpected. Though it might be useful as a trial approach to determine the feasibility of establishing a viable native plant plot within the lake following treatment with herbicide to document the growth and expansion of a replacement plant community, plant competition is not recommended for widespread use in Bowdish Lake because of its high initial cost and the fact that it is still largely experimental and would most likely involve multiple years of ongoing labor to supplement native plants.

5.0 MONITORING PROGRAM

A cost-effective monitoring program would provide continuous background data for the purposed of tracking the effectiveness of any future management practices that may be implemented. Since water quality in Bowdish Lake currently meets state criteria, the water quality monitoring program should focus on tracking in-lake conditions during the peak growing season each year. This will allow quantification of the normal range of parameter values and recognition of any potentially detrimental shifts or trends. Phosphorus and nitrogen levels would be the key variables in this regard. Also, assessment of easily measured field parameters (pH, dissolved oxygen, temperatures, conductivity, turbidity, and clarity [Secchi depth]) would be beneficial. Evaluation of plant species density and distribution should be the focus of biological monitoring with particular focus on the distribution of exotic plant species.

Evaluating water quality and plant coverage trends requires several years of continuous data, often with multiple sample dates in each year. Evaluation of management techniques would be more immediate, allowing comparisons between pre- and post-management periods. It would seem most appropriate to collect a single sample from a central area of the lake's main basin in June and August to represent the period of greatest usage and potential impact. If funding were available, it would be useful to include investigative sampling to further characterize storm water and tributary inputs over time. Annual plant mapping should also be conducted, with particular attention to the growth and spread of nuisance and potential invasive species.

Components for a proposed monitoring plan for Bowdish Lake are outlined in Table 6. This program would cost approximately $5,000 per year including water quality and plant community assessment along with a review of data by a qualified expert. Some cost savings in the annual data collection can be achieved if participation in the URIWW program is continued. Currently, this program requires volunteer participation for most field sample collection but costs approximately $600 per year. However, data generated through participation in the program is limited for lake management purposes since it focuses mainly on in-lake water quality. The value of these data would be improved by including tributary water quality and measuring discharge during water quality sampling efforts so that pollutant loading estimates could be made.

Monitoring of plant cover in the lake should be performed on an annual basis in order to track expansion of variable-leaf milfoil and fanwort as well as to support early detection of any new aquatic invasive species that may spread into Bowdish Lake. Plant monitoring also allows evaluations of implemented management actions to be made and strategies adjusted, as necessary.

If drawdown is continued as part of the management strategy at Bowdish Lake, additional biological monitoring components (e.g., freshwater mussels, wetland vegetation plots, fish surveys, amphibian surveys, etc.) may need to be added to the annual program.

6.0 SUMMARY OF MANAGEMENT RECOMMENDATIONS

The most critical management action identified through this study is the need to address invasive aquatic weed growth, particularly the extremely dense variable leaf milfoil present throughout much of the lake. In addition, the recently introduced exotic plant known as fanwort is present with very limited distribution and this should be managed immediately. Water quality was not a primary concern of lake stakeholders, but should not be overlooked when it comes to developing a comprehensive lake management program.

To address water quality issues in the watershed ESS recommends:

1. Implement an education program focused on teaching watershed residents, particularly those living close to Bowdish Lake and the other ponds in its watershed, about the benefits of proper yard care (fertilization being a key focus), pet waste management, and other small behavioral changes they can adopt to make improvements in the lake's water quality. Goose management will also be essential toward preventing a resident population of Canada geese from becoming established at Bowdish Lake. Education will be a primary means for accomplishing this objective as well.

   Educational costs can vary widely depending upon the level of implementation. A typical program focusing on the development of a watershed specific brochure focused on the above topics can be created specifically for Bowdish Lake's watershed residents for less than $3,000. Education materials could then be distributed by the Bowdish Lake Association or even used in the public school if presented properly with appropriate age-based messages. Some towns we have worked with have opted to distribute brochures with utility bills or other town mailings for very little additional cost. The 319 NPS Pollution grant program may be used to fund a portion of the costs for education as part of a comprehensive project to reduce NPS pollution within the watershed.

2. Additional safeguards for protecting future water quality can also be provided through improvements to the watershed's storm water infrastructure. The addition of storm water detention and infiltration facilities at key runoff locations could greatly reduce the phosphorus reaching the lake and would also be able to significantly reduce bacterial contamination as well. There are relatively few, if any storm water BMPs currently in the watershed, and those that do exist were designed to remove water from roadways quickly; however, the infrastructure could be upgraded by incorporating infiltrating chambers to the outflows or other LID features such as grassed swales, rain gardens, detention ponds, etc. Opportunities for enhancing storm water infiltration for developed properties in the watershed should be identified. A study to evaluate the watershed to identify the sites that may be superior candidates for retrofitting with LID or other storm water management techniques would be expected to cost on the order of $15,000 to $20,000.

Restoration of Bowdish Reservoir in a manner that is comprehensive and long lasting will require additional investment in priority management actions. Based on our findings in this study and on the previously reported management efforts in this regard, ESS is recommending the following actions be taken to address invasive plant management objectives:

1. Urgent action is required to eliminate fanwort from Bowdish Lake. Fanwort is currently becoming established in the immediate vicinity of the lake's floating wetland and in a small patch along its northern shoreline in the vicinity of the Bowdish Lake Campground (Figure 8). It cannot be stressed enough how important it will be to address this outbreak immediately. In its present distribution the fanwort is not more than an acre in total area and is only sparse to moderately dense. This condition lends itself quite readily to hand harvesting or DASH. Given the current limited extent of fanwort in Bowdish Lake, hand pulling of this species may be allowed by RIDEM under a Rule 6.0 exemption.

Likewise, because DASH can be performed without significant additional substrate disturbance, it may also be granted an exemption under Rule 6.0. However, prior to beginning a hand pulling or DASH program for fanwort, RIDEM should be contacted for more specific guidance on whether a wetland alteration permit would be needed. This can be accomplished by filing a Request for Regulatory Applicability with the Fresh Water Wetlands Program. The fee for filing this request is $150.

Costs for the immediate plan outlined above will be minimal compared with the potential costs should fanwort be allowed to overtake the lake as it likely will if left unmanaged. Fanwort is one of the more resistant plants when it comes to herbicide control, with the only option really being the herbicide fluridone (trade name Sonar). If fanwort is allowed to grow unchecked, the cost to treat Bowdish Lake at a later date with fluridone is likely to be on the order of $200,000, and may need to be repeated within 2 years. In contrast, the recommended approach of a hand or diver assisted harvesting program for fanwort, as discussed here, will likely be less than $15,000 to complete.

2. For variable leaf milfoil, herbicides are likely to be the most effective option available at Bowdish Lake over the short-term and are recommended as the most appropriate means by which to get the system back to a level where the invasive species can be managed through more sustainable options. Presently, the milfoil only occupies over 230 acres of the lake at varying densities. A lake-wide herbicide treatment program is recommended using the selective and systemic herbicide 2,4-D (trade name Navigate). This approach will minimize impacts to native and desirable plants while providing a longer lasting level of control. Re-growth of milfoil should be at reduced levels in subsequent years and follow-up treatment with 2,4-D may still be necessary depending upon the degree, however, it is fully expected that management of milfoil could shift to other control techniques such as DASH or even hand harvesting in subsequent years. Total costs for an initial herbicide treatment program which includes a full lake treatment with 2,4-D along with the necessary supporting investigations, permitting, and monitoring would be on the order of $120,000, but would be an essential component to restoring the lake's recreation value and habitat quality.

3. Benthic barriers can be used on a localized basis if herbicide use is not welcome or in critical areas that must remain weed free. Barrier material could be placed at the public beach for an estimated cost of between $10,000 and $20,000 depending upon the area to be managed. Barrier material could also be used to manage weeds in areas where herbicide treatment cannot be safely performed such as in the immediate vicinity of wells. Although permits are likely to be required, very little long-term environmental impact can be expected from such a management approach. This approach also does not address the weed issue on a basin-wide basis.

4. Winter lake level drawdown has been the active management approach used by the Lake Association for many years to manage nuisance weed growth. It can be very effective for controlling milfoil if performed correctly, but based on ESS's understanding of the program that has been performed most recently, the approach is not ideally suited to Bowdish Lake and the results confirm this. ESS is recommending that if weed management is to move forward using a winter drawdown as the primary approach, the drawdown should be properly designed and implemented to provide the greatest impact on the milfoil and the least impact on native species of plants and wildlife.

Drawdowns are often perceived to be "free" and to have little or no environmental impacts; however, this is often not the case. Furthermore, drawdown will never be able to control milfoil in the deeper areas of the lake unless the lake is fully drained. "Extreme" drawdowns conducted at Bowdish Lake prior to state ownership of the dam were implemented to address shoreline protection and flood control issues and not specifically for aquatic weed control. Current environmental protection requirements (state and federal) would generally prohibit such an action due to the negative impacts on fish and wildlife as well as to the hydrologically connected wetlands.

If done correctly, drawdowns typically require some level of assessment of the baseline conditions, such as provided in this Lake Management Plan, as well as some drawdown specific assessments and calculations. ESS is recommending that a drawdown feasibility study be performed to address some of the outstanding issues and to develop the necessary Drawdown Operations Plan, inclusive of all hydrologic calculations.

Cost to perform a drawdown feasibility study and develop a Drawdown Operations Plan, given that a substantial amount of information is now available in this Lake Management Plan, are expected to be on the order of $8,000. Once completed, this information can then be used to file a Request for a Preliminary Determination to determine whether the drawdown, as proposed, represents a significant alteration to the freshwater wetland. It is quite possible that once the necessary data is made available, this will be the only permitting required. The cost for filing this permit application is likely to range between $1,000 and $3,000, including fees. If a full Application to Alter a Freshwater Wetland is deemed necessary, the cost for permitting would require an additional $6,000 to $10,000. It is also likely that a monitoring program will be required as a permit condition, which could cost on the order of $5,000 per year to execute.

In order to restore Bowdish Lake in a manner that is comprehensive and will be long-lasting the cost will be significant. However, with proper planning and by being ready to take advantage of funding opportunities as they arise, it can be done in a reasonable amount of time. Initial actions to address the recent infestation by fanwort should be implemented immediately, while action targeting the widespread growth of variable leaf milfoil is less urgent since it has already spread throughout much of the lake. Given the extensive costs associated with implementing the recommended long term program for full control of the milfoil problem in the lake through herbicides and diver assisted harvesting, it is likely that interim measures will be required in order to meet the short-term objectives of keeping the lake safe for recreational use and maintain a level of quality with regard to aquatic habitat value. It is recommended that the drawdown program be continued for the near-term, assuming that the required permits can be obtained.

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8.0 GLOSSARY OF LIMNOLOGICAL TERMS

Abiotic: A term that refers to the nonliving components of an ecosystem (e.g., sunlight, physical and chemical characteristics).

Algae: Typically microscopic plants that may occur as single-celled organisms, colonies or filaments.

Anoxic: Greatly deficient in oxygen.

Aquifer: A water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring.

Aquatic plants: A term used to describe a broad group of plants typically found growing in water bodies. The term may generally refer to both algae and macrophytes, but is commonly used synonymously with the term macrophyte.

Bacteria: Typically single celled microorganisms that have no chlorophyll, multiply by simple division, and occur in various forms. Some bacteria may cause disease, but many do not and are necessary for fermentation, nitrogen fixation, and decomposition of organic matter.

Bathymetric Map: A map illustrating the bottom contours (topography) and depth of a lake or pond.

Best Management Practices: Any of a number of practices or treatment devices that reduce pollution in runoff via runoff treatment or source control.

Biomass: A term that refers to the weight of biological matter. Standing crop is the amount of biomass (e.g., fish or algae) in a body of water at a given time. Biomass is often measured in grams per square meter of surface.

Biota: All living organisms in a given area.

Cultural Eutrophication: The acceleration of the natural eutrophication process caused by human activities, occurring over decades as opposed to thousands of years.

***E. coli* Bacteria:** Found naturally in the intestinal tracts of warm blooded animals, high levels of this bacteria in water or sludge is an indicator of pollution and possible contamination by pathogens.

Ecosystem: An interactive community of living organisms, together with the physical and chemical environment they inhabit.

Endangered/Threatened Species: An animal or plant species that is in danger of extinction that is recognized and protected by state or federal agencies.

Erosion: A process of breakdown and movement of land surface that is often intensified by human disturbances.

Eutrophic: A trophic state (degree of eutrophication) in which a lake or pond is nutrient rich and sustains high levels of biological productivity. Dense macrophyte growth, fast sediment accumulation, frequent algae blooms, poor water transparency and periodic oxygen depletion in the hypolimnion are common characteristics of eutrophic lakes and ponds.

Eutrophication: The process, or set of processes, driven by nutrient, organic matter, and sediment addition to a pond that leads to increased biological production and decreased volume. The process occurs naturally in all lakes and ponds over thousands of years.

Exotic Species: Species of plants or animals that occur outside of their normal, indigenous ranges and environments. Populations of exotic species may expand rapidly and displace native populations if natural predators are absent or if conditions are more favorable for the exotics growth than for native species.

Filamentous: A term used to refer to a type of algae that forms long filaments composed of individual cells.

Groundwater: Water found beneath the soil surface and saturating the layer at which it is located.

Habitat: The natural dwelling place of an animal or plant; the type of environment where a particular species is likely to be found.

Herbicide: Any of a class of compounds that produce mortality in plants when applied in sufficient concentrations.

Infiltration Structures: Any of a number of structures used to treat runoff quality or control runoff quantity by infiltrating runoff into the ground. Includes infiltration trenches, dry wells, infiltration basins, and leaching catch basins.

Invasive: Spreading aggressively from the original site of planting.

Isopach Map: A map illustrating the depth of sediments within a lake or pond.

Limnology: The study of lakes.

Littoral Zone: The shallow, highly productive area along the shoreline of a lake or pond where rooted aquatic plants grow.

Macroinvertebrates: Aquatic insects, worms, clams, snails and other animals visible without aid of a microscope that may be associated with or live on substrates such as sediments and macrophytes. They supply a major portion of fish diets and consume detritus and algae.

Macrophytes: Macroscopic vascular plants present in the littoral zone of lakes and ponds.

Morphometry: A term that refers to the depth contours and dimensions (topographic features) of a lake or pond.

Nonpoint Source: A source of pollutants to the environment that does not come from a confined, definable source such as a pipe. Common examples of non-point source pollution include urban runoff, septic system leachate, and runoff from agricultural fields.

Nutrient Limitation: The limitation of growth imposed by the depletion of an essential nutrient.

Nutrients: Elements or chemicals required to sustain life, including carbon, oxygen, nitrogen and phosphorus.

pH: An index derived from the inverse log of the hydrogen ion concentration that ranges from zero to 14 indicating the relative acidity or alkalinity of a liquid.

Photosynthesis: The process by which plants use chlorophyll to convert carbon dioxide, water and sunlight to oxygen and cellular products (carbohydrates).

Phytoplankton: Algae that float or are freely suspended in the water.

Pollutants: Elements and compounds occurring naturally or man-made introduced into the environment at levels in excess of the concentration of chemicals naturally occurring.

Secchi disk: A black and white or all white 20 cm disk attached to a cord used to measure water transparency. The disk is lowered into the water until it is no longer visible (Secchi depth). Secchi depth is generally proportional to the depth of light penetration sufficient to sustain algae growth.

Seepage meter: A device used to measure the groundwater volume entering a lake, pond or stream over time.

Sediment: Topsoil, sand, and minerals washed from the land into water, usually after rain or snowmelt.

Septic system: An individual wastewater treatment system that includes a septic tank for removing solids, and a leachfield for discharging the clarified wastewater to the ground.

Septic System Leachate: The clarified wastewater discharged into the ground from a septic system.

Siltation: The process in which inorganic silt settles and accumulates at the bottom of a lake or pond.

Stormwater Runoff: Runoff generated as a result of precipitation or snowmelt.

Temperature Profile: A series of temperature measurements collected at incremental water depths from surface to bottom at a given location.

Thermal Stratification: The process by which a lake or pond forms several distinct thermal layers. The layers include a warmer well-mixed upper layer (epilimnion), a cooler, poorly mixed layer at the bottom (hypolimnion), and a middle layer (metalimnion) that separates the two.

Thermocline: A term that refers to the plane of greatest temperature change within the metalimnion. Often used interchangeably with metalimnion.

TKN: Total Kjeldahl nitrogen, essentially the sum of ammonia nitrogen and organic forms of nitrogen.

TSS: Total suspended solids, a direct measure of all suspended solid materials in the water.

Turbidity: A measure of the light scattering properties of water; often used more generally to describe water clarity or the relative presence or absence of suspended materials in the water.

Vegetated Buffer: An undisturbed vegetated land area that separates an area of human activity from the adjacent water body; can be effective in reducing runoff velocities and volumes and the removal of sediment and pollutant from runoff.

Water Column: Water in a lake or pond between the interface with the atmosphere at the surface and the interface with the sediment at the bottom.

Water Quality: A term used to reference the general chemical and physical properties of water relative to the requirements of living organisms that depend upon that water.

Watershed: The surrounding land area that drains into a water body via surface runoff or groundwater recharge and discharge.

Zooplankton: Microscopic animals that float or are freely suspended in the water.

Tables

Table 1. Land Use in the Bowdish Lake Watershed, 2003/2004.

Class	Subclass	Area (Acres)	Area (%)
Agriculture	Groves/Cropland	5	0.28
Agriculture	Idle Agriculture	3	0.15
Agriculture	Pasture	7	0.36
Barren		2	0.09
Forest*		1355	70.88
Mines		0	0.00
Recreation	Other	1	0.06
Recreation	Beach	2	0.08
Recreation	Bowdish Lake Camping Area	101	5.29
Tranportation, Utilities, Communications		0	0.00
Urban or Built up	Residential	105	5.49
Urban or Built up	Commerical	6	0.29
Water		323	16.87
Wetland		3	0.15
Total		1912	100.00

*Forest land use total includes forested wetland in 2003/2004 dataset

Table 2. Historic Land Use in the Bowdish Lake Watershed, 1988

Class	Subclass	Area (Acres)	Area (%)
Agriculture	Groves/Cropland	2	0.10
Agriculture	Idle Agriculture	4	0.21
Agriculture	Pasture	8	0.42
Barren		0	0.00
Forest		1194	62.44
Mines		2	0.12
Recreation		0	0.00
Recreation	Beach	0	0.00
Recreation	Bowdish Lake Camping Area	115	6.01
Tranportation, Utilities, Communications		8	0.42
Urban or Built up		91	4.76
Water		316	16.52
Wetland		172	8.99
Total		1912	100.00

Table 3. Summary of Soils in the Bowdish Lake Watershed

Soil Map Unit	Soil Name	Hydrologic Group	Area (Acres)	Area (%)
Aa	Adrian muck	A/D	37	1.95
CaC	Canton-Charlton-Rock outcrop complex	D	7	0.37
CaD	Canton-Charlton-Rock outcrop complex	D	55	2.85
CdA	Canton and Charlton fine sandy loams	B	7	0.35
CdB	Canton and Charlton fine sandy loams	B	3	0.14
CeC	Canton and Charlton very fine sandy loams	B	550	28.77
ChB	Canton and Charlton very stony fine sandy loams	B	108	5.66
ChC	Canton and Charlton very stony fine sandy loams	B	140	7.31
ChD	Canton and Charlton very stony fine sandy loams	B	7	0.38
CkC	Canton and Charlton extremely stony fine sandy loam	B	169	8.82
Co	Carlisle muck	A/D	89	4.67
HkC	Hinkley gravelly sandy loam	A	135	7.06
HkD	Hinkley gravelly sandy loam	A	12	0.65
Rf	Ridgebury, Whitman, and Leicester	C	157	8.22
Rk	Rock outcrop	D	1	0.03
Sb	Scarboro muck	D	5	0.26
SuB	Sutton fine sandy loam	B	51	2.66
SvB	Sutton extremely stony loam	B	78	4.07
UD	Udorthents-Urban land complex	-	1	0.07
W	Water	-	300	15.70

Table 4. Summary of Recent and Historical Water Quality Data for Bowdish Lake

Date	Dissolved Phosphorus (mg/L)	Total Phosphorus (mg/L)	Secchi Depth (m)	Chlorophyll a (ug/L)	Enterococci (MPN/100mL)	pH (SU)	Alkalinity (mg/L $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Calcium (mg/L)
8/1988[1]	NS	0.02	NS	0.7	NS	6.4	NS	7	1.9
10/1988[1]	NS	0.03	NS	0.4	NS	5.3	NS	8	2.1
5/2006[2]	ND	0.011	2.7	1.7	0.1	5.3	0.5	NS	NS
7/2006[2]	ND	ND	2.9	2.0	0.1	6.3	3.1	NS	NS
10/1/2006[2]	ND	0.007	2.5	5.0	0	NS	NS	NS	NS
5/2007[2]	ND	0.006	2.5	NS	3.1	5.9	0.8	NS	NS
7/2007[2]	0.004	0.012	2.5	NS	<1	6.1	2.2	NS	NS
9/2007[2]	0.014	0.010	2.3	NS	1	6.2	1.1	NS	NS
5/2008[2]	0.026	0.017	2.4	2.0	NS	NS	NS	NS	NS
7/2008[2]	0.005	0.007	2.7	33.9	0	NS	NS	NS	NS
8/2008[2]	NS	NS	2.8	2.1	NS	NS	NS	NS	NS
9/2008[2]	ND	0.004	3.6	2	0	NS	NS	NS	NS

Source: 1. US Geological Survey, 1988; 2. University of Rhode Island Watershed Watch, 2006-2008

NS = Not sampled

ND = Not detected

Table 5. Summary of Water Bodies Located Upstream and Downstream of Bowdish Lake*

Location	Name
Upstream	7 Unnamed Tributaries
	Lake Washington
	Wilbur Pond
Downstream	Unnamed Outlet Stream
	Unnamed Impoundment (Sawmill Pond)
	Clarkville Pond
	Hawkins Pond
	Mary Brown Brook
	Mary Brown Pond
	Fivemile River (Connecticut)

*Based on USGS 7.5 minute topos

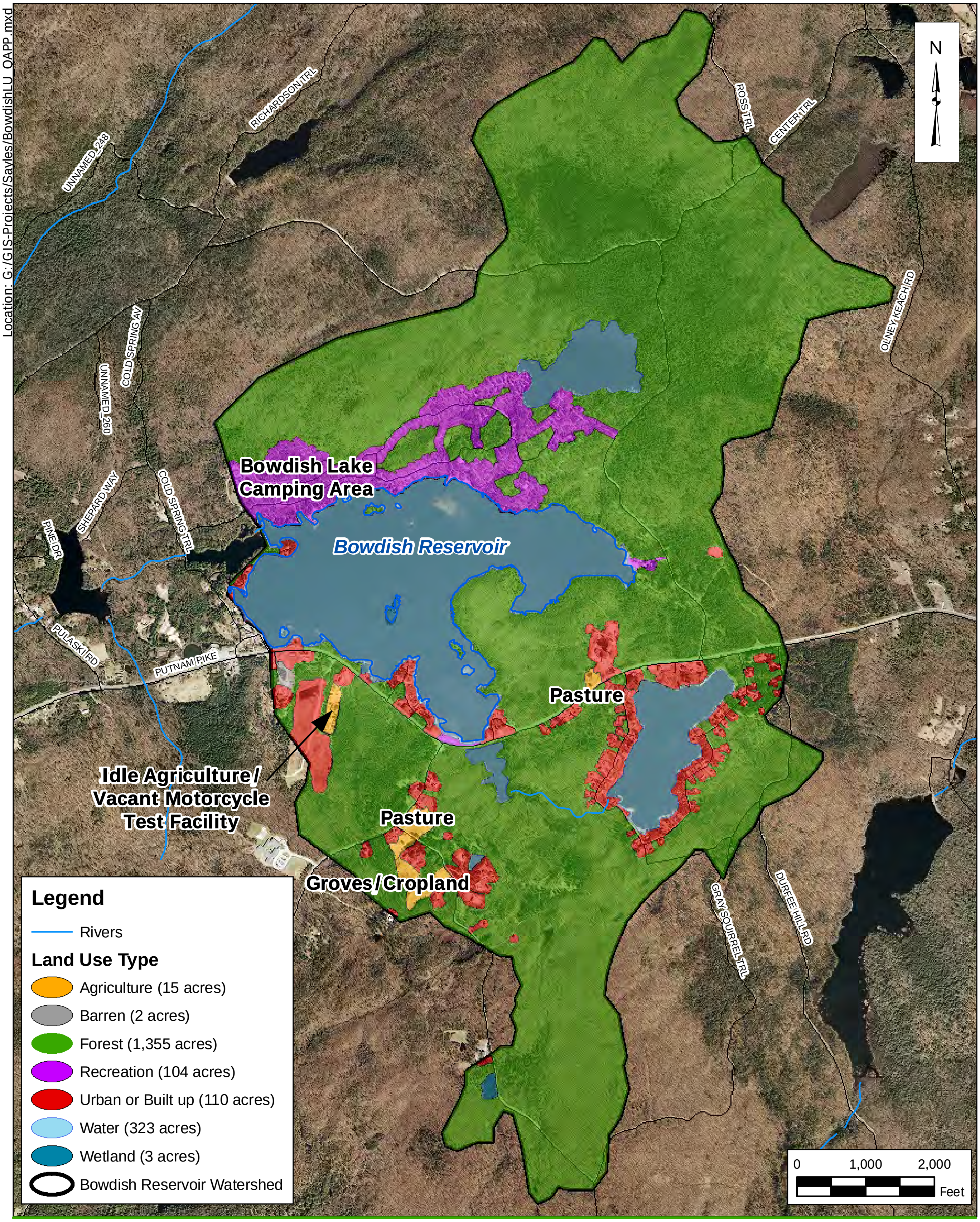
Table 6. Proposed Monitoring Program Elements for Bowdish Lake

Monitoring Parameter	Target	Location(s)	Minimum Frequency/ Timing
Plant Cover/Biovolume	Nuisance aquatic weed growth	In-lake	Annually (June)
Secchi Depth	Water clarity	In-lake	Biannually (June/August)
Temperature	Aquatic life	In-lake, selected tributaries	Biannually (June/August)
Dissolved Oxygen	Aquatic life	In-lake, selected tributaries	Biannually (June/August)
pH	Aquatic life	In-lake, selected tributaries	Biannually (June/August)
Specific Conductance	Dissolved pollutants	In-lake, selected tributaries	Biannually (June/August)
Turbidity	Water clarity	In-lake, selected tributaries	Biannually (June/August)
Chlorophyll a	Water clarity	In-lake	Biannually (June/August)
Total Phosphorus	Fertility	In-lake, selected tributaries	Biannually (June/August)
Dissolved Phosphorus	Fertility	In-lake, selected tributaries	Biannually (June/August)
Total Nitrogen	Fertility	In-lake, selected tributaries	Biannually (June/August)
Wetland Vegetation*	Hydrology/wetlands	Shoreline/connected wetlands	Annually (Summer)
Erosion*	Shoreline/bank stability	Shoreline/outlet stream	Annually (Spring/Summer)
Benthic Macroinvertebrates*	Aquatic life	In-lake	Annually (Summer [general] and/or Autumn [mussel surveys])
Amphibians*	Aquatic life	Shoreline/connected wetlands	Annually (Spring)
Fish*	Aquatic life	In-lake	Every two to three years (Late Summer or Winter)

*These monitoring parameters may be required for drawdown actions. The scope, frequency, or timing of each is preliminary and should be finalized in an approved Drawdown Operations Plan.

Figures

Location: G:/GIS-Projects/Sayles/BowdishLU_QAPP.mxd



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BOWDISH RESERVOIR
Glocester, Rhode Island

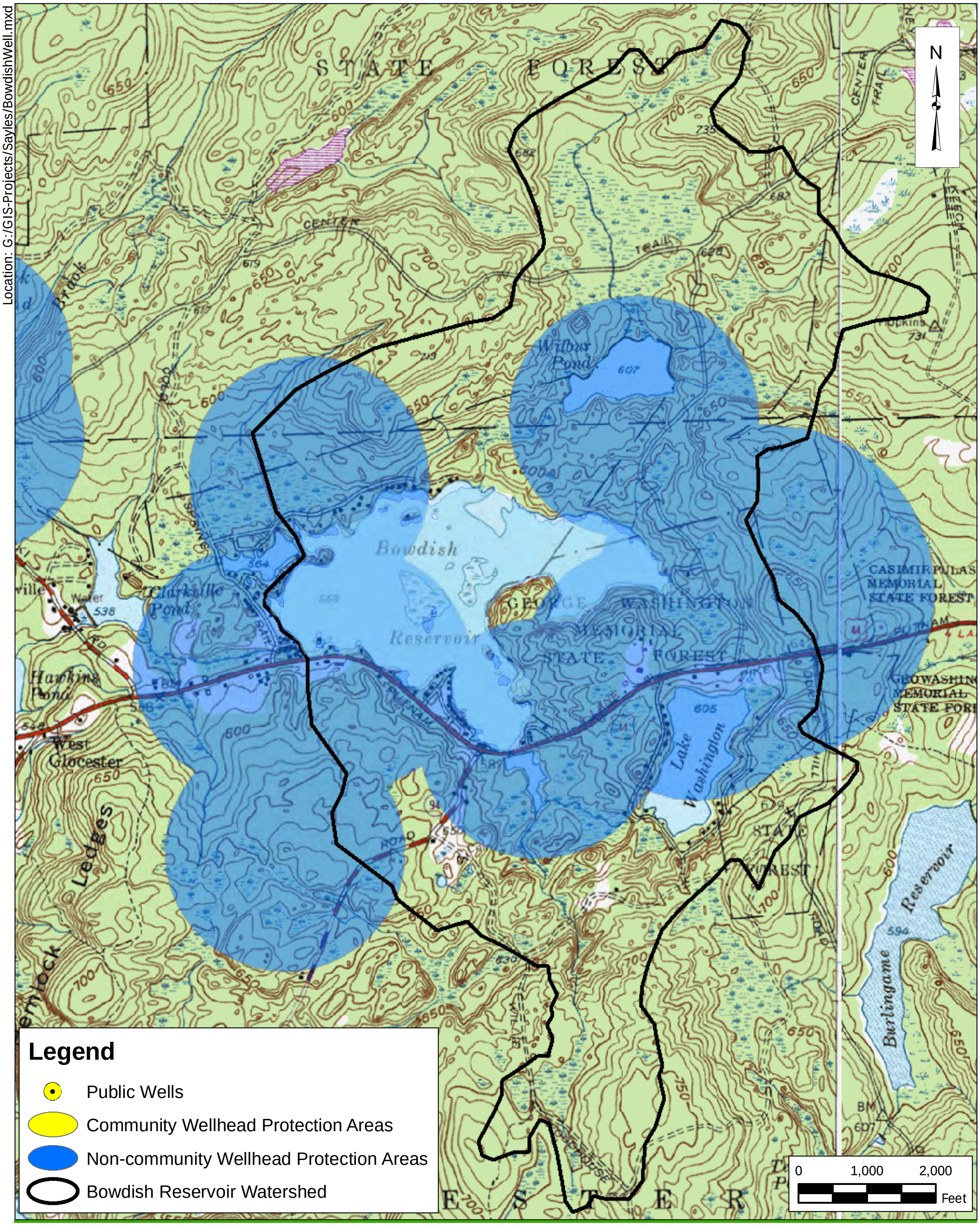
Scale: 1" = 2,000'

Source: 1) RIGIS, Orthos, 2004
2) RIGIS, Land Use 2003/2004

Bowdish Reservoir Watershed
Land Use

Figure 1

Location: G:/GIS-Projects/Sayles/BowdishWell.mxd



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Glocester, Rhode Island

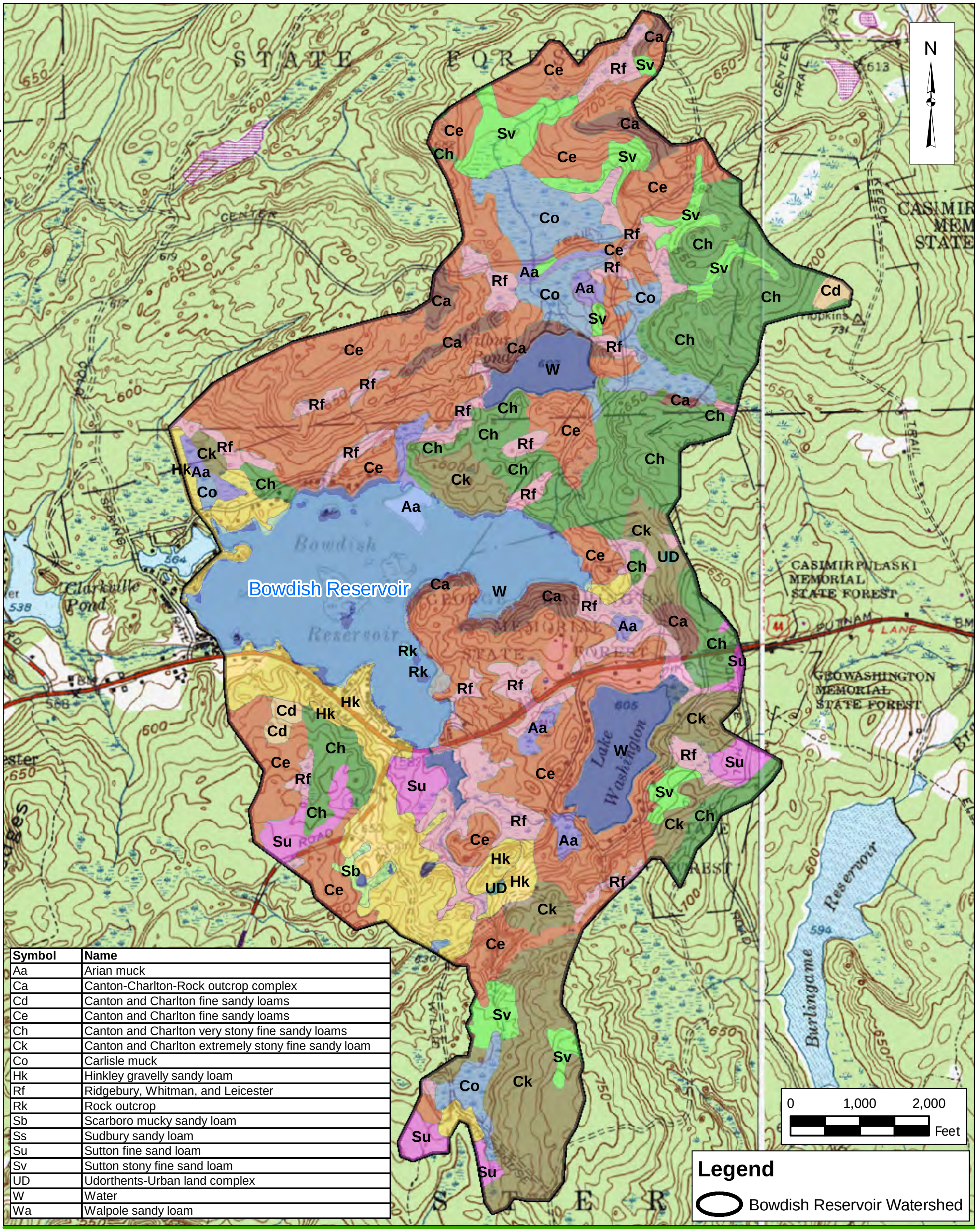
Scale: 1" = 2,000'

Source: 1) RIGIS, USGS Thompson and Chepachet quads, 1975
2) RIGIS, Wellhead Protection Areas, 2005

Bowdish Reservoir Watershed
Wellhead Protection Areas

Figure 2

Location: G:/GIS-Projects/Sayles/BowdishSoil.mxd



Symbol	Name
Aa	Arian muck
Ca	Canton-Charlton-Rock outcrop complex
Cd	Canton and Charlton fine sandy loams
Ce	Canton and Charlton fine sandy loams
Ch	Canton and Charlton very stony fine sandy loams
Ck	Canton and Charlton extremely stony fine sandy loam
Co	Carlisle muck
Hk	Hinkley gravelly sandy loam
Rf	Ridgebury, Whitman, and Leicester
Rk	Rock outcrop
Sb	Scarboro mucky sandy loam
Ss	Sudbury sandy loam
Su	Sutton fine sand loam
Sv	Sutton stony fine sand loam
UD	Udorthents-Urban land complex
W	Water
Wa	Walpole sandy loam

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Glocester, Rhode Island

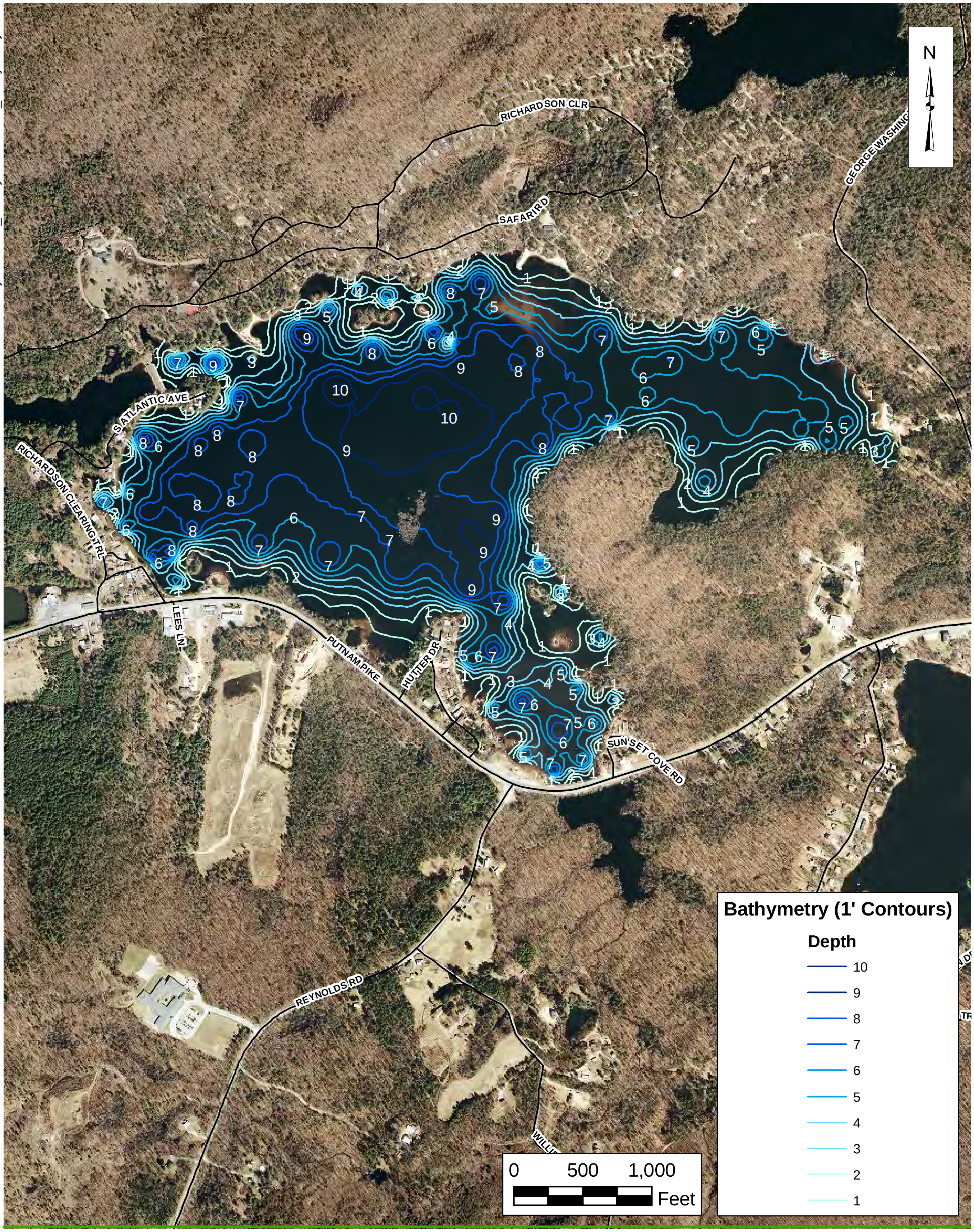
Scale: 1" = 2,000'

Source: 1) RIGIS, USGS Thompson and Chepachet quads, 1975
2) SSURGO Soil Data, 2008

Bowdish Reservoir Watershed
Soil Types

Figure
3

Location: G:/GIS-Projects/Data_RI/Sayles/Bowdish_Bathymetry.mxd



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Glocester, Rhode Island

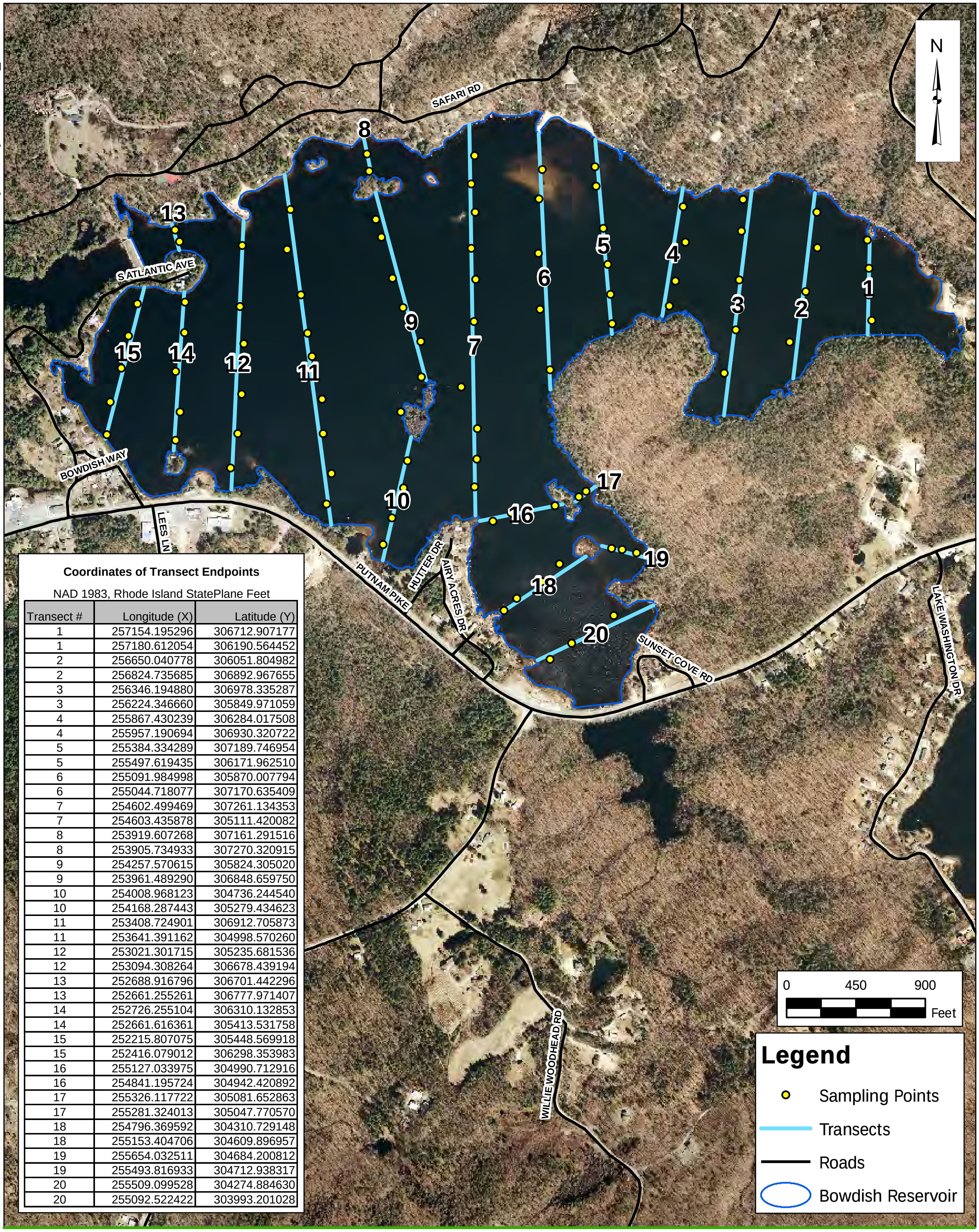
Scale: 1" = 1,000'

Source: 1) USDA, Bathymetry Data, 2009
2) RIGIS, Orthos, 2005; 3) RIGIS, Roads, 1997

Bathymetry of Bowdish Reservoir

Figure 4

Location: G:/GIS-Projects/Sayles/Bowdish_Field.mxd



Coordinates of Transect Endpoints

NAD 1983, Rhode Island StatePlane Feet

Transect #	Longitude (X)	Latitude (Y)
1	257154.195296	306712.907177
1	257180.612054	306190.564452
2	256650.040778	306051.804982
2	256824.735685	306892.967655
3	256346.194880	306978.335287
3	256224.346660	305849.971059
4	255867.430239	306284.017508
4	255957.190694	306930.320722
5	255384.334289	307189.746954
5	255497.619435	306171.962510
6	255091.984998	305870.007794
6	255044.718077	307170.635409
7	254602.499469	307261.134353
7	254603.435878	305111.420082
8	253919.607268	307161.291516
8	253905.734933	307270.320915
9	254257.570615	305824.305020
9	253961.489290	306848.659750
10	254008.968123	304736.244540
10	254168.287443	305279.434623
11	253408.724901	306912.705873
11	253641.391162	304998.570260
12	253021.301715	305235.681536
12	253094.308264	306678.439194
13	252688.916796	306701.442296
13	252661.255261	306777.971407
14	252726.255104	306310.132853
14	252661.616361	305413.531758
15	252215.807075	305448.569918
15	252416.079012	306298.353983
16	255127.033975	304990.712916
16	254841.195724	304942.420892
17	255326.117722	305081.652863
17	255281.324013	305047.770570
18	254796.369592	304310.729148
18	255153.404706	304609.896957
19	255654.032511	304684.200812
19	255493.816933	304712.938317
20	255509.099528	304274.884630
20	255092.522422	303993.201028

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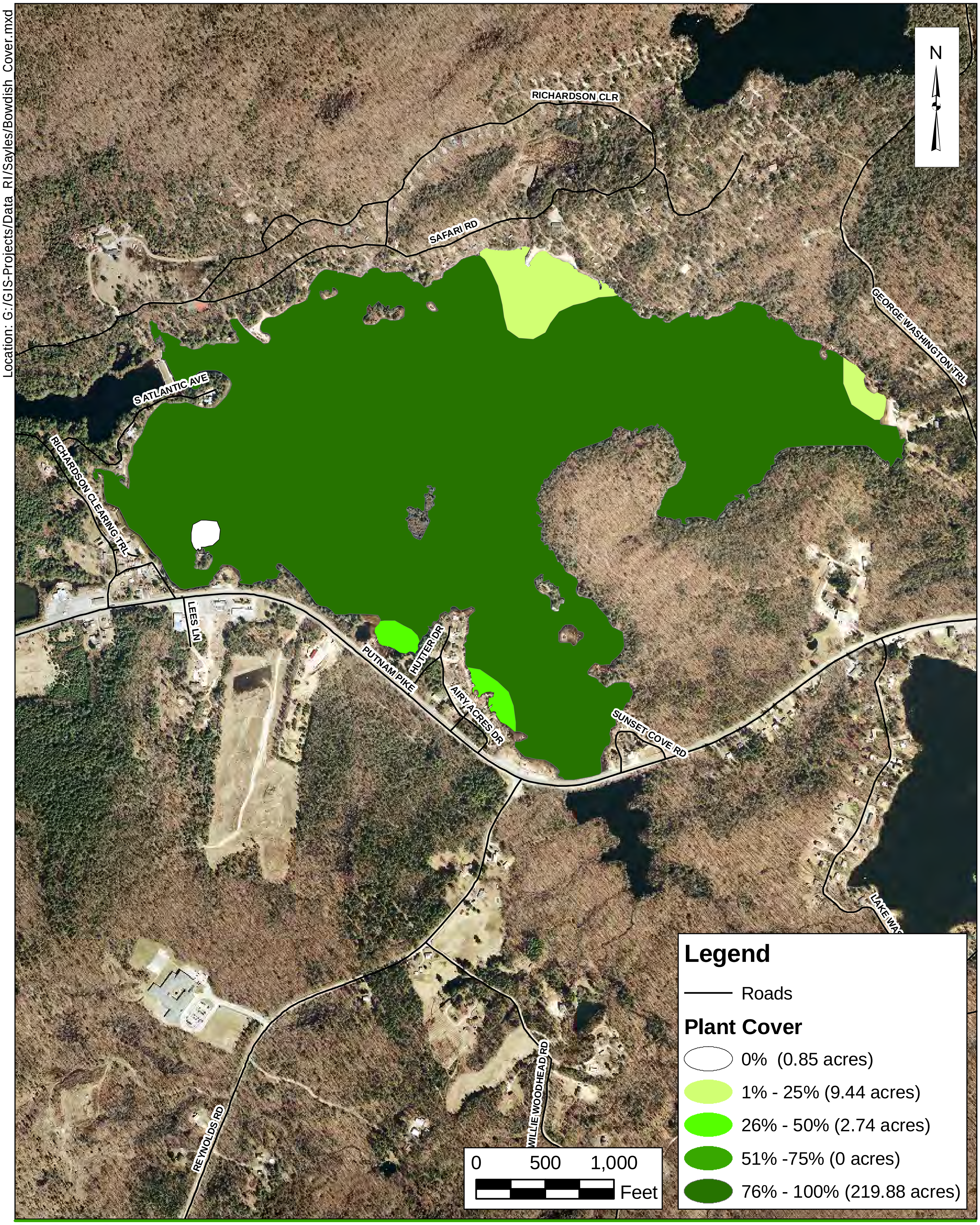
Scale: 1" = 900'

Source: 1) ESS, 2009
2) RIGIS, Orthos, 2004
3) RIGIS, Roads, 1997

Plant Mapping Transects

Figure 5

Location: G:/GIS-Projects/Data RI/Sayles/Bowdish Cover.mxd



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BOWDISH RESERVOIR
Glocester, Rhode Island

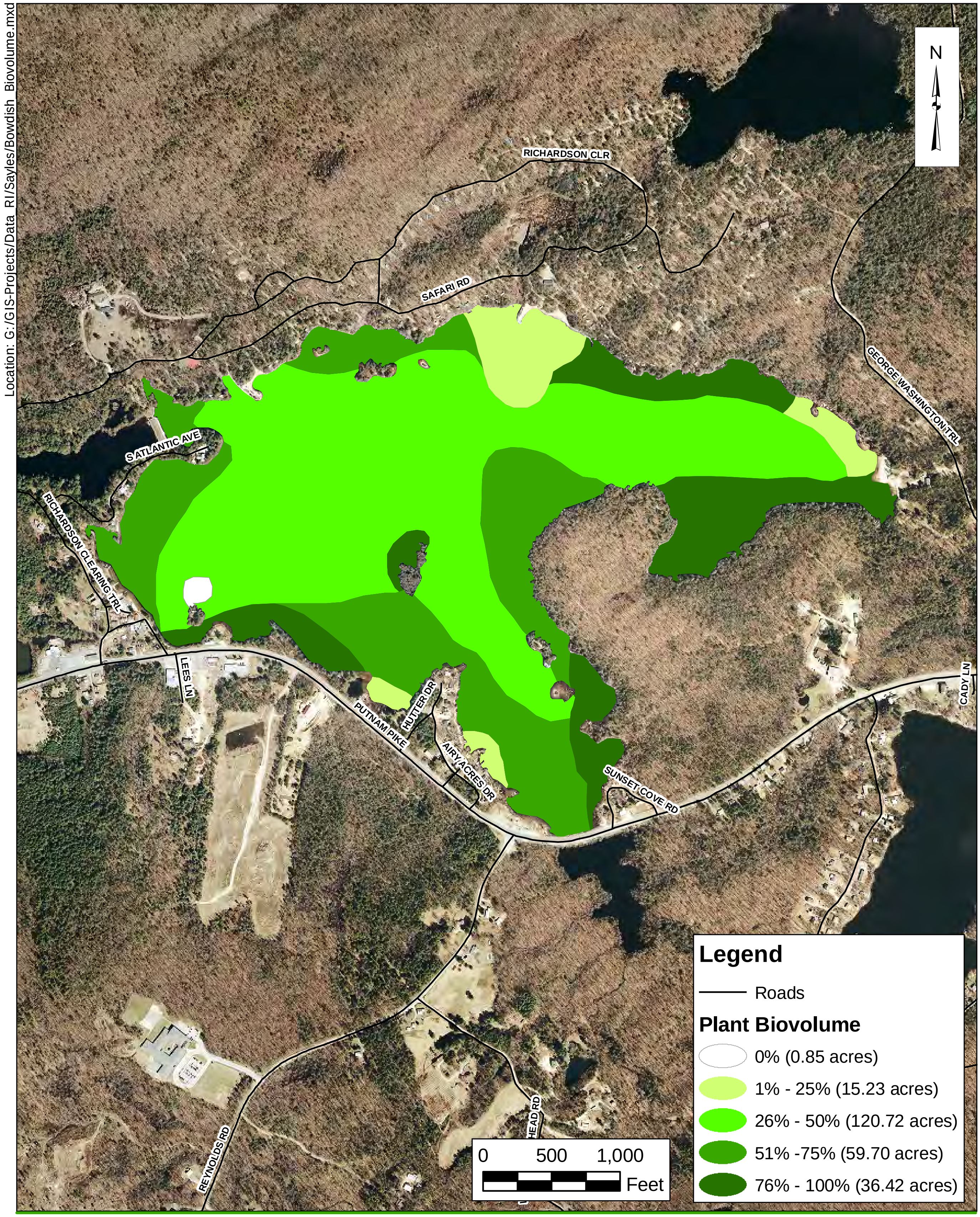
Survey Conducted on August 19 & 21, 2009

Scale: 1" = 1,000'

Source: 1) ESS, Plant Data, 2009
2) RIGIS, Orthos, 2004; 3) RIGIS, Roads, 1997

Plant Cover

Figure 6



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Glocester, Rhode Island

Survey Conducted on August 19 & 21, 2009

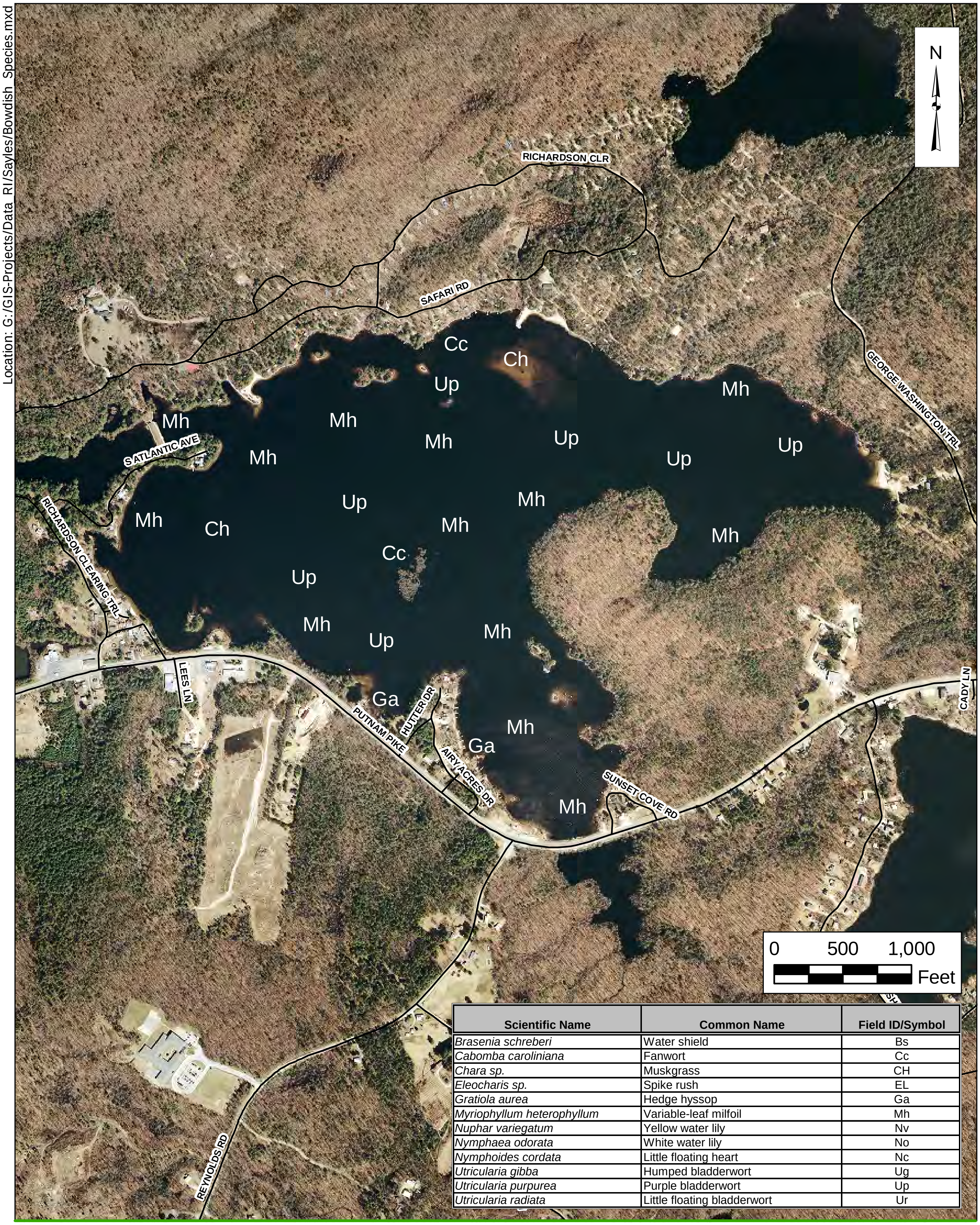
Scale: 1" = 1,000'

Source: 1) ESS, Plant Data, 2009
2) RIGIS, Orthos, 2004; 3) RIGIS, Roads, 1997

Plant Biovolume

Figure 7

Location: G:/GIS-Projects/Data RI/Sayles/Bowdish Species.mxd



Scientific Name	Common Name	Field ID/Symbol
Brasenia schreberi	Water shield	Bs
Cabomba caroliniana	Fanwort	Cc
Chara sp.	Muskgrass	CH
Eleocharis sp.	Spike rush	EL
Gratiola aurea	Hedge hyssop	Ga
Myriophyllum heterophyllum	Variable-leaf milfoil	Mh
Nuphar variegatum	Yellow water lily	Nv
Nymphaea odorata	White water lily	No
Nymphoides cordata	Little floating heart	Nc
Utricularia gibba	Humped bladderwort	Ug
Utricularia purpurea	Purple bladderwort	Up
Utricularia radiata	Little floating bladderwort	Ur

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Glocester, Rhode Island

Survey Conducted on August 19 & 21, 2009

Scale: 1" = 1,000'

Source: 1) ESS, Plant Data, 2009
2) RIGIS, Orthos, 2004; 3) RIGIS, Roads, 1997

Plant Species

Figure 8

Appendix A

Selected Existing Water Quality Data

Date of Sample	Station Number	Parameter Name	Concentration	Unit Code	Detection Limit	Depth (m)	Site Name
5/21/06	WW135	Secchi Depth	2.65	m	0.1		Bowdish Reservoir
5/21/06	WW135	Temperature	16.9	C	0	1	Bowdish Reservoir
5/21/06	WW135	Chlorophyll a (digital)	1.7	ug/l	0.1	1	Bowdish Reservoir
5/21/06	WW135	Alkalinity	**0.5**	mg/L	0.2	1	Bowdish Reservoir
5/21/06	WW135	Chloride	**24**	mg/l	3	1	Bowdish Reservoir
5/21/06	WW135	Enterococci	**0.1**	MPN/100	1	0.5	Bowdish Reservoir
5/21/06	WW135	Nitrogen, Ammonia Dissolved as N	**40**	ug/l	30	1	Bowdish Reservoir
5/21/06	WW135	Nitrate + Nitrite, Dissolved	**20**	ug/l	40	1	Bowdish Reservoir
5/21/06	WW135	Nitrogen, Total	**250**	ug/l	40	1	Bowdish Reservoir
5/21/06	WW135	pH	**5.3**	S.U.	0.2	1	Bowdish Reservoir
5/21/06	WW135	Phosphorus, Dissolved	**2**	ug/l	4	1	Bowdish Reservoir
5/21/06	WW135	Phosphorus, Total	**11**	ug/l	4	1	Bowdish Reservoir
7/1/06	WW135	Secchi Depth	2.875	m	0.1		Bowdish Reservoir
7/1/06	WW135	Temperature	25.9	C	0	1	Bowdish Reservoir
7/1/06	WW135	Chlorophyll a (digital)	1.9	ug/l	0.1	1	Bowdish Reservoir
7/15/06	WW135	Secchi Depth	2.9	m	0.1		Bowdish Reservoir
7/15/06	WW135	Temperature	27.3	C	0	1	Bowdish Reservoir
7/15/06	WW135	Chlorophyll a (digital)	1.9	ug/l	0.1	1	Bowdish Reservoir
7/28/06	WW135	Secchi Depth	2.9	m	0.1		Bowdish Reservoir
7/28/06	WW135	Temperature	29.2	C	0	1	Bowdish Reservoir
7/28/06	WW135	Chlorophyll a (digital)	2.0	ug/l	0.1	1	Bowdish Reservoir
7/28/06	WW135	Alkalinity	**3.1**	mg/L	0.2	1	Bowdish Reservoir
7/28/06	WW135	Enterococci	**0.1**	MPN/100	1	0.5	Bowdish Reservoir
7/28/06	WW135	Nitrogen, Ammonia Dissolved as N	**15**	ug/l	30	1	Bowdish Reservoir
7/28/06	WW135	Nitrate + Nitrite, Dissolved	**20**	ug/l	40	1	Bowdish Reservoir
7/28/06	WW135	Nitrogen, Total	**280**	ug/l	40	1	Bowdish Reservoir
7/28/06	WW135	pH	**6.3**	S.U.	0.2	1	Bowdish Reservoir
7/28/06	WW135	Phosphorus, Dissolved	**2**	ug/l	4	1	Bowdish Reservoir
7/28/06	WW135	Phosphorus, Total	**2**	ug/l	3	1	Bowdish Reservoir
8/26/06	WW135	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
9/10/06	WW135	Secchi Depth	**2**	m	0.1		Bowdish Reservoir
9/10/06	WW135	Chlorophyll a (digital)	**1**	ug/l	0.1	1	Bowdish Reservoir
10/1/06	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
10/1/06	WW135	Temperature	**17**	C	0	1	Bowdish Reservoir
10/1/06	WW135	Chlorophyll a (digital)	**5**	ug/l	0.1	1	Bowdish Reservoir
10/1/06	WW135	Enterococci	**0**	MPN/100	1	0.5	Bowdish Reservoir
10/1/06	WW135	Nitrogen, Ammonia Dissolved as N	**15**	ug/l	30	1	Bowdish Reservoir
10/1/06	WW135	Nitrate + Nitrite, Dissolved	**20**	ug/l	40	1	Bowdish Reservoir
10/1/06	WW135	Nitrogen, Total	**230**	ug/l	40	1	Bowdish Reservoir
10/1/06	WW135	Phosphorus, Dissolved	**2**	ug/l	4	1	Bowdish Reservoir
10/1/06	WW135	Phosphorus, Total	**7**	ug/l	4	1	Bowdish Reservoir
5/12/07	WW135	Alkalinity	**1**	mg/L	0.2	1	Bowdish Reservoir
5/12/07	WW135	Chloride	**21**	mg/l	1	1	Bowdish Reservoir
5/12/07	WW135	Enterococci	**3**	MPN/100	1	0.5	Bowdish Reservoir
5/12/07	WW135	Nitrogen, Ammonia Dissolved as N	**15**	ug/l	30	1	Bowdish Reservoir
5/12/07	WW135	Nitrate + Nitrite, Dissolved	**15**	ug/l	30	1	Bowdish Reservoir
5/12/07	WW135	Nitrogen, Total	**230**	ug/l	30	1	Bowdish Reservoir
5/12/07	WW135	pH	**6**	S.U.	1	1	Bowdish Reservoir
5/12/07	WW135	Phosphorus, Dissolved	**3**	ug/l	5	1	Bowdish Reservoir
5/12/07	WW135	Phosphorus, Total	**6**	ug/l	3	1	Bowdish Reservoir
5/12/07	WW135	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
5/12/07	WW135	Secchi Depth	**2**	m	0.1		Bowdish Reservoir
5/12/07	WW135	Temperature	**20**	C	0	1	Bowdish Reservoir
5/26/07	WW135	Chlorophyll a (digital)	**1**	ug/l	0.1	1	Bowdish Reservoir
5/26/07	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
5/26/07	WW135	Temperature	**23**	C	0	1	Bowdish Reservoir
6/23/07	WW135	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
6/23/07	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
6/23/07	WW135	Temperature	**22**	C	0	1	Bowdish Reservoir
7/7/07	WW135	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
7/7/07	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
7/7/07	WW135	Temperature	**24**	C	0	1	Bowdish Reservoir
7/21/07	WW135	Alkalinity	**2**	mg/L	0.2	1	Bowdish Reservoir
7/21/07	WW135	Enterococci	**0**	MPN/100	1	0.5	Bowdish Reservoir
7/21/07	WW135	Nitrogen, Ammonia Dissolved as N	**30**	ug/l	30	1	Bowdish Reservoir
7/21/07	WW135	Nitrate + Nitrite, Dissolved	**30**	ug/l	20	1	Bowdish Reservoir

Date of Sample	Station Number	Parameter Name	Concentration	Unit Code	Detection Limit	Depth (m)	Site Name
7/21/07	WW135	Nitrogen, Total	**370**	ug/l	30	1	Bowdish Reservoir
7/21/07	WW135	pH	**6**	S.U.	1	1	Bowdish Reservoir
7/21/07	WW135	Phosphorus, Dissolved	**4**	ug/l	5	1	Bowdish Reservoir
7/21/07	WW135	Phosphorus, Total	**12**	ug/l	3	1	Bowdish Reservoir
7/21/07	WW135	Chlorophyll a (digital)	**3**	ug/l	0.1	1	Bowdish Reservoir
7/21/07	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
7/21/07	WW135	Temperature	**25**	C	0	1	Bowdish Reservoir
8/19/07	WW135	Chlorophyll a (digital)	**4**	ug/l	0.1	1	Bowdish Reservoir
8/19/07	WW135	Secchi Depth	**2**	m	0.1		Bowdish Reservoir
8/19/07	WW135	Temperature	**24**	C	0	1	Bowdish Reservoir
9/2/07	WW135	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
9/2/07	WW135	Secchi Depth	**2**	m	0.1		Bowdish Reservoir
9/2/07	WW135	Temperature	**25**	C	0	1	Bowdish Reservoir
9/16/07	WW135	Chloride	**24**	mg/l	1	1	Bowdish Reservoir
9/16/07	WW135	Enterococci	**1**	MPN/100	1	0.5	Bowdish Reservoir
9/16/07	WW135	Nitrogen, Ammonia Dissolved as N	**30**	ug/l	30	1	Bowdish Reservoir
9/16/07	WW135	Nitrate + Nitrite, Dissolved	**30**	ug/l	20	1	Bowdish Reservoir
9/16/07	WW135	Nitrogen, Total	**310**	ug/l	30	1	Bowdish Reservoir
9/16/07	WW135	pH	**6**	S.U.	1	1	Bowdish Reservoir
9/16/07	WW135	Phosphorus, Dissolved	**14**	ug/l	5	1	Bowdish Reservoir
9/16/07	WW135	Phosphorus, Total	**10**	ug/l	3	1	Bowdish Reservoir
9/16/07	WW135	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
9/16/07	WW135	Secchi Depth	**2**	m	0.1		Bowdish Reservoir
9/16/07	WW135	Temperature	**21**	C	0	1	Bowdish Reservoir
10/1/07	WW135	Alkalinity	**1**	mg/L	0.2	1	Bowdish Reservoir
10/1/07	WW135	pH	**6**	S.U.	0.2	1	Bowdish Reservoir
5/10/08	WW135	Secchi Depth	**2**	m	0.1		Bowdish Reservoir
5/10/08	WW135	Temperature	**15**	C	0	1	Bowdish Reservoir
5/10/08	WW135	Chloride	**22**	mg/l	2	1	Bowdish Reservoir
5/10/08	WW135	Enterococci	**Not run**	MPN/100	1	0.5	Bowdish Reservoir
5/10/08	WW135	Nitrate + Nitrite, Dissolved	**<10**	ug/l	10	1	Bowdish Reservoir
5/10/08	WW135	Nitrogen, Ammonia Dissolved as N	**30**	ug/l	20	1	Bowdish Reservoir
5/10/08	WW135	Nitrogen, Total	**340**	ug/l	30	1	Bowdish Reservoir
5/10/08	WW135	Phosphorus, Dissolved	**26**	ug/l	5	1	Bowdish Reservoir
5/10/08	WW135	Phosphorus, Total	**17**	ug/l	4	1	Bowdish Reservoir
5/26/08	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
5/26/08	WW135	Temperature	**20**	C	0	1	Bowdish Reservoir
6/12/08	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
6/21/08	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
6/21/08	WW135	Temperature	**24**	C	0	1	Bowdish Reservoir
7/20/08	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
7/20/08	WW135	Temperature	**29**	C	0	1	Bowdish Reservoir
7/20/08	WW135	Enterococci	**0**	MPN/100	1	0.5	Bowdish Reservoir
7/20/08	WW135	Nitrate + Nitrite, Dissolved	**<10**	ug/l	10	1	Bowdish Reservoir
7/20/08	WW135	Nitrogen, Ammonia Dissolved as N	**<20**	ug/l	20	1	Bowdish Reservoir
7/20/08	WW135	Nitrogen, Total	**220**	ug/l	30	1	Bowdish Reservoir
7/20/08	WW135	Phosphorus, Dissolved	**5**	ug/l	5	1	Bowdish Reservoir
7/20/08	WW135	Phosphorus, Total	**7**	ug/l	4	1	Bowdish Reservoir
8/10/08	WW135	Secchi Depth	**3**	m	0.1		Bowdish Reservoir
8/10/08	WW135	Temperature	**26**	C	0	1	Bowdish Reservoir
9/21/08	WW135	Secchi Depth	**4**	m	0.1		Bowdish Reservoir
9/21/08	WW135	Temperature	**22**	C	0	1	Bowdish Reservoir
9/21/08	WW135	Chloride	**25**	mg/l	2	1	Bowdish Reservoir
9/21/08	WW135	Enterococci	**0**	MPN/100	1	0.5	Bowdish Reservoir
9/21/08	WW135	Nitrate + Nitrite, Dissolved	**20**	ug/l	10	1	Bowdish Reservoir
9/21/08	WW135	Nitrogen, Ammonia Dissolved as N	**40**	ug/l	20	1	Bowdish Reservoir
9/21/08	WW135	Nitrogen, Total	**290**	ug/l	30	1	Bowdish Reservoir
9/21/08	WW135	Phosphorus, Dissolved	**<5**	ug/l	5	1	Bowdish Reservoir
9/21/08	WW135	Phosphorus, Total	**4**	ug/l	4	1	Bowdish Reservoir
5/10/08	WW136	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir
8/10/08	WW136	Chlorophyll a (digital)	**34**	ug/l	0.1	1	Bowdish Reservoir
9/21/08	WW136	Chlorophyll a (digital)	**2**	ug/l	0.1	1	Bowdish Reservoir

Appendix B

Photographic Log

Photograph No. 1:

Flowering bracts emerge from dense bed of variable leaf watermilfoil (*Myriophyllum heterophyllum*) along northern shoreline of Bowdish Reservoir.

Photograph No. 2:

View toward the spillway at the Bowdish Dam.

ESS Group, Inc.

Photographic Log

Bowdish Reservoir
Glocester, Rhode Island

PROJECT NO.
N457-000

Photograph No. 3:

View of the floating bog in the vicinity of transects 9 and 10..

Photograph No. 4:

Extensive cover of variable-leaf milfoil (*Myriophyllum heterophyllum*) and fanwort (*Cabomba caroliniana*) is evident in the southern arm of the lake.

Photograph No. 5:

View from transect 20 toward Route 44. Note proximity of highway to lake and extension of pavement toward lake directly behind green buoy.

Photograph No. 6:

Southern shoreline along Route 44 showing evidence of erosion.

ESS Group, Inc.	**Photographic Log** Bowdish Reservoir Glocester, Rhode Island	Sheet 3 of 4 PROJECT NO. N457-000

Photograph No. 7:

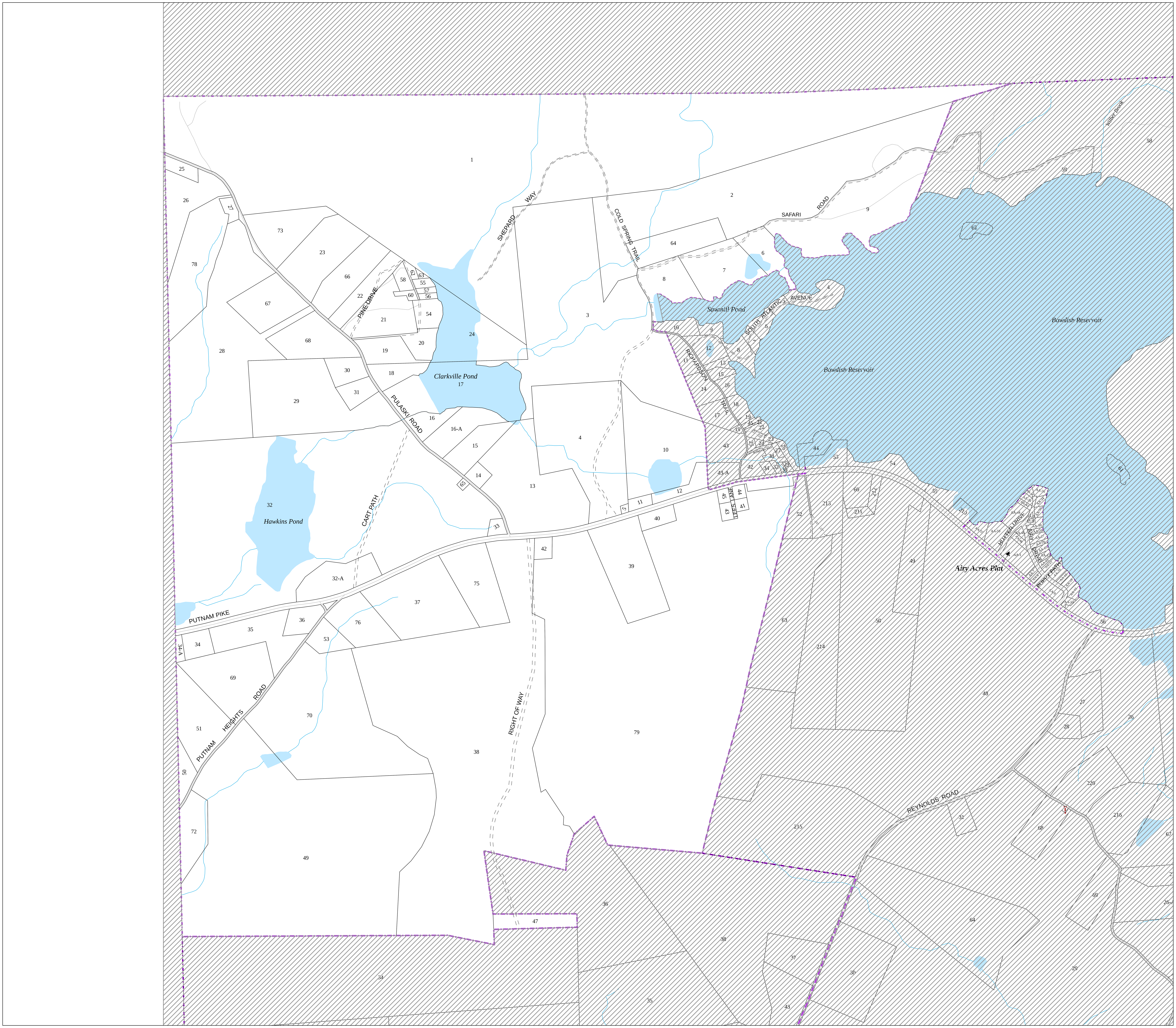
Outfall pipe near public access.

Photograph No. 8:

The immediate vicinity of the public boat launch is relatively free from nuisance aquatic plant cover.

Appendix C

Town of Glocester Assessors Maps



Legend

- Cemeteries
- Parcel Boundaries
- Rivers and Streams
- Easements
- Road Centerlines
- Lakes and Ponds
- Plat and Recorded Plat Boundaries

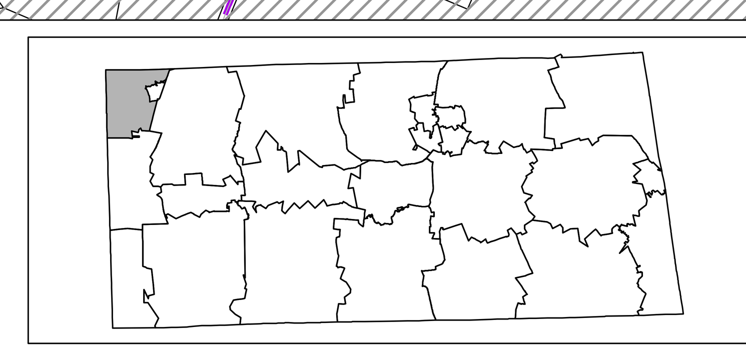
Graphic Scale

200 100 0 200 400 600 Feet

Town of Glocester

Assessor's Plat 1

1 inch equals 250 feet

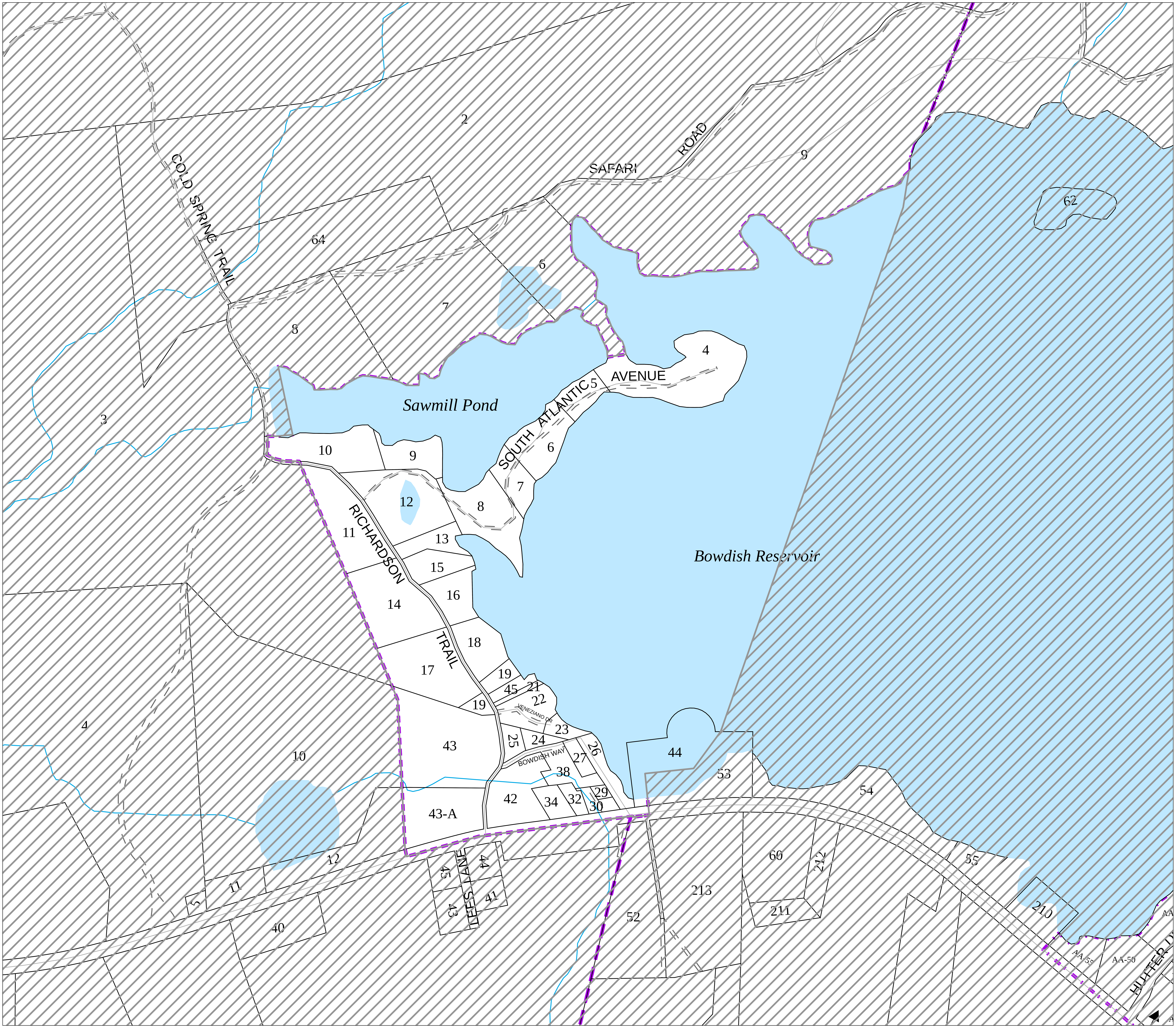


This map is for planning and assessment purposes only. It is not intended to be used for authoritative description, boundary line definition or property conveyance. It is not the product of a land survey.

Parcel boundaries up to date as of December 31, 2008.

Data Sources: Parcels, plat boundaries, and easements developed by the Town of Glocester. Roads and hydrography acquired from RIGIS.

Map produced by the Town of Glocester, March 2009.



Legend

Cemeteries
Easements
Parcel Boundaries
Road Centerlines
Rivers and Streams
Lakes and Ponds
Plat and Recorded Plat Boundaries

Graphic Scale

200 100 0 200 400 600 Feet

Town of Glocester

Assessor's Plat 1A

1 inch equals 100 feet

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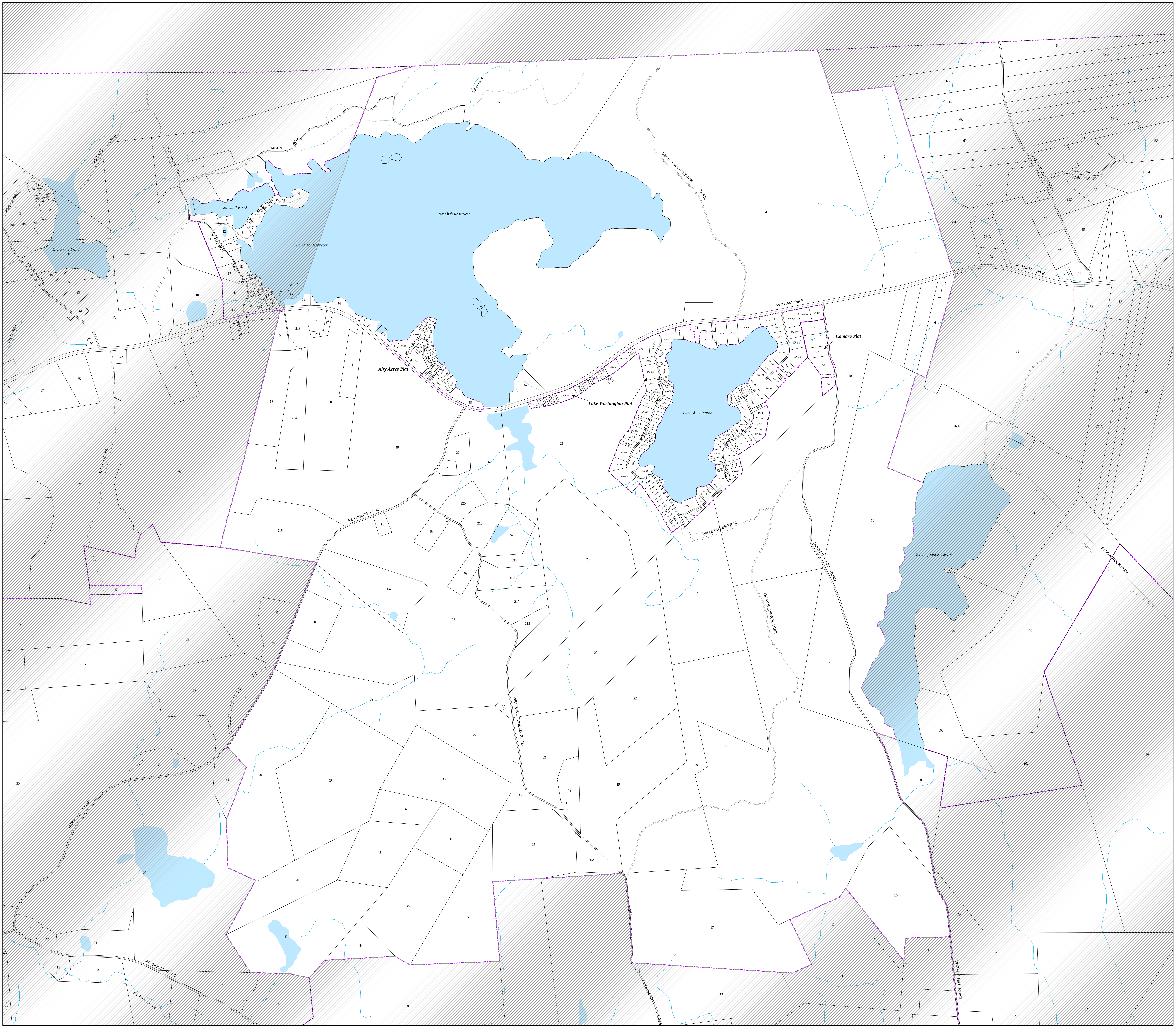
Parcel boundaries up to date as of December 31, 2008.

Data Sources: Parcels, plat boundaries, and easements developed by the Town of Glocester. Roads and hydrography acquired from RIGIS.

Map produced by the Town of Glocester, March 2009.



Legend

- Cemeteries
- Parcel Boundaries
- Rivers and Streams
- Easements
- Road Centerlines
- Lakes and Ponds
- Plat and Recorded Plat Boundaries

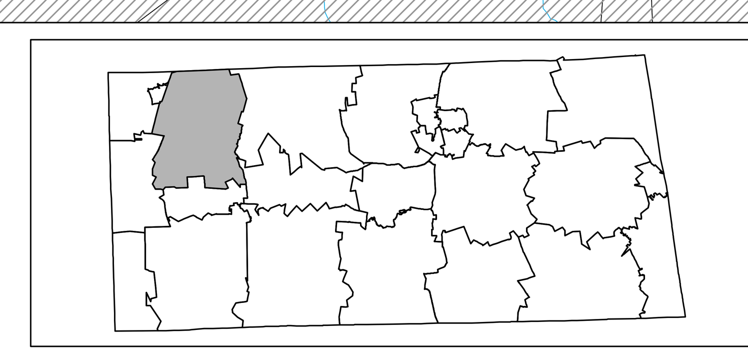
Graphic Scale

200 100 0 200 400 600 Feet

Town of Glocester

Assessor's Plat 4

1 inch equals 400 feet



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Parcel boundaries up to date as of December 31, 2008.

Data Sources: Parcels, plat boundaries, and easements developed by the Town of Glocester. Roads and hydrography acquired from RIGIS.

Map produced by the Town of Glocester, March 2009.

Appendix D

Suggested Plant Management Decision Matrix and Annual Report Card

ESS Group, Inc.

BOWDISH LAKE MANAGEMENT ANNUAL REPORT CARD

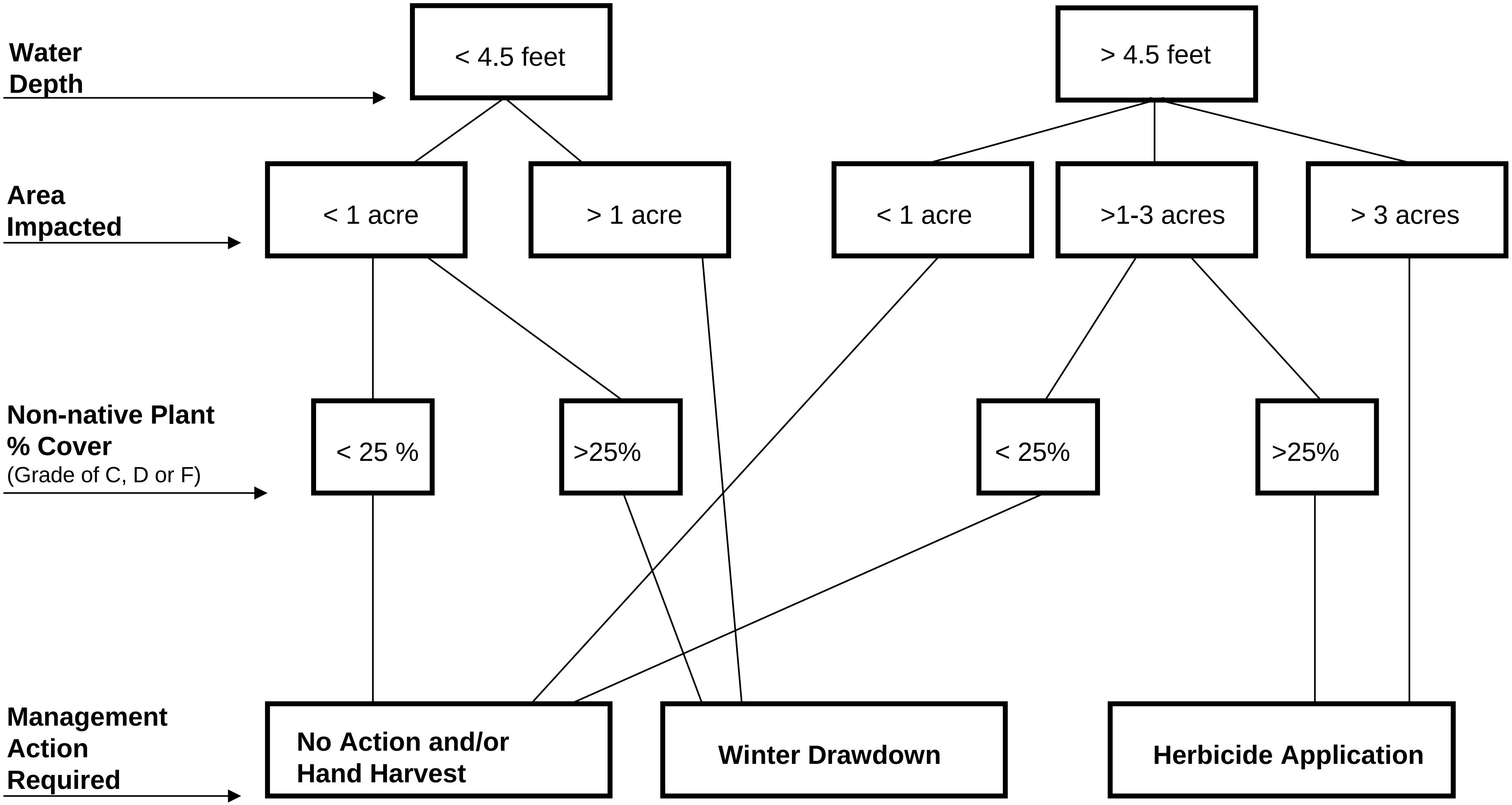
(Completed by qualified lake expert annually in July)

RESOURCE	A	B	C	D	F	GRADE
BOWDISH LAKE						
Plant Community (<4.5' deep)						
Aquatic Native Plants	Dominant	Common	Occasional	Rare	Absent	
Emergent Native Plants	Dominant	Common	Occasional	Rare	Absent	
Aquatic Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Emergent Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Plant Community (>4.5' deep)						
Submerged Aquatic Native Plants	Dominant	Common	Occasional	Rare	Absent	
Emergent Native Plants	Dominant	Common	Occasional	Rare	Absent	
Aquatic Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Emergent Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Invertebrate Community (<4.5' deep)						
Freshwater Mussels	>0.5/ft^2	0.2-0.5/ft^2	0.1-0.2/ft^2	0-0.1/ft^2	Absent	
Other Macroinvertebrates	>8 taxa	6-8 taxa	3-5 taxa	1-2 taxa	Absent	
Invertebrate Community (>4.5' deep)						
Freshwater Mussels	>0.5/ft^2	0.2-0.5/ft^2	0.1-0.2/ft^2	0-0.1/ft^2	Absent	
Other Macroinvertebrates	>8 taxa	6-8 taxa	3-8 taxa	1-2 taxa	Absent	
Water Quality						
Clarity (turbidity/Secchi depth)	<1 NTU or >4 m	1-2 NTU or 3-4 m	2-5 NTU or 2-3 m	5-10 NTU or 1.2-2 m	>10 NTU or <1.2 m	
Phosphorus Concentration (mg/L)	<0.01	0.01-0.02	0.02-0.03	0.03-0.05	>0.05	
Nitrogen Concentration (mg/L)	<0.5	0.5-0.8	0.8-1.0	1.0-2.0	>2.0	
Dissolved Oxygen @ surface (mg/L)	>10.0	7.0-10.0	6.0-7.0	5.0-6.0	<5.0	
Erosion						
Shoreline	No evidence	Wave erosion only	Undercut banks	Bank failures	Numerous bank failings	
Downstream of Dam	No evidence	Limited undercut banks	Extensive undercut banks	Loss of minor shoreline vegetation	Loss of trees and roots	
Impacted Wetlands Upstream of Lake						
Plant Community (<4.5' deep)						
Aquatic Native Plants	Dominant	Common	Occasional	Rare	Absent	
Emergent Native Plants	Dominant	Common	Occasional	Rare	Absent	
Aquatic Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Emergent Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Plant Community (>4.5' deep)						
Aquatic Native Plants	Dominant	Common	Occasional	Rare	Absent	
Emergent Native Plants	Dominant	Common	Occasional	Rare	Absent	
Aquatic Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Emergent Exotic/Invasive Plants	Absent	Rare	Occasional	Common	Dominant	
Invertebrate Community (<4.5' deep)						
Freshwater Mussels	>0.5/ft^2	0.2-0.5/ft^2	0.1-0.2/ft^2	0-0.1/ft^2	Absent	
Other Macroinvertebrates	>8 taxa	6-8 taxa	3-8 taxa	1-2 taxa	Absent	

NOTES FOR COMPLETION OF REPORT

1. For the plant community assessment, the locations to be evaluated in Bowdish Lake should include representative shoreline segments along the north and south shores, a shallow sloped cove, and the floating island near the middle of the lake. For invertebrates, water quality, and erosion, the locations should be consistent on an annual basis in order to compare with baseline data. In addition, water quality samples should be collected at the surface and bottom of the lake (data made available from URI Waterwatch is acceptable but must be evaluated in the context of making annual adjustments to the management program). Grades for each resource can be recorded for each individual area assessed in a field notebook, however, only a composite grade assessing the entire lake should be recorded on the report card.
2. Plant community assessment in upstream wetlands should be performed as plant plot assessments and should be consistent in location from year to year. Macroinvertebrate sampling locations should also be consistent on an annual basis. Grades for each resource can be recorded for each individual area assessed in a field notebook, however, only a composite grade for the entire impacted wetland area should be recorded on the report card.
3. Observations for plants and invertebrates made in shallow water (<4.5') should be made with appropriate gear including plant rakes, clam rake with ¼" mesh openings, and direct observation via aquascope® or snorkel gear. Observations made in deeper water (>4.5') must be made with either snorkel gear or underwater video camera.
4. A completed Report Card should be submitted to the RIDEM and the Bowdish Lake Association each year by no later than September 15th. Recommendations by a qualified lake expert for the upcoming year should be provided along with the Report Card so that any management actions deemed necessary could be implemented. Management recommendations are expected to focus on winter drawdown beginning in November, herbicide application the following June, a combination of drawdown and herbicide application, or no action.
5. Copies of any field notes, laboratory data, or other results used to derive the grade for each resource should be made available to the RIDEM and/or Bowdish Lake Association upon request.
6. Scoring for Plant Community Resources is based on an estimation of the plant coverage within the littoral zone (lake area where light penetration reaches bottom) for each vegetation category listed on the Report Card. Scoring is defined as follows:

    - Absent — Vegetation category is not present at location observed
    - Rare — Vegetation category occupies <5% of the littoral bottom area
    - Occasional — Vegetation category occupies 5% to 10% of the littoral bottom area
    - Common — Vegetation category occupies 10% to 25% of the littoral bottom area
    - Dominant — Vegetation category occupies >25% of the littoral bottom area



Note: This is intended to serve as a guideline, not a set of absolute choices. Decisions may be refined based on condition of other Report Card criteria (water quality, macroinvertebrates, native plant community, etc.).

ESS Group, Inc.
Engineers
Scientists
Consultants

Bowdish Lake
Rhode Island

Flow Chart for Determining Site Specific Control Techniques

Appendix D

Appendix E

Plant Management Strategies and Options for Bowdish Lake

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Recommended Strategies and Options - Watershed Level										
Behavioral Modifications	Prevents nutrients from entering the pond at virtually no monetary cost	-Requires widespread participation to reach threshold at which benefits are detectable -Often slow to work -Efforts to encourage participation may be viewed as attack on personal liberties	Potential decrease in future algal/macrophyte growth due to external nutrient loading	Shoreline and streamside properties	NA	Potentially moderate to high (if modifications become part of the local culture – i.e., accepted by a sustaining percentage of the population)	None	$3,000 for educational brochure. Other costs/cost savings borne by individuals.	Existence of an active lake association is likely to accelerate adoption of behavioral modifications.	Recommended to maintain high water quality at Bowdish Lake as population grows and summer cottages are converted to year-round residences
Low Impact Development and Stormwater Management Improvements - Implementation and Maintenance	Potential to remove a large portion of pollutants and attenuate flooding	-Expensive -Typically requires large area -Maintenance intensive -End-of-pipe solution does not work to control source of pollutants -~2,000 acre watershed to consider	Potential decrease in future algal/macrophyte growth due to external nutrient loading	-New developments -Roadsides (Route 44) -Dirt roads within watershed -Individual homeowner lots retrofitted with LID approaches	NA	High (with adequate maintenance)	Varies depending upon location and scope of project	Costs for evaluating the watershed to identify the sites that may be superior candidates for retrofitting with LID or other stormwater management techniques would be on the order of $15,000 to $20,000 Capital costs vary widely: -$5,000 (deep sump catch basins and swales) -$15,000 (leaching systems) -$20,000 to $40,000 (detention/created wetland systems) Maintenance costs vary depending on number/size of system/s.	-Space requirements -Depth to groundwater -Commitment to long-term system maintenance	-Recommended for future development per the draft Stormwater Guidance by RIDEM -Recommended for LID retrofits of individual homeowner lots

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Maintenance and Upgrade of On-site Disposal Systems	Reduces potential for nutrients and some pathogens to enter lake directly	May be somewhat expensive	Potential decrease in future algal/macrophyte growth due to external nutrient loading	Shoreline properties with failing or poorly sited systems	Year-round	High	- Not required for maintenance - Possible for upgrade (OWTS Application for Repair, local building permit, wetlands, etc.)	-Varies widely by system and type of maintenance/ installation. 20% to 30% reduction in cost may be achieved by placing orders or service requests in bulk (by street or neighborhood) - Cost for education of lake residents on benefits of maintaining OWTS likely to be $2,000	- Individual site constraints - Knowledge of local residents on the nature of the issues and the necessary maintenance required for OWTS limited without education	-Proper maintenance and repair is recommended for all OWTS in order to maximize efficiency -Public education on OWTS could be incorporated into other lake-wide educational programs -No specific actions are recommended beyond this (e.g. watershed-wide surveys or inspections) for Bowdish Lake due to its high overall water quality and low population density
Wildlife Control (Resident Canada Goose Populations)	-Reduces input of nutrients and pathogens to the pond -Addresses aesthetic and public health issues associate with goose feces -Reduces potential conflicts between aggressive geese and lake users (especially children)	-Possible conflicts with individuals or groups who advocate the protection or enhancement of resident goose populations -Some approaches may transfer problem to other area lakes with little or no goose control	-Potential decrease in future algal/macrophyte growth due to external nutrient loading -Decrease in local nuisance resident goose populations	Shoreline and streamside properties, public access points, and nesting areas	Varies by individual approach – generally spring and summer	Varies by individual approach - comprehensive program could be highly effective over a long period of time	-Permits not needed for initial study -Various permits or registrations could be required for individual management actions	-$6,000 for a study to determine flock size, primary nesting and grazing areas and recommend a specific management program for Bowdish Lake -$3,000 for development of an educational brochure or workshop series	-An effective program will likely require extensive cooperation from lake and watershed residents, including volunteer participation	Recommended – the number of resident Canada geese at Bowdish Lake is likely to be sufficiently large. Each resident goose can contribute up to 1 kg of phosphorus per year. A resident population of 50 geese may contribute as much as 20% of the annual load of phosphorus to the lake.

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Recommended Strategies and Options - In-Lake Level										
Bottom Sealing	-Directly eliminates habitat for macrophyte growth -Can achieve almost 100% control over small areas	-Non-selective method locally eliminates or reduces native flora and fauna over long term -Sediment deposition or damage to cover material may allow nuisance macrophytes to recolonize the area	Decrease in macrophyte density and biovolume	-Small areas near private docks and areas of high recreational use (e.g. beaches) -Could also be used in areas where other techniques are not allowed such as is the case with herbicides in the northern end of the lake due to wellheads	Year-round	High – ten years of control or more may be achieved	-None typically for small projects but may require filing for a Preliminary Determination (PD) -Wetlands alteration permit for larger projects (RIDEM Office of Water Resources)	~$2.00/square foot ($90,000/acre) but could be less with volunteer labor and bulk material orders Additional permitting cost possible for larger projects: $1,000 to $3,000 for a Preliminary Determination -plus- $2,000 to $6,000 to prepare and file for a Wetlands Alteration Permit	-Not feasible for large areas (high labor and material costs) -Not feasible for areas with irregular lakebed (boulders/wood)	Recommended for consideration on a limited and localized basis
Chemical Treatments (Herbicides)	-One of the fastest ways to control nuisance plants -See below for specific benefits	-Certified applicator needed -Recreational use and drinking restrictions after application -Possible resistance of some populations of target speices -Possible toxicity to non-target organisms -See below for specific drawbacks	Decrease in macrophyte density and biovolume.	See below for information by individual herbicide	Varies but usually summer	Low to Moderate	See below for information by individual herbicide	Varies widely – see below for details	See below for information by individual herbicide	See below for information by individual herbicide

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Diquat	As a contact herbicide, diquat can clear large areas of weeds in a very short time	-Not selective – would also reduce biovolume of indigenous flora -Possible toxicity to non-target organisms -Temporary recreation restrictions -Dieback of plant growth could release nutrients/reduce dissolved oxygen	Decrease in macrophyte density and biovolume.	Large areas with nuisance macrophyte cover	Summer – typically early to mid-June	Low – limited to one growing season but there can be carry-over to a subsequent year which can result in decreased treatment acreage over a period of years	-Herbicide application permit (RIDEM Division of Agriculture and Division of Fish and Wildlife)	$250 for permit $6,000 for reduced scope program (20 to 25 acres) -or- $35,000 to $40,000 for entire lake	-Possible resistance from stakeholders opposed to herbicide use. -Will need annual diquat treatment until milfoil is reduced to area of less than 10 acres.	Recommended on a limited basis for areas where other control measures would be ineffective in the short term.
Triclopyr	-Targets dicot species such as milfoils -As a systemic herbicide, actually kills entire plant	-Possible toxicity to non-target organisms -Temporary recreation restrictions -Dieback of plant growth could release nutrients/reduce dissolved oxygen -Expensive -Requires 2 to 4 days of contact time for maximum effect	Decrease in macrophyte density and biovolume.	Areas with high milfoil density and biovolume	Summer	Moderate – two to three years of control	-Herbicide application permit (RIDEM Division of Agriculture and Division of Fish and Wildlife)	$250 for permit $1,000/acre -or- ~$100,000 for key recreational areas -or- ~$200,000 for entire lake	-Possible resistance from stakeholders opposed to herbicide use. -Local experience suggests that high dosage would be needed to achieve desired results. -Need to maintain contact time of 2 to 4 days	Recommended on a limited basis (no more than 50 acres at a time) if 2,4-D is not used.

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
2,4-D	-Targets dicot species such as milfoils -More effective and less expensive than Triclopyr -Does not impact monocots, which are mostly desirable native species	-Possible toxicity to non-target organisms -Temporary recreation restrictions -Dieback of plant growth could release nutrients/reduce dissolved oxygen -Additional study possibly required to determine safe setback distance for nearby wells -More expensive than diquat	Decrease in macrophyte density and biovolume.	Large areas with high milfoil density and biovolume	Summer	Moderate – two to three years of control	-Herbicide application permit (RIDEM Division of Agriculture and Division of Fish and Wildlife)	~$120,000 for entire lake, includes the following: $250 for permit $10,000 to $12,000 for pre-application hydrogeologic study/monitoring -plus- $100,000 cost to apply 2,4-D to entire lake -plus- $3,000 - $5,000 post-application monitoring costs	-Possible resistance from stakeholders opposed to herbicide use -Should not be used near water supply wells (hydrogeologic investigation would be needed to determine safe distance)	Recommended, if at least half the lake will be treated.
Macrophyte Harvesting (Mechanical, Diver Assisted Suction Harvesting, or Hand Pulling)	Directly removes plant biovolume from the water column	-Loose fragments may spread the infestation of invasive milfoils -Mechanical harvesting is generally not species specific	Decrease in macrophyte density and biovolume	-Mechanical – Good for clearing large recreational areas -DASH/hand pulling - Good for long term maintenance, clearing boating channels or treating small, isolated beds	Summer	Low (mechanical harvesting) to high (harvesting entire plants from isolated beds)	-Wetlands alteration permit (RIDEM Office of Water Resources) required for mechanical and possibly for DASH -No permit likely required for hand pulling of invasive exotic species or smaller DASH projects	-Mechanical - $2,000 per acre plus $2,000 to $6,000 to prepare and file for a Wetlands Alteration Permit -DASH - $5,000 per acre (<$15,000 for current fanwort infestation) -Cost varies for hand pulling, depending upon use of volunteers	-Variable-leaf milfoil infestation is too extensive to be feasibly controlled through DASH or hand pulling at this time -Mechanical harvesting could be used annually if herbicides are not desired -Fanwort control through DASH/hand pulling is feasible due to small, isolated nature of existing fanwort beds	-Mechanical only recommended for variable-leaf milfoil if use of herbicides is no longer desired -Hand pulling/DASH recommended for fanwort

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Water Level Control (Drawdown)	-Controls summer plant growth through off-season management -Provides additional flood control -Allows for localized nearshore maintenance by landowners -Control of vegetatively reproducing species is usually good -Has been implemented to a depth of 4 feet on a regular basis in recent years with few issues reported	-May impact non-target organisms through desiccation, thermal instability, or reduction in habitat volume. Impacts may be exacerbated by improper planning or execution. -Water quantity (downstream) or supply (wells) impacts possible -Reduction of area/time period available for winter recreation -Seed-producing species (typically native but can include invasive curly-leaf pondweed) often increase in density	Decrease in rooted macrophyte density and biovolume	-Regulated water bodies (impoundments) that regularly freeze over -Key to control is to achieve freezing and desiccation of root zone (freeze drying) which typically occurs when dry sediments are subjected to sub-25 degree weather. -Snow cover is counter-productive due to insulating effect.	Winter	Moderate to high within areas subjected to drawdown, but varies from lake to lake.	-Wetlands alteration permit (RIDEM Office of Water Resources)	Operational costs are low, if appropriate infrastructure is already in place. Initial study and Drawdown Operations Plan likely to cost ~$8,000. -plus- $1,000 to $3,000 for a Preliminary Determination from RIDEM (good up to four years) -plus- If necessary, $6,000 to $10,000 to prepare and file a Wetlands Alteration Permit. -plus- If necessary, $200 to renew Wetlands Alteration Permit on an annual basis for up to four years -plus- If required under permit conditions, $5,000 in annual monitoring costs	-Drawdown to six feet would be targeted to achieve control of variable-leaf milfoil over a significant portion of the lake. -Additional study would be needed to examine technical feasibility and establish appropriate timing and rate of drawdown.	Recommended

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Other Strategies and Options (No Recommended Actions at this Time) – Watershed Level										
Agricultural Best Management Practices	Removes a source of pollution at low cost	Only effective where agricultural lands are a significant source of pollutants	Potential decrease in future algal/macrophyte growth due to external nutrient loading. However, no detectable response anticipated at Bowdish Lake	Agricultural areas	Varies	Varies	Varies	Varies	Agricultural land use makes up <1% of total area. Benefits are not likely to be detectable.	No specifically recommended actions identified based on this limited study. However, good stewardship of the land is always advised.
Bank and Slope Stabilization	Removes a source of sedimentation and nutrients	Only effective where bank and slope erosion is a problem	Varies	High slopes along shorelines and tributary streambanks	NA	Varies	Varies	Varies	Erosion does not appear to contribute significant amounts of sediment to Bowdish Lake, although localized erosion was evident at the state boat launch and along the shoreline adjacent to Route 44.	No specific bank or slope management actions were identified based on this limited study; however, proper maintenance of a vegetated buffer along all waterways is good practice and should be encouraged as part of any future educational efforts.
Increased Street Sweeping and Catch Basin Cleaning	Removes accumulated sediments and pollutants before mobilization into waterways	-Limited benefits in rural watersheds -Not applicable to dirt roads	Potential decrease in future algal/macrophyte growth due to external nutrient loading. However, no detectable response anticipated at Bowdish Lake.	Roads/stormwater system	Monthly or bimonthly	NA	NA	Depends on frequency and extent of maintenance	NA	No recommended actions identified
Provision of Sanitary Sewers	Essentially removes all nutrients and pathogens due to wastewater	-Very expensive to build and maintain -Alters basin-specific water budgets (counts as out-of-basin transfer) -Transfers pollutants to other areas	Potential decrease in future algal/macrophyte growth due to external nutrient loading	Neighborhoods adjacent to waterways and along the shoreline	NA	NA	Multiple permits are likely to be required for a comprehensive project	Very high	Development density in watershed is low which makes this option less feasible	Sewering is not currently recommended due to the high cost and limited potential benefits to Bowdish Lake
Storm Water or Wastewater Diversion	Prevents pollutants from entering the lake	Transfers pollutants to areas outside the watershed	Potential decrease in future algal/macrophyte growth due to external nutrient loading	Most appropriate for lakes that are located downstream of a major point source polluter	NA	NA	Typically a large scale project with numerous permitting requirements	Moderate to very high	NA	No recommended actions identified
Zoning and Land Use Planning	Long-term strategy to preventing future degradation in water quality and plant growth	-May not improve current loads -Reduced utility in watersheds with large proportions of protected land	Potential decrease in future algal/macrophyte growth due to external nutrient loading	Communities experiencing or anticipating rapid growth	NA	NA	NA	$6,000 (watershed build-out analysis)	NA	No recommended actions identified

Appendix E. Plant Management Strategies and Options for Bowdish Lake

Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Treatment of Runoff or Stream Flows	Works quickly, especially for control of planktonic algae.	Expensive and does not address pollutant sources	Decrease in algal growth /potential decrease in macrophyte growth due to external nutrient loading	Tributaries with highest nutrient loading	Varies	Low	-Wetlands alteration permit (RIDEM Office of Water Resources) and possibly others	-Additional study would be required before considered seriously -High to very high (~$250,000 for installation of a dosing station with $50,000 to $75,000 for annual operating costs)	Not currently feasible given the lack of data on nutrient loading from tributaries	No recommended actions identified due to high water quality within Bowdish Lake. It is better to control sources of pollutants rather than to treat the tributaries as they enter the lake.

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Other Strategies and Options (No Recommended Actions at this Time) - In-Lake Level										
Aeration and/or Destratification	-Locally disrupts growth of algae and reduces unsightly algal scums -Improves dissolved oxygen levels in deeper habitats	-Can spread invasive plant fragments -Costs skyrocket and benefits tail off with increasing pond size	Decrease in algal growth but could encourage invasive plant growth through fragmentation	Small coves with high recreational usage and a propensity for nuisance algae blooms	Summer	Low	-Wetlands alteration permit (RIDEM Office of Water Resources)	High to very high, depending on extent of treatment and the type/number of units	Not feasible for an entire 233 acre lake.	No recommended actions identified
Barley Straw	-Gradual decrease in algal density may prevent spike in oxygen demand associated with fast acting methods -Often embraced by the public as it does not involve use of chemicals or physical manipulations	-Method is currently unreliable -Mechanism by which barley straw controls algae is poorly understood	Decrease in future algal density and biovolume	Small ponds with regular algae blooms	Varies	Poorly understood	-Wetlands alteration permit (RIDEM Office of Water Resources) -Listed as an unregistered herbicide by US EPA (cannot be covered by a permit to apply herbicides by the Rhode Island Division of Agriculture)	Undetermined	Algae blooms do not currently appear to be a problem – therefore treatment is unnecessary at this time.	No recommended actions identified
Dilution and/or Flushing	-Reduces in-lake nutrient concentrations and residence time	-Temporarily increases nutrient loads to downstream waters -Requires large supply of nutrient-poor water -Does not address nutrient sources	Decrease in algal (and possibly macrophyte) density and biovolume	Most effective in small ponds with algae blooms and nutrient-poor sediments	During time of highest nutrient concentratio ns	Low – effective only while dilution is occurring	Numerous permits likely for entire project including necessary infrastructure	Extremely high for larger water bodies	Lake is too large for dilution to be feasible	No recommended actions identified

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Dredging	-May directly reduce nutrient cycling from sediments -May reduce sediment oxygen demand and level of legacy pollutants -Increases water depth -Provides opportunity to "start over"	-Removes existing habitats and non-target organisms -Temporary increase in stressors to lake organisms (increased turbidity, reduced cover, drying out) -Removed sediment must be appropriately disposed of or reused -Extensive study, design, and permitting required (one or more years) before dredging can commence	Decrease in macrophyte density and biovolume due to increased depth if dredged to a depth greater than light penetration	Areas with deep layers of fine sediments	Anytime but fall-winter is preferred	High – benefits of dredging are likely to last for decades if done properly	-Section 404 permit (federal) -Section 401 Water Quality Certificate (state) -Wetlands alteration permit (state)	~$30 to $40 per cubic yard of sediment removed Even a small dredging project would likely cost ~$2M to design, permit, and execute	Access for dredging equipment and locating sites for sediment disposal could be difficult.	Due to the very good water quality in Bowdish Lake, dredging would only be effective if performed to achieve depths in excess of 15 feet. Due to the high costs and disruptive nature of such an extensive project, this approach is not recommended at this time.
Dye Addition	Reduces growth of plant and algae species with high light requirements and insufficient food reserves	-Relatively ineffective in shallow water -Possible downstream impacts	Decrease in algal and macrophyte density and biovolume	Small, deep ponds	Spring-summer	Low – effects unlikely to last more than one season	Subject to approval by RIDEM	Possibly as high as $100 per acre with a whole lake treatment required ($23,300). Monitoring for effectiveness and potential impacts to non-target organisms would also be a likely requirement ($6,000).	Lake is too large and shallow for dyes to be effective	No recommended actions identified
Hydroraking and Rotovation	-Hydroraking removes the plant and its roots and is therefore longer lasting than basic mechanical harvesting -Rotovation is a fast way to cut macrophyte growth at the roots	-Loose fragments may spread the infestation of invasive milfoils -Time-consuming -Disposal of collected materials may be problematic -Temporary increase in turbidity -Likely to increase nutrients due to suspension of sediments	Decrease in macrophyte density and biovolume	Water lily beds or specific weed beds of highest priority where herbicides may not be appropriate	Spring-summer	If thorough, may be effective for several years	Wetlands Alteration Permit (RIDEM Office of Water Resources)	$2,000 to $5,000 per acre plus trucking costs (if removed to an offsite location)	Hydroraking not feasible for large areas due to slow rate of advance (~ one acre per day). Rotovation not feasible due to likelihood of milfoil spread via fragmentation.	No recommended actions identified

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Method	Advantages	Disadvantages	Expected Response of Target Species	Location/Habitat in which Method Is Most Effective	Seasonal Timing	Efficacy over Time	Permits Needed	Cost	Feasibility Considerations	Professional Recommendation
Hypolimnetic Withdrawal	Targets portion of the water column with lowest dissolved oxygen and (in many cases) highest nutrient concentrations	-Downstream thermal, dissolved oxygen, and nutrient impacts -Requires new infrastructure -Unintended drawdown possible	Decrease in algal density and biovolume	Deep, strongly stratified lakes	Summer	NA	Wetlands Alteration Permit (RIDEM Office of Water Resources)	High capital cost	Withdrawal of the hypolimnion is unlikely to feasible due to the shallow lake bathymetry.	No recommended actions identified
Food Web Manipulation (Fish Stocking or Removal)	-May increase water clarity -May increase production of desirable fish species -Often embraced by the public as it does not involve use of chemicals or physical manipulations	-Complexity of food webs makes the outcome of manipulation difficult to predict -May worsen algal growth problems by encouraging growth of less desirable species	Decrease in algal density and biovolume	Lakes and ponds with nuisance algal blooms	Varies	Uncertain	-Wetlands alteration permit (RIDEM Office of Water Resources) -Review by RIDEM Division of Fish and Wildlife	-$500 to $1,500/acre for piscivorous fish stocking -$1,000 to $5,000/acre for planktivorous fish removal	Algae blooms do not currently appear to be a problem – therefore treatment is unnecessary at this time.	No recommended actions identified
Herbivorous Fish Stocking	-Fish directly consume macrophytes -Can ramp up treatment as needed through stocking -Often embraced by the public as it does not involve use of chemicals or physical manipulations	-Requires the introduction of exotic, potentially invasive fish species -Fish selectively feed on certain plant species over others and may cause damage to non-target species -Grass carp may negatively affect desirable game species	Decrease in macrophyte density and biovolume.	Water bodies with macrophytes (especially fanwort)	Varies	Approximately five years	Not currently permitted	$30 to $200 per acre ($6,000 to $43,000 for treatment of 220 acres)	Introduction of grass carp prohibited in Rhode Island.	Not allowed
Insect Stocking	-In the case of Eurasian milfoil, the milfoil weevil is a native species that does not feed on non-target species -Can ramp up treatment as needed through stocking -Often embraced by the public as it does not involve use of chemicals or physical manipulations	-Method is currently applicable to very few species of plants (e.g. Eurasian milfoil, purple loosestrife) -Not compatible with other methods that severely restrict or eliminate growth of the insect's host species (i.e., insect needs a base population of host plants to sustain itself)	Decrease in macrophyte density and biovolume	Water bodies with large populations of appropriate host species	Varies – multiple generations may be produced per year	Can provide long term control if carefully managed	-Wetlands alteration permit (RIDEM Office of Water Resources) -Review by RIDEM Division of Fish and Wildlife	~$3,000 per acre for initial stocking. Cost varies thereafter, according to needs of the management program. -A monitoring program to track success of approach is highly recommended ($5,000).	Not currently feasible at Bowdish Lake as the main invasive host species for milfoil weevil (Eurasian milfoil) is not present	No recommended actions identified

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Nutrient Inactivation	-Quickly controls algal growth by reducing the availability of nutrients in water column -May reduce recycling of nutrients from the sediments	-Temporary: does not address watershed nutrient loading -May not efficiently sequester nutrients in sediments -May be toxic to non-target organisms -Large pH swings possible	Decrease in algal density and biovolume – will not significantly impact rooted plants	Directly in-lake	Summer	Moderate to high in deeper lakes with low flushing rates Would likely be of minimal benefit to Bowdish Lake, lasting up to one season	Wetlands Alteration Permit (RIDEM Office of Water Resources)	Moderate to high (~$500/acre or $116,000 for total in-lake treatment)	Algae blooms do not currently appear to be a problem – therefore treatment is unnecessary.	No recommended actions identified
Pathogen Introduction	-High abundance and diversity of host-specific species -Usually harmless to non-target organisms -Easily disseminated and self-maintaining	-Method is still largely experimental in most cases -Not compatible with other methods that severely restrict or eliminate growth of the pathogen's host species (i.e., pathogen needs a base population of host plants to sustain itself)	Decrease in algal or macrophyte density and biovolume	Water bodies with large populations of appropriate host species	Varies	Reported to provide long term control if carefully managed	NA	Experimental – costs cannot be determined accurately at this time.	Feasibility for variable-leaf milfoil and fanwort is currently undetermined.	No recommended actions identified
Plant Competition	-Uses natural processes to control aquatic invasives -May be self-perpetuating after an initial establishment period -Easily integrated with other approaches	-Method is still largely experimental -Requires a high initial investment -Requires multiple years of ongoing labor to supplement native plants	Decrease in macrophyte density and biovolume	Small areas in which previous invasions of nuisance plant species have been knocked back to reduce competition (generally through herbicides).	Varies	Poorly understood but potential exists for long term success	Wetlands alteration permit (RIDEM Office of Water Resources)	Varies, but costs exceeding $5,000 per acre would not be unexpected	Not likely to be feasible under existing conditions of widespread variable-leaf milfoil growth. Most feasible following control of early and small infestation.	No recommended actions identified