Lake Massabesic Watershed Management Plan

Draft Report
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Section 1 Introduction

Lake Massabesic is a naturally occurring lake that lies on the far eastern side of the City of Manchester and occupies a large portion of the neighboring Town of Auburn, New Hampshire. With a dam at the southwest end of the lake in the City of Manchester, the surface area of the lake is approximately 2,560 acres with a storage capacity of nearly 15 billion gallons[1]. The watershed draining to Lake Massabesic is approximately 42 square miles, which lies mostly within the Towns of Auburn, Candia and Hookset with smaller portions in the City of Manchester and Towns of Chester and Allenstown, New Hampshire (Figure 1-1).

The Manchester Water Works (MWW) is the State of New Hampshire's largest water utility, serving over 160,000 consumers in the City of Manchester and portions of Auburn, Bedford, Derry, Goffstown, Hooksett and Londonderry. To satisfy stringent state and federal drinking water regulations, the lake water is treated at Manchester's Water Treatment Plant located in Manchester adjacent to Lake Massabesic. The treatment facility was built in 1974 with a major upgrade in 2006 with a maximum hydraulic capacity of 50 million gallons per day (MGD).

The purpose of this Lake Massabesic Watershed Management Plan (WMP) plan is to supplement a 1999 plan through:

- an updated assessment of source water protection measures;
- updating the existing inventory of potential contamination sources (PCS);
- evaluating and prioritizing existing and potential threats to water quality; and
- planning for future steps and land acquisitions.

The WMP identifies existing pollution contributions and sources, helps establish water quality goals, and estimates pollution reductions needed to meet the water quality goals.

The primary goal for MWW is to provide safe drinking water to the communities it serves. Part of that goal is met by implementation of a multiple barrier approach (Figure 1-2) that combines the state of the art water treatment facility and continuous distribution improvement with strong watershed protection.

[1] City of Manchester, NH. Water Works. (n.d.). Lake Massabesic Watershed. Retrieved from https://www.manchesternh.gov/Departments/Water-Works/Lake-Massabesic-Watershed.

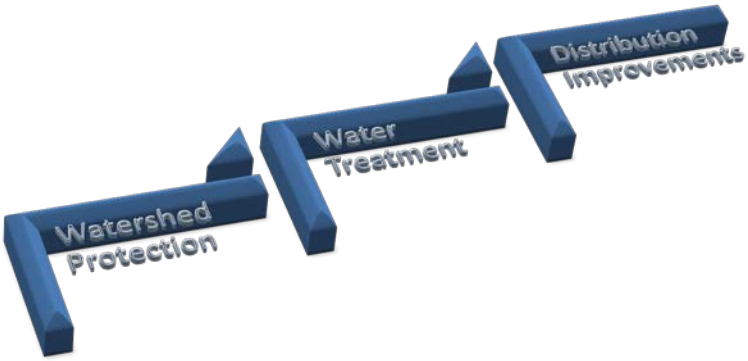


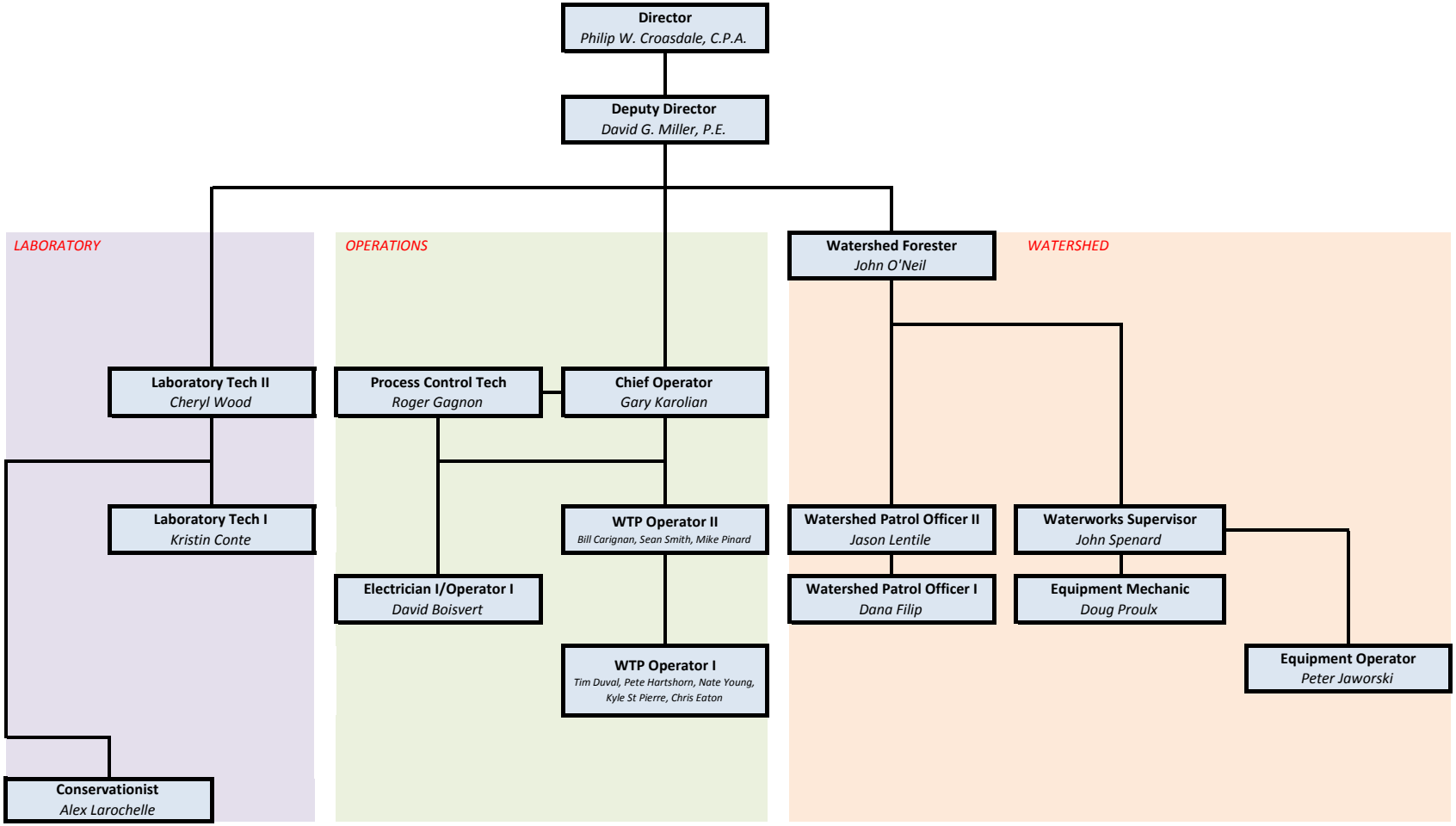
Figure 1-2. Multiple Barrier Process

The MWW Water Supply Division is responsible for meeting these goals through the use of in-house resources and staff that provide laboratory analytical services, treatment plant operations and watershed patrols. Refer to Figure 1-3 for an organizational chart of Water Supply Division staff in each of these areas.

More specifically, the Manchester Water Works employs a full-time, NH Licensed Professional Forester whose primary responsibility is the protection of the Lake Massabesic and the entire Massabesic Watershed. This Watershed Forester works closely with NH DES to update, every eight (8) years, Watershed Protection Rules specifically designated for the protection of the purity of the water and ice of Lake Massabesic or any pond, reservoir or stream tributary within the Massabesic Watershed. It is the Watershed Forester who must be the primary advocate for the entire watershed which includes monitoring and directing all activities that happen within the watershed boundary. These activities include but are not limited to; recreation, development, farming and forestry, road maintenance and construction, business management and development, community projects, community activities, research projects, property management, and lawmaking at the local, state, and federal levels. The Forester is supported by a staff of 2 full time Patrol Officers, 2 season Patrol Officers, and 3 Watershed Maintenance Personnel. The Forest must direct policy and activities within the Massabesic Watershed in a clear and consistent fashion to minimize or eliminate any or all potential negative impacts to Lake Massabesic. The Watershed Forester must maintain a long term perspective of not only what has been historically troublesome but also being aware of developing threats to water quality. This Plan will provide a roadmap from which the Forester will formulate more specific plans and projects to be implanted by the Manchester Water Works and outside consultants.

Protecting Lake Massabesic from contamination threats has been a priority of the Manchester Water Works for many years – key features of their protection program include watershed patrol staff; a forestry program; a school outreach program and considerable shoreline land ownership. More details on the existing protection measures and responsibilities and duties of watershed patrol staff are provided in Section 4.0.The existing level of staffing is inadequate to allow the performance of all of the watershed patrol duties to the level needed.

Figure 1-3.
MANCHESTER WATER WORKS
WATER SUPPLY DIVISION
Organizational Chart



This report:

1) updates a 1999 watershed plan[2];
2) documents ongoing efforts and staffing;
3) makes any necessary improvements/modifications to the program based on the latest watershed techniques and tools; and
4) sets up a database to track water quality and other data.

Although the watershed management efforts have been rigorous, the lake does have low dissolved oxygen in the bottom layers and an aeration system was added in 2010 to the western basin. This system does provide significant improvements in oxygen at the bottom of the lake, which is important for reducing the release of both manganese and phosphorus from anoxic (low oxygen) sediments. It also is listed on the 2012 Section 303(d) List of impaired waters for impairment of the Primary Contact Recreation use due to cyanobacteria hepatoxic microcystins (cyanobacteria), although blooms have not been frequent. The lake is also listed for impairment of the aquatic life use due to low dissolved oxygen (DO) and dissolved oxygen saturation, non-native aquatic plants, and pH. Reducing phosphorus loads and concentrations in the lake will reduce algal growth and improve the DO conditions in the deep areas of the lake. This is discussed further in Section 3.0.

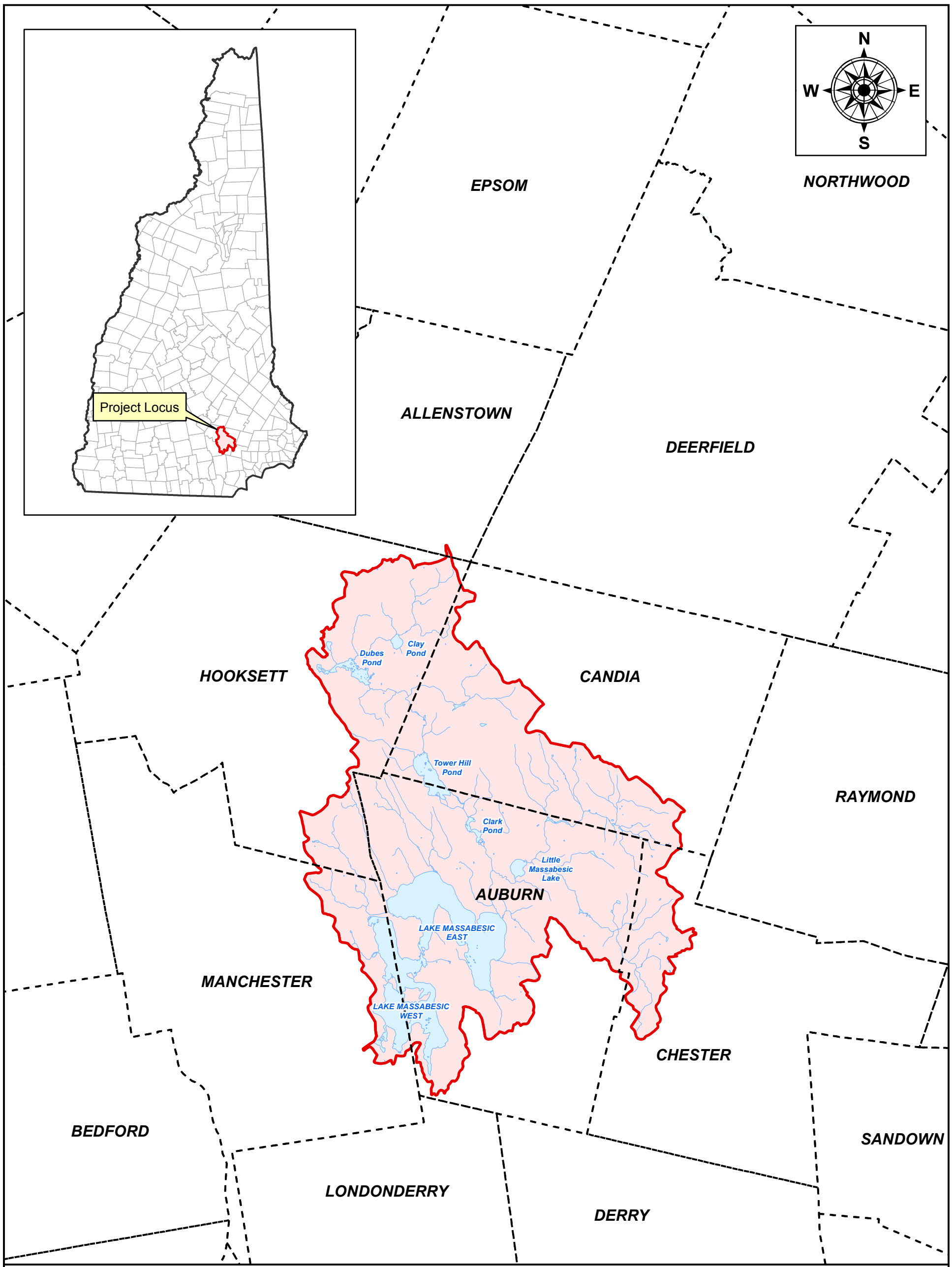
The WMP represents the MWW continued efforts to better protect, preserve, and maintain water resources in the Lake Massabesic watershed. Based on the most recent available information, recommendations were developed for long-term watershed protection goals.

A Section 319 Watershed Planning Grant was awarded to MWW through the New Hampshire Department of Environmental Services (NHDES) Watershed Assistance Section to assist in preparing this WMP with matching funds provided by MWW. The scope of work to prepare this plan included:

- Delineation and mapping of the watershed and subwatersheds using existing GIS data and field investigations, including wetlands, waterways, topography, land uses, zoning, soil types and potential contaminant sources (refer to Section 2.0Watershed Characteristics).
- Evaluation of water quality concerns and how it impacts designated uses of the lake (Refer to Section 3.0 Water Quality).
- Watershed investigations to identify potential contaminant sources of pollution to Lake Massabesic, including a review of NHDES GIS database a watershed survey (refer to Section 4.0 Potential Contamination Sources and Existing Protection Measures).
- Estimation of phosphorus loads under existing conditions using a standard model[3] (refer to Section 5.0 Pollutant Load Analysis).

[2]Normandeau Associates Inc. 1999. Lake Massabesic Watershed Management Plan.
[3]Lake Loading Response Model (LLRM) (also called SHEDMOD or ENSR-LRM).

- Development of realistic water quality goals and associated phosphorus reductions to achieve them (refer to Section 6.0 Assimilative Capacity Analysis and Water Quality Goals).
- Recommendations to develop watershed management alternatives to reduce impacts to water resource in the Lake Massabesic watershed (refer to Section 7.0 Recommendations).



Legend

- Lake Massabesic Watershed
- Town Boundary
- Lake/Pond
- Stream/Brook

0 5,000 10,000 20,000 30,000 Feet

0 0.5 1 2 3 4 5 Miles

Figure 1-1

Lake Massabesic Watershed Management Plan

Project Locus Map

Manchester Water Works

Comprehensive Environmental Inc.

Section 2 Watershed Evaluation

This section describes Lake Massabesic and the contributing watershed, including its size and boundaries and characteristics such as land use and soils, which are important in estimating pollutant loads and possible measures to control these pollutant loads. It includes information collected through New Hampshire Department of Environmental Services (NHDES) GIS data and field investigations.

2.1 Waterbody Characteristics

Lake Massabesic is a natural lake that was raised by construction of a dam to increase storage for use as a water supply. It has been used as the drinking water supply in the regional Manchester area since the completion of the dam and low service pumping station in 1874. The lake lies within the City of Manchester and Town of Auburn, New Hampshire and is divided at Deer Neck Bridge on the Londonderry Turnpike (Route #28 Bypass). The so-called front pond, herein referred to as Lake Massabesic East, located on the eastern side of the bridge is within the Town of Auburn while the back pond, herein referred to as Lake Massabesic West, located on the western side of the bridge is divided north and south by the Auburn-Manchester town lines. Lake Massabesic East flows into Lake Massabesic West.

Lake Massabesic is approximately 2,560 acres with a storage capacity of nearly 15 billion gallons[1]. The majority of this storage (76%) is in Lake Massabesic East with the remainder in Lake Massabesic West. The watershed draining to Lake Massabesic is approximately 42 square miles (excluding the area of Lake Massabesic), and is located within the City of Manchester and Towns of Auburn, Candia, Chester, Hooksett, as well as a small area within the Town of Allenstown. The lake has a maximum depth of 55 feet and a mean depth of 16 ft. Figure 2-1 illustrates the bathymetry of the lake. Lake Massabesic East has a flushing rate of about 2 times a year, while Lake Massabesic West has a flushing rate of about 6 times a year due to its significantly smaller volume.

The lake is stratified at its deep locations during the summer months, which means that a layer of warm water overlays a cooler layer below, resulting in limited movement of water and nutrients during summer. The lake stratifies at a depth of about 20 feet. Turnover occurs as temperatures change during the fall and spring seasons and oxygen and nutrients get distributed throughout the water column as the water mixes. Refer to Table 2-1 for a summary of lake characteristics.

Lake Massabesic enjoys a vital and healthy fish and wildlife population. The lake has a warm water fishery with both largemouth and smallmouth bass (*Micropterus salmoides*) and (*Micropterus dolomieu*), white perch (*Morone americana*), yellow perch (*Perca flavescens*), pickerel (*Esox americanus*), and horned pout (*Ameiurus nebulosus*). The lake

[1] City of Manchester, NH. Water Works. (n.d.). Lake Massabesic Watershed. Retrieved from https://www.manchesternh.gov/Departments/Water-Works/Lake-Massabesic-Watershed.

is also periodically stocked with brook trout and rainbow trout by the N.H. Department of Fish and Game[2].

Table 2-1. Characteristics of Lake Massabesic		
Parameter	**East**	**West**
Lake Area (acres)	1,385	1,175
Lake Volume (billion gallons)	~11.5	~3.5
Watershed Area (acres)	25,447	27,660
Mean Depth (ft)	25	9
Max Depth (ft)	55	40
Flushing Rate (yr^{-1})	2	6
Hypolimnetic Anoxia	Yes/Stratified	Yes/Stratified

The non-native aquatic plant species, variable milfoil (*Myriophyllum heterophyllum*), is present in the lake and Manchester Water Works takes continuous actions to prevent its spread. Observations of bladderwort (*Utricularia vulgaris* and *Utricularia purpurea*) and fanwort (*Cabomba caroliniana*) have also been made in the lake. Locations where non-native aquatic plants have been observed in the lake are presented in Figure 2-2.

2.2 Watershed Characteristics

The Lake Massabesic watershed has nineteen drainage areas or subwatersheds as delineated in an earlier study[3]. The subwatershed boundaries represent drainage areas for each of the major tributaries in the Lake's watershed, and for the direct drainage area surrounding the lake (e.g., overland runoff into the lake). The subwatershed areas were used for pollutant and hydrologic modeling purposes to efficiently present the results and allow for prioritization. Figure 2-3 shows the watershed and subwatershed boundaries and major tributary features.

2.2.1 Land Uses

Land use information was obtained from a GIS database provided by the Southern New Hampshire Planning Commission (SNHPC). Figure 2-4 shows the land use areas throughout the watershed. Land uses were consolidated into land use categories compatible with the pollutant load model used for this study (refer to Appendix A).

Based on the consolidated land uses, the Lake Massabesic watershed is primarily undeveloped with approximately 67% of the land categorized as mixed forest and open areas (meadow and barren). The next largest land use is Water at 11% (Open 1 (Wetland/Pond)), which represents pond and lake areas throughout the watershed, this is followed by low density residential (10%), wetlands (6.5%), agricultural (1.6%), and Parks and Recreation (1.2%).

A breakdown of the land use areas for each subwatershed is provided in Table 2-2.

[2] City of Manchester, NH. Water Works. (n.d.). Lake Massabesic Watershed. Retrieved from https://www.manchesternh.gov/Departments/Water-Works/Fishing.
[3] Normandeau Associates Inc. 1999. Lake Massabesic Watershed Management Plan.

Table 2-2. Land Use Categories by Lake Massabesic Subwatersheds

	Area (acres)																				
Subwatershed	**Clark Pond**	**Clay Pond**	**Dube's Pond**	**Fan Merrill**	**Hook Brook**	**Little Lake Massabesic**	**Massebesic East**	**Massebesic West**	**Kinnicum Pond**	**Murray Mill Brook**	**Neal Brook**	**Pine Hill Road**	**Preston Brook**	**Reed Brook**	**Severance Brook**	**Spring Valley**	**Spruce Pond**	**Sucker Brook**	**Tower Hill Pond**	**Total**	**Percent**
Urban 1 (Low Density Residential)	108	37	82	385	45	1	456	201	169	325	98	146	198	30	46	303	183	65	152	3,029	10.1%
Urban 2 (Medium Density Residential, Commercial)	14	2	4	23	0	0	19	24	18	25	42	7	0	18	0	50	16	0	6	269	0.9%
Urban 3 (Roads)	53	4	9	65	4	3	50	34	11	101	21	43	17	18	8	63	22	11	14	549	1.8%
Urban 4 (Industrial)	0	0	4	0	0	0	0	31	0	0	40	0	0	4	0	54	0	0	0	133	0.4%
Urban 5 Parks, Recreation Fields, Institutional)	3	0	2	2	2	9	23	20	38	153	11	8	2	24	1	23	1	26	1	350	1.2%
Agricultural 1 (Cover Crop)	3	7	1	20	18	4	42	76	46	128	2	22	25	0	3	30	25	17	3	471	1.6%
Forest 3 (Mixed)	735	1,828	1,174	894	173	247	1,969	1,581	1,463	1,962	521	805	682	59	103	731	1,839	485	2,231	19,480	64.7%
Forest 4 (Wetland)	23	200	186	116	17	138	88	96	238	95	56	13	30	6	7	60	326	94	156	1,945	6.5%
Open 1 (Wetland/Pond)[1]	46	93	140	21	8	56	1,194	1,383	12	20	25	2	2	6	3	15	32	8	256	3,320	11%
Open 2 (Meadow)	5	0	5	12	3	7	42	27	39	63	13	36	6	0	1	6	102	21	19	406	1.3%
Open 3 (Barren/Open)	1	0	30	4	4	0	5	21	7	27	23	0	7	0	1	18	16	2	7	173	0.6%
Total Area	990	2,170	1,637	1,544	275	465	3,888	3,494	2,042	2,897	851	1,082	967	164	172	1,353	2,562	728	2,844	30,126	100%

Notes:
1 Open 1 (Wetland/Pond) represents surface water bodies (ponds and lakes) within the watershed.

Following are some general observations made regarding land uses throughout the watershed:

Commercial, Industrial and Residential
The majority of the commercial and industrial development within the watershed is located along the Londonderry Turnpike corridor in Hooksett and Manchester. Low density residential development is found along primary road corridors and small clusters throughout the watershed.

Highway Corridor
Route 101 runs through the center of the watershed and stormwater runoff from the highway drains toward Lake Massabesic. Some stormwater BMPs have been installed along the highway to collect and treat stormwater before discharging to tributaries or the lake. There are also two large detention ponds located along Londonderry Turnpike and Manchester Road, but neither these nor the stormwater controls on the highway were evaluated as part of this study

Conservation Land and Patrols
About 9,200 acres of land are protected from future development through conservation easements, deed restrictions or fee ownership (Figure 2-5). MWW owns and controls more than 8,000 acres of this land to help protect its source water supply. MWW performs forest management in accordance with its Forestry Practices Standard Operating Procedures (SOPs) (Appendix B). As added protection, the MWW also employs a staff of watershed patrol officers who monitor all activity in the watershed and enforce the regulations pertaining to Lake Massabesic. Part of the lake and watershed is also closed to public access and is well marked.

Restricted Area
A portion of Lake Massabesic West and its watershed is restricted for the use of all recreational activities, due to the proximity of the water intake. The restricted MWW land is shown on the conservation land map (Figure 2-5).

Agricultural/Farming
Field observations of agricultural lands found the majority of these properties are open fields that are used to grow hay and were not being farmed as cropland or used for raising livestock. Active farming practices in the watershed are generally limited to hobby farms and boarding horses.

2.2.2 Zoning

Zoning regulations control how land can be developed in the future. Figure 2-6 shows the zoning classifications and boundaries within the watershed. A discussion of local zoning ordinances and regulations is included in Section 4.0.

2.2.3 Recreational Uses

Although MWW's primary land management goal is to protect and preserve its water supply, a significant portion of MWW land is open to the public for a variety of passive

recreational uses. Common recreational activities within the watershed include boating, fishing, hiking, jogging, biking, horse riding, dog walking and picnicking. The MWW Board of Water Commissioners adopted local watershed protection rules that pertain to the use of MWW property, including requirements for collecting horse and dog waste and management of pets on MWW property. A copy of the rules is included in Appendix C and they are discussed further in Section 4.0.

There are currently two full time and two part time watershed patrol officers to monitor and regulate recreational use activities in the watershed. Watershed officers patrol the watershed daily and enforce the MWW Rules using their Standard Operating Procedures (SOPs) (Appendix D). Officers also provide the public with educational information about the watershed and respond to emergencies.

Boating

Boating on Lake Massabesic is enjoyed by many users, with the following restrictions:

- no boating in the posted restricted area near the intake;
- boating speed is limited to 35 MPH;
- no contact between the boater and the water.

There are three public launches located on the lake which are owned and operated by MWW. The launches are in Auburn Village just past the Town Hall; a second is located off Rte. 121 near the Manchester-Auburn town line and a third at Deer Neck Bridge. The launch at Deer Neck Bridge is for cartop boats only (No Trailers).

Boaters are asked to maintain care and caution in their activities and recognize that the lake provides vital drinking water supply. Signs are posted at each public boat launch to inform the lake user about milfoil in the lake and what they should do to protect the lake. MWW also participates in the Lake Host Program, which is a courtesy boat inspection program administered by NH LAKES to prevent the introduction and spread of aquatic invasive species, plants and animals, from waterbody to waterbody. Trained Lake Hosts staff boat ramps to educate visiting boaters about aquatic invasive species and how to prevent their spread, as well as to conduct courtesy boat and trailer inspections for invasive species.

MWW also provides public docks at public boat ramps that allow boaters easy access to their boats without having to come into contact with the water.

Fishing

Lake Massabesic, and the ponds in the watershed offer many and varied fishing opportunities. The lake offers a complex shoreline and some vegetated coves in select areas which provide good fishing.

Running, Hiking and Biking

About 50 miles of fire roads on MWW land are accessible to the public for running, hiking and biking use. A network of trails near Little Massabesic Lake offer more

challenging loops. It includes more than 13 miles of singletrack trails that were built and are maintained by The Friends of Massabesic Bicycling Association (FOMBA).

Horseback Riding

Horseback riding in the Lake Massabesic watershed is only allowed on gravel fire roads on MWW property. Horses must be equipped with a device designed to collect horse waste as it is produced and all waste must also be removed from MWW property. There is a 900 acre exception area around Little Massabesic Lake known to riders as "The Maze", where horses are permitted to ride without a device to collect horse waste. Volunteers pick up horse waste twice a week in this area. During organized riding events, horses are permitted to ride on designated trails, provided waste is removed immediately following such events. Horses are prohibited from entering the lakes, ponds or tributaries in the watershed and are not permitted in public park areas, boat launches and on the shoreline and beaches of any lake or pond on or within MWW property.

Current Challenges

During daily patrols, patrol officers record observations of recreational activities and violations of the Posted Rules. Examples of daily recreational use and violation monitoring logs are included in Appendix E. Based on these observations, MWW has developed a list of challenges of passive recreation on the Massabesic Watershed (Appendix F) that require further attention. A summary of these challenges identified by patrol staff is provided below:

1. Recreational Usage: has increased over the years and at times the need for enforcement overwhelms the existing patrol staff since recreational users often do not follow signage.
2. Animals: horses enter backcountry areas or sensitive areas, and although the regulations call for diapers to be used, it does not always happen. In addition, dogs off leash go in the water and their owners are not removing waste or leave the bags behind.
3. Trash and waste: continue to be a problem including by trail users and hunters.
4. Entrance in prohibited areas: fishermen, geocachers and hunters often go into restricted areas.
5. Rule changes: take a long time and are sometimes ineffective.

2.2.4 Soils and Groundwater Features

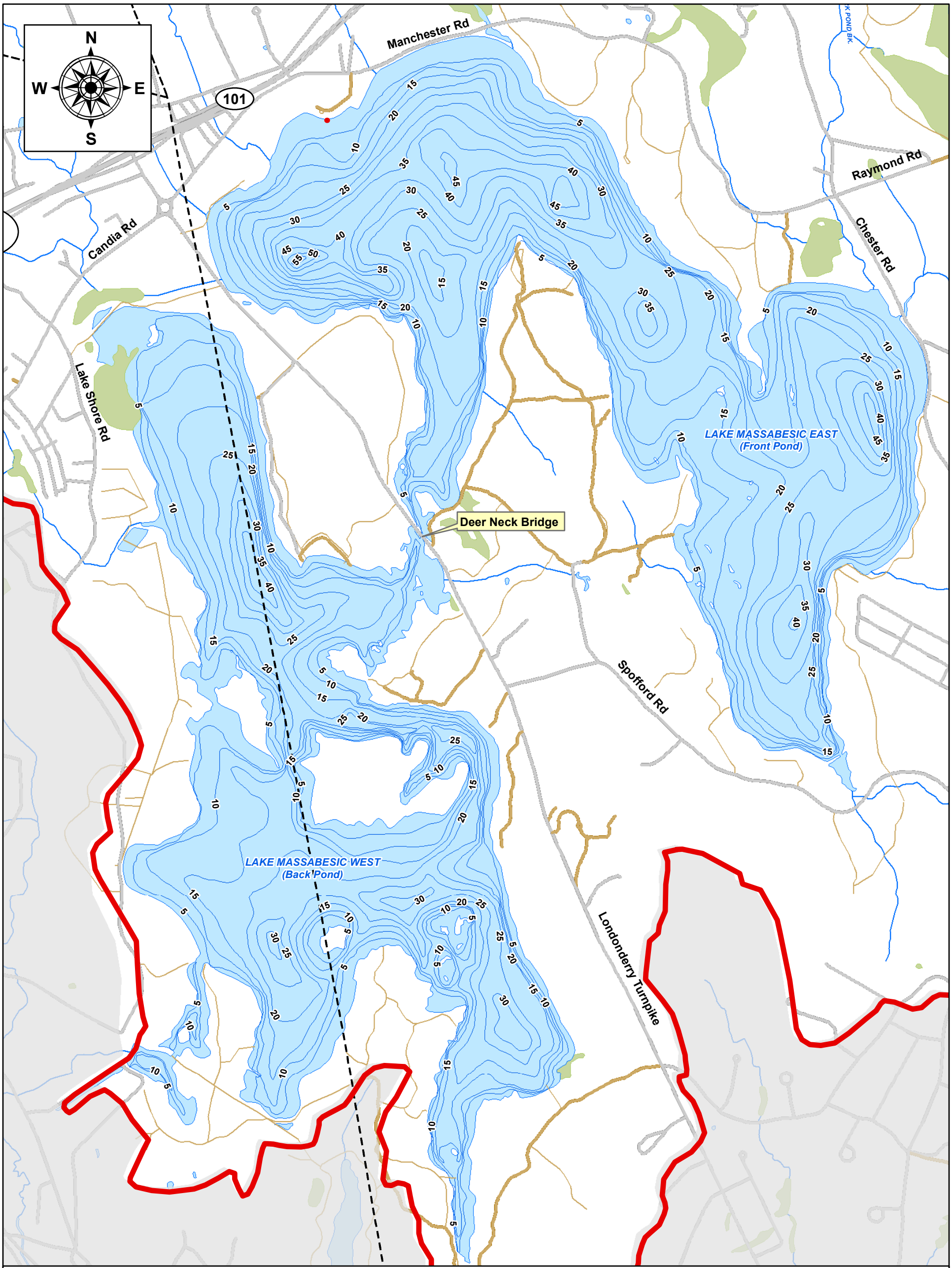
Soils are typically classified into hydrologic soil groups (HSG) A through D. HSG A and B soils have the highest infiltration rates, allowing for greater stormwater recharge potential. HSG C and D soils are typically tighter soils, limiting recharge potential. This information is important when selecting stormwater best management practices (BMPs) to treat stormwater runoff, as infiltration BMPs typically offer better pollutant removal while minimizing the volume of stormwater runoff and increasing the volume of water that recharges groundwater base flow.

Most of the watershed contains Hydrologic Soil Group (HSG) B soils (55%) and HSG C soils (31%). HSG B soils percolate water quickly and are good for stormwater infiltration

treatment. Small areas of HSG A soil are located throughout the watershed, some where sand pit operations have historically been located. The remaining HSG D soils can be found in constantly wet areas or under standing water. Refer to Figure 2-7 for soil characteristics in the watershed.

2.2.5 Waterfowl

Records for most waterfowl populations are not kept by MWW, however field staff report the number of waterfowl observed on the lake are typically low and have not observed any water quality impacts associated with waterfowl. Typical waterfowl identified on the lake include loons and wood ducks. Canadian geese have been observed near the water treatment plant and a small flock of seagulls (approximately 30-50 seagulls) have been observed congregating near the intake. Loons are the only waterfowl population that is monitored. The Loon Preservation Society maintains several floating nests in the lake and has documented the presence of nine pairs of loons on the lake.



Legend

- Bathymetric Contours - feet (2003)
- Lake Massabesic Watershed

Roads

- Paved
- Unpaved

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook
- Town Boundary

Bathymetric Contour Data Source: MWW

0 750 1,500 3,000 4,500 Feet

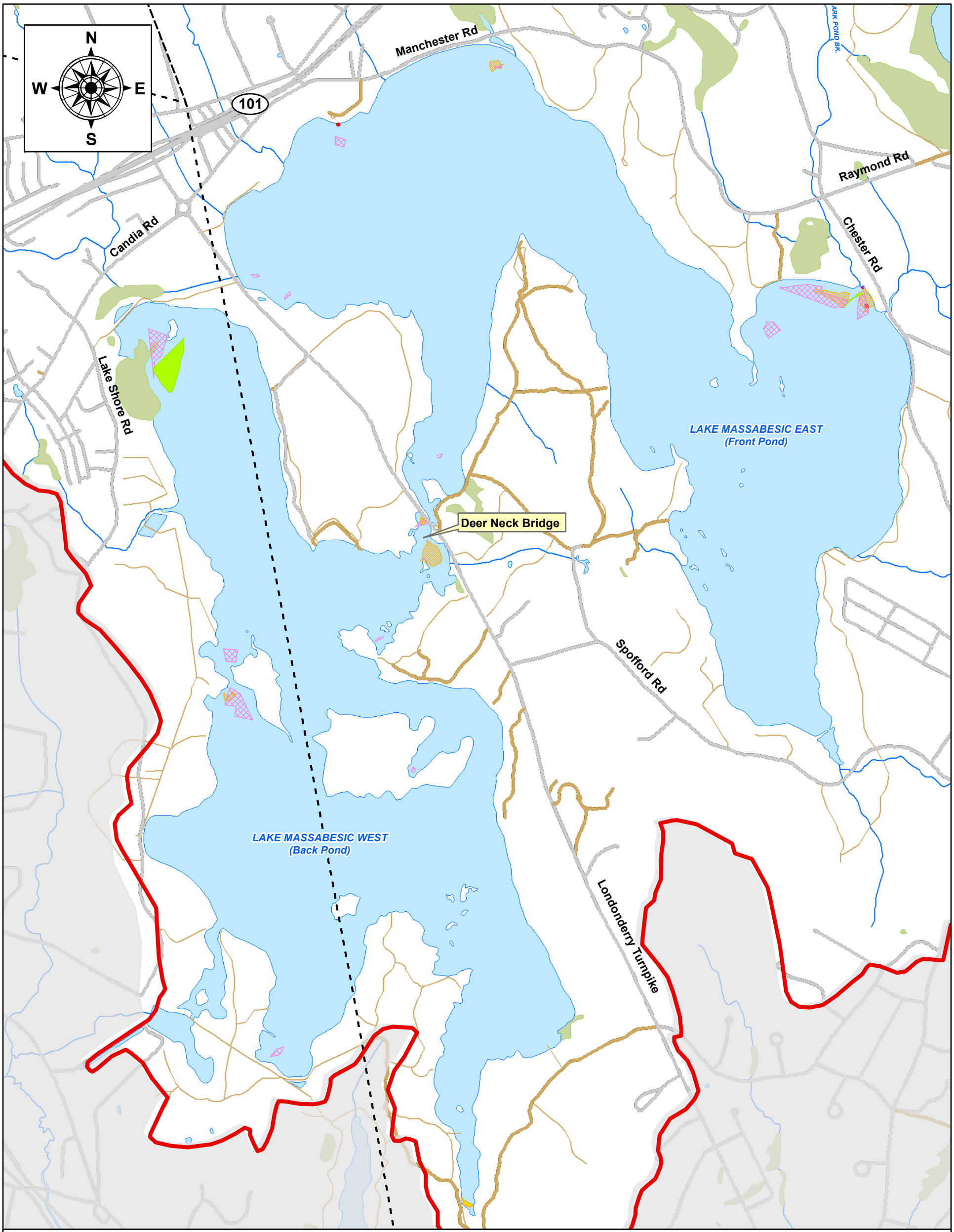
Figure 2-1

Lake Massabesic Watershed Management Plan

Lake Massabesic Bathymetric Map

Manchester Water Works

Comprehensive Environmental Inc.



Legend

Non-Native Aquatic Vegetation

- Milfoil Area 2003
- Milfoil Area 2004
- Milfoil Area 2014
- Bladderwort Area
- Fanwort Area 2003
- Lake Massabesic Watershed
- Town Boundary

Roads

- Paved
- Unpaved

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

Aquatic Vetegation Data Source: MWW

0 750 1,500 3,000 4,500 Feet

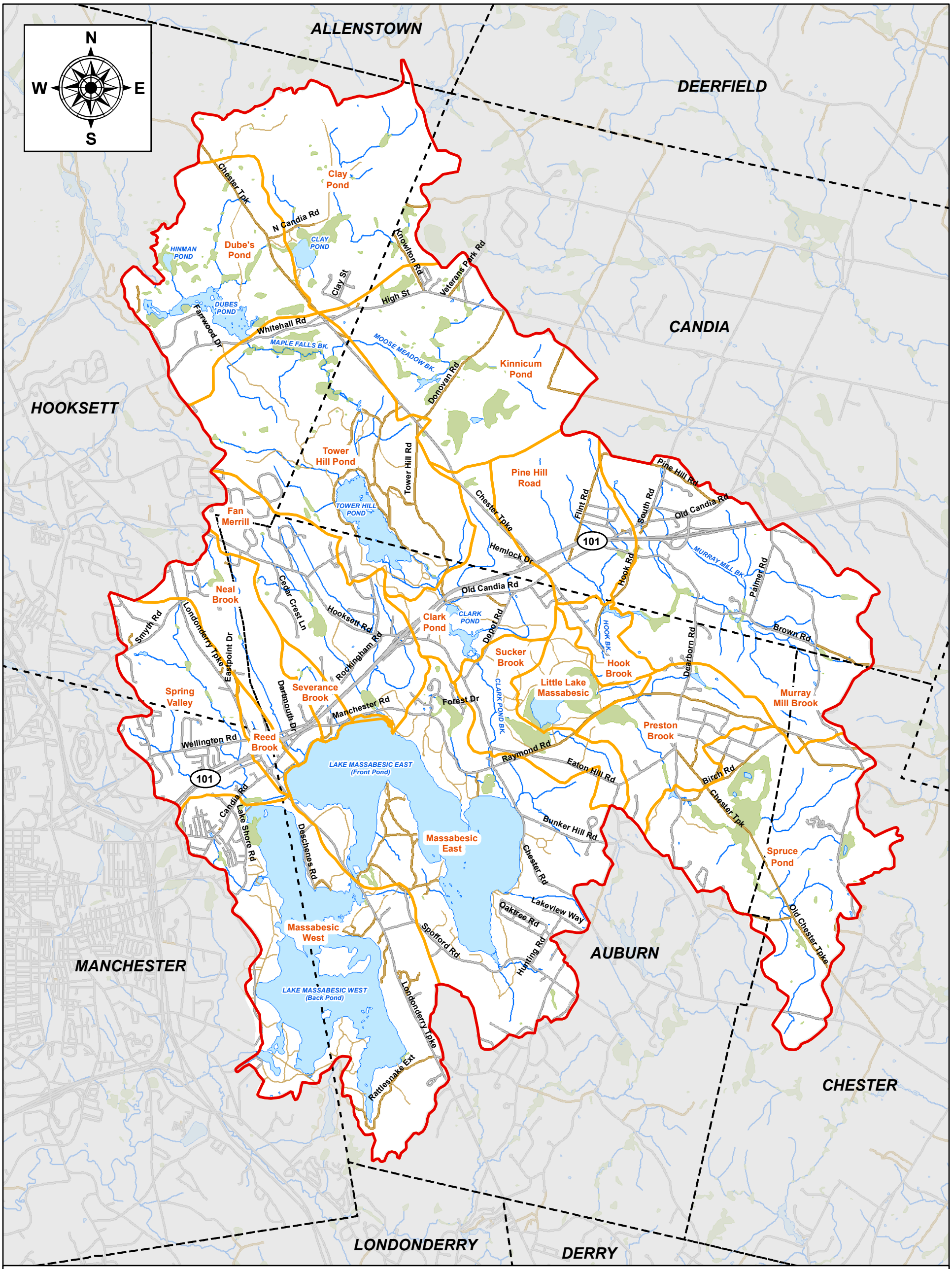
Figure 2-2

Lake Massabesic Watershed Management Plan

Non-Native Aquatic Vegetation Location Map

Manchester Water Works

Comprehensive Environmental Inc.



Legend

- Lake Massabesic Watershed
- Subwatershed Boundaries
- Town Boundary

Roads

- Paved
- Unpaved

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

Data Sources: GRANIT, MWW, City of Manchester

0 2,500 5,000 10,000 15,000 Feet

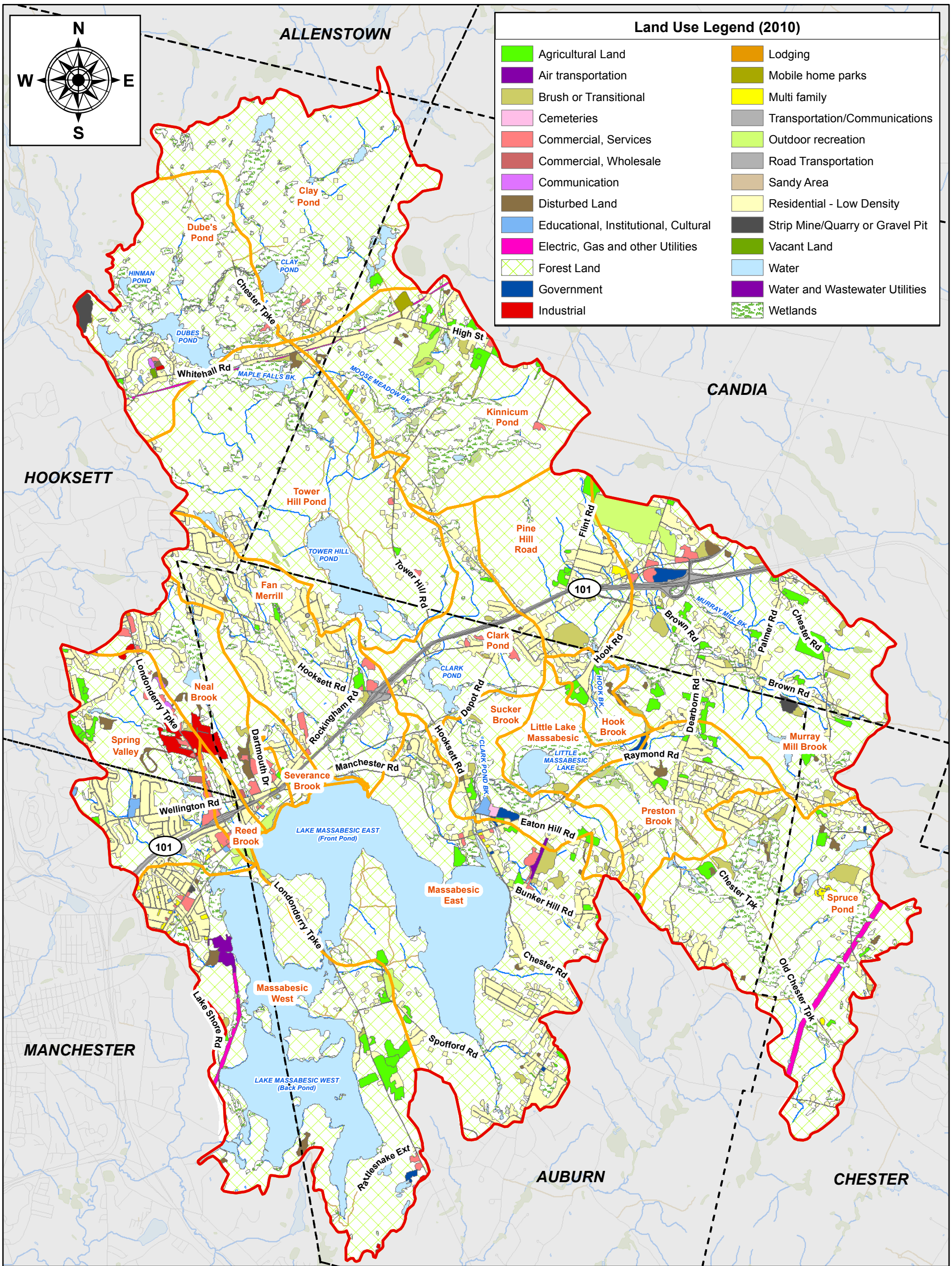
Figure 2-3

Lake Massabesic Watershed Management Plan

Lake Massabesic Watershed Boundary Map

Manchester Water Works

Comprehensive Environmental Inc.



Legend

- Lake Massabesic Watershed
- Subwatershed Boundaries
- Town Boundary

Roads

- Paved
- Unpaved

Land Use Data Source: SNHPC

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

0 2,500 5,000 10,000 15,000 Feet

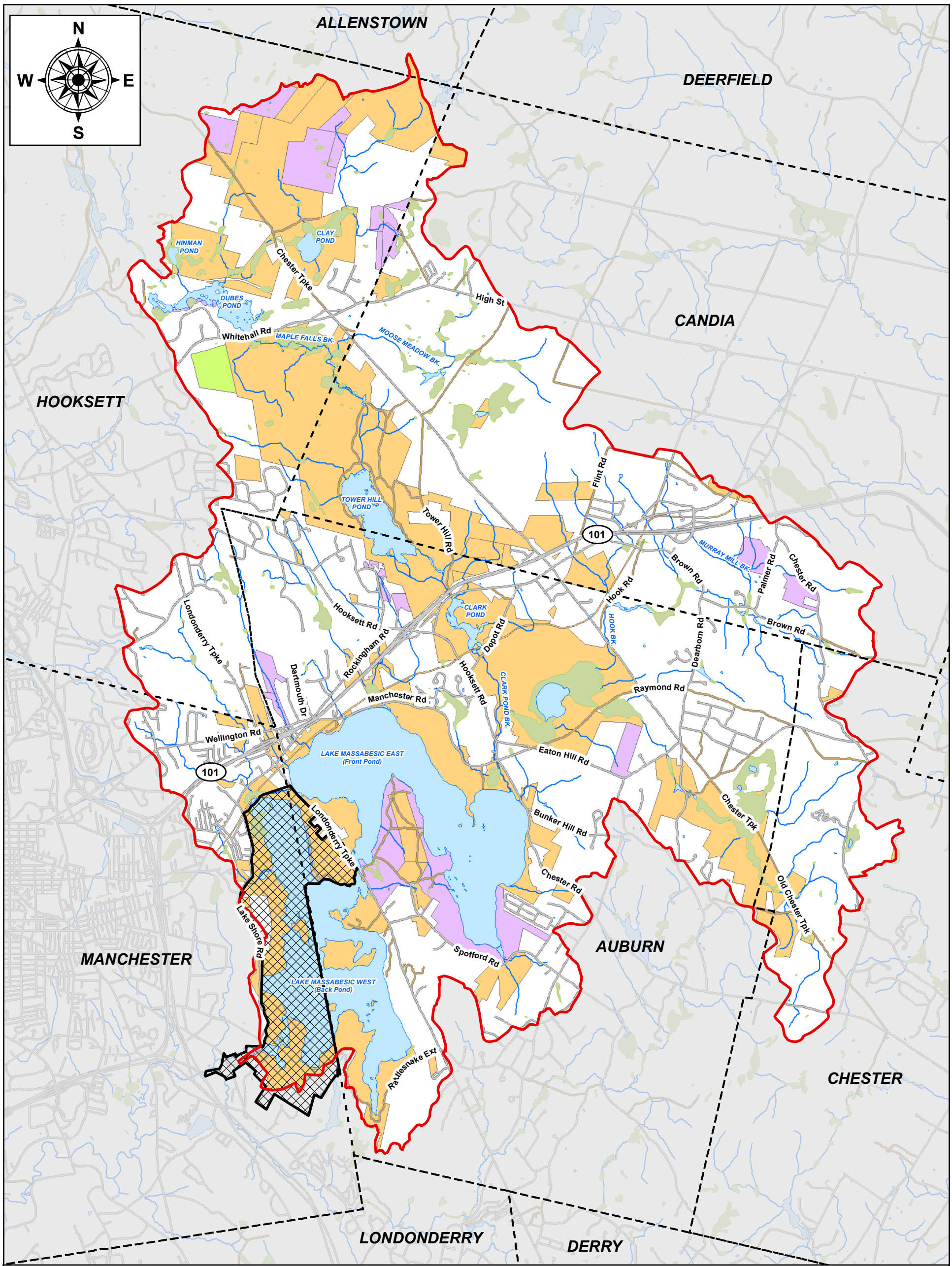
Figure 2-4

Lake Massabesic Watershed Management Plan

Land Use Characteristics

Manchester Water Works

Comprehensive Environmental Inc.



Legend

- Restricted Access Area

Conservation/Public Lands

- Conservation Easement
- Deed Restriction
- Fee Ownership
- Lake Massabesic Watershed

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook
- Town Boundary

Data Sources: GRANIT, MWW

0 2,500 5,000 10,000 15,000 Feet

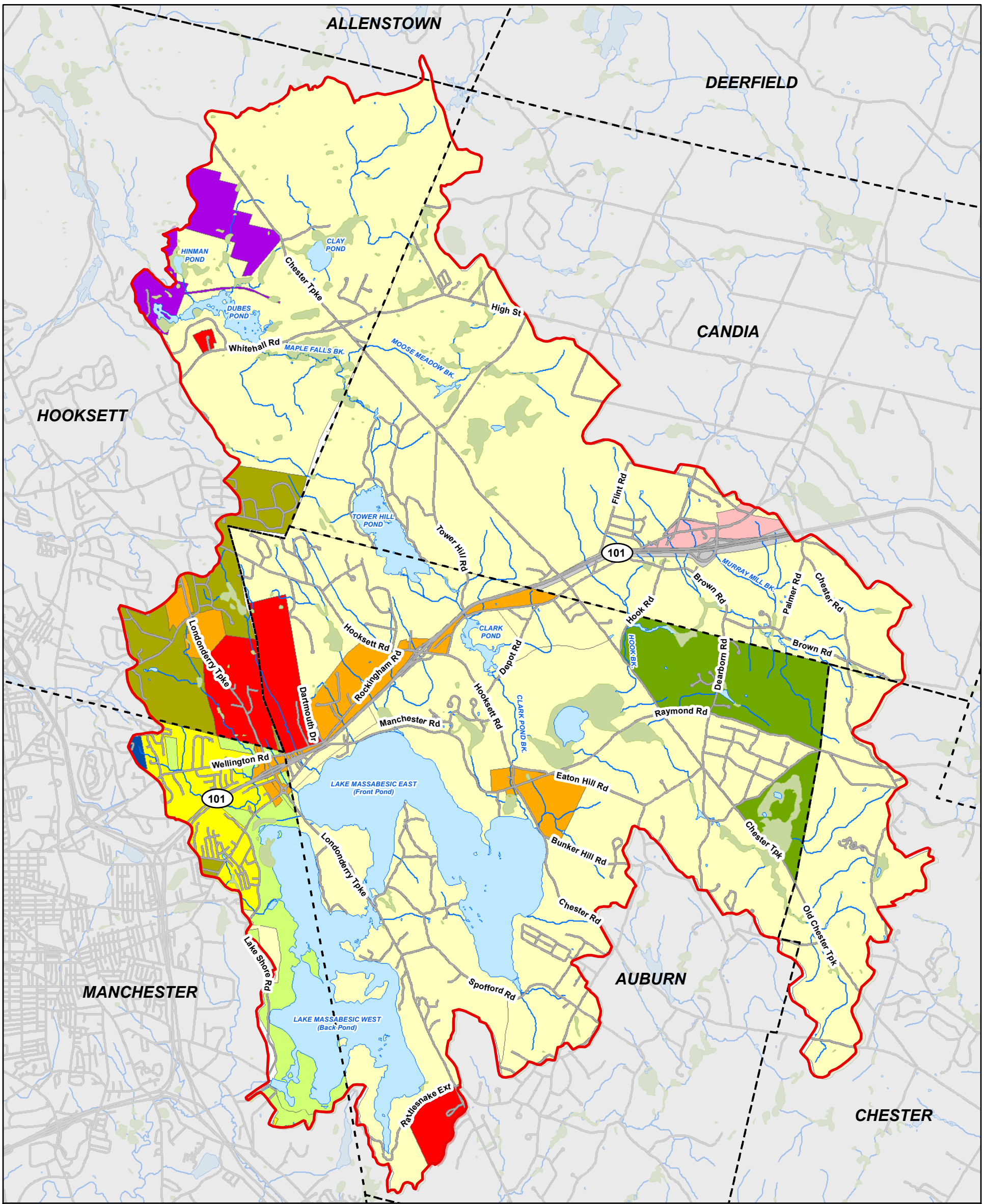
Figure 2-5

Lake Massabesic Watershed Management Plan

Conservation & Public Lands

Manchester Water Works

Comprehensive Environmental Inc.



Legend

Zoning Boundaries

- Conservation District
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Rural
- Civic-Hospital District
- Commercial/General Business
- Light Industrial
- Industrial
- Mixed Use
- Highway Corridor

- Lake Massabesic Watershed

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook
- Town Boundary

Data Sources: GRANIT, MWW, SNHPC

0 2,500 5,000 10,000 15,000 Feet

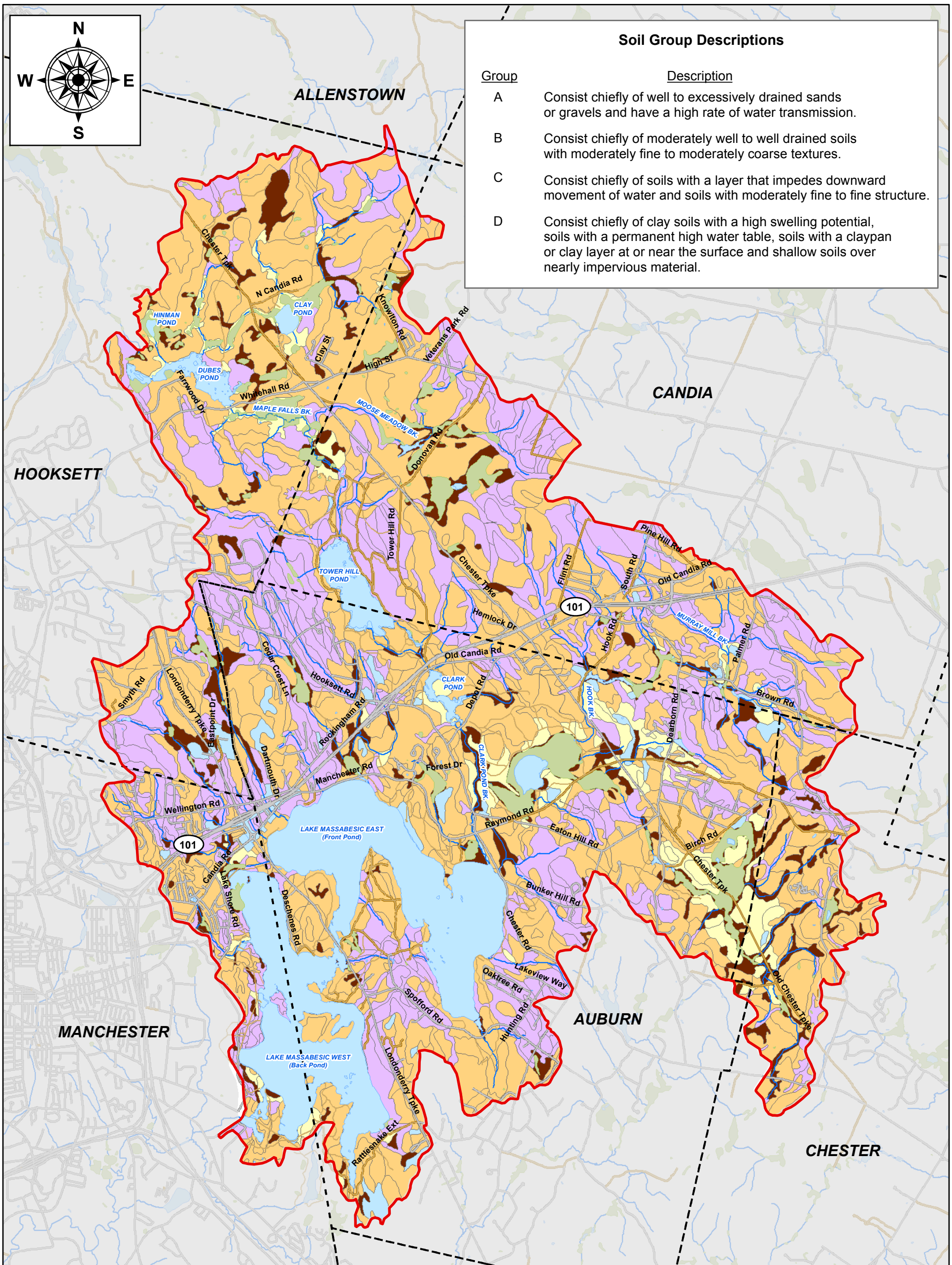
Figure 2-6

Lake Massabesic Watershed Management Plan

Watershed Zoning Map

Manchester Water Works

Comprehensive Environmental Inc.



Soil Group Descriptions

Group	Description
A	Consist chiefly of well to excessively drained sands or gravels and have a high rate of water transmission.
B	Consist chiefly of moderately well to well drained soils with moderately fine to moderately coarse textures.
C	Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

Legend

Soils Hydrologic Groups (2009)

- A
- B
- C
- D
- Lake Massabesic Watershed
- Town Boundary

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

Roads

- Paved
- Unpaved

Soils Data Sources: GRANIT (SSURGO)

0 2,500 5,000 10,000 15,000 Feet

Figure 2-7

Lake Massabesic Watershed Management Plan

Soil Characteristics

Manchester Water Works

Comprehensive Environmental Inc.

Section 3 Water Quality

This section summarizes water quality concerns in Lake Massabesic and how it impacts designated uses of the lake.

3.1 Designated Uses

Lake Massabesic is assigned a surface water classification of A by the State of New Hampshire. Surface water classifications establish designated uses for a waterbody. Designated uses are desirable uses that must be protected. Water quality standards are designed to protect these designated uses. Class A waters are generally of the highest quality and are considered potentially usable for water supply after adequate treatment.

3.2 Pollutants of Concern

Lake Massabesic (NHLAK700060702-03) is listed on the 2012 305(b)/303(d) List of Threatened or Impaired Waters (NHDES 2012a) for failure to meet the following designated uses:

Table 3-1. Designated Uses and Impairments of Lake Massabesic

Designated Use	DES Category	Impairment	Source[1]
Aquatic Life	5-M	Dissolved oxygen saturation	Unknown
	5-M & 5-P	Dissolved Oxygen	Unknown
	4C-M	Non-native Aquatic Plants	Unknown
	4A-M	pH	Atmospheric Deposition - Acidity
Primary Contact Recreation	5-M	Cyanobacteria hepatotoxic microcystins	Unknown

Notes:
4A-M – A Total Maximum Daily Load (TMDL) has been completed for the pollutant. The TMDL for pH covers 158 lakes, including Lake Massabesic, with pH impairment due to acid rain. The impairment is relatively slight or marginal. Implementation of the TMDL is primarily the responsibility of the U.S. EPA.
4C-M – A TMDL is not required since the impairment is not caused by a pollutant. The impairment is relatively slight or marginal.
5-M – Parameter is a pollutant that requires a TMDL. The impairment is relatively slight or marginal.
5-P – Parameter is a pollutant that requires a TMDL. The impairment is more severe and causes poor water quality.
The impairments requiring a TMDL are also included on the Draft 2014 303(d) list.

Dissolved oxygen (DO) is a measure of the amount of oxygen in the water. DO levels in water are typically measured in milligrams per liter (mg/l) and as a percent (dissolved

[1] Source was unknown at the time of listing.

oxygen saturation). DO is vital to bottom-dwelling organisms, fish and amphibians that reside in the water. It gets into the water from the atmosphere, aeration of water (i.e., flowing streams) and through photosynthesis of plant material, a process that requires sunlight to occur. So, while aquatic plants and algae may produce oxygen during the day, they consume it at night.

Bacteria also use oxygen both day and night when they process/break down organic matter. A significant amount of oxygen can be consumed during the decomposition of algae that sinks to the bottom of a lake or pond after it dies, leading to undesirable DO levels, and sometimes fish kills. Most fish need a DO level of 5 mg/l to survive and can suffocate and die when levels fall below 2 mg/l. The process whereby DO decreases as a result of algae and other plant growth due to lake enrichment by phosphorus or nitrogen, is called cultural eutrophication and also has consequences for water quality in that anoxic (without oxygen) sediments can release stored nutrients like phosphorus as well as metals such as manganese which affect water quality in very negative ways. A lake that has too much nitrogen or phosphorus is known as eutrophic.

The DO assessment criteria used by the Consolidated Assessment and Listing Methodology (CALM) for Class A surface waters is <6 mg/l (instantaneous) and <75% saturation (daily average) does not support aquatic life (NHDES 2012b). DO readings in the bottom 1 meter of the lake are not used in assessments due to natural boundary layer conditions that result in decreased DO at the sediment to water column interface.

Phosphorus is a nutrient that is essential to plants and animals. It gets into the water from the atmosphere and through stormwater runoff that picks it up as it travels across land surface. It can also enter lakes and ponds from wastewater discharges and animal feces. It is typically the limiting nutrient in a freshwater system, and excess amounts can cause excessive algae growth, which in turn contribute to low DO levels. Control of phosphorus sources to Lake Massabesic should therefore improve conditions related to DO such that designated uses are supported. For this reason, total phosphorus (TP) was selected as the pollutant to target in this management plan. Phosphorus levels in water are generally measured in units of micrograms per liter (ug/l) or parts per billion (ppb) and 1 ug/l is equal to 1 ppb.

Phosphorus thresholds by trophic class for aquatic life are defined by CALM as follows:

Table 3-2. Phosphorus Thresholds by Trophic Class

Trophic Status	TP (ug/l or ppb)
Oligotrophic	<8
Mesotrophic	≤12
Eutrophic	≤28

Non-native aquatic plants can include exotic macrophytes and algae that are present in the lake. Exotic plants can quickly dominate and choke out native aquatic plant growth in the surface water. The non-native aquatic plant species, variable milfoil (*Myriophyllum heterophyllum*), is present in the lake and MWW takes continuous actions to prevent its

spread. Observations of bladderwort (*Utricularia vulgaris* and *Utricularia purpurea*) and fanwort (*Cabomba caroliniana*) have also been made in the lake.

3.3 Applicable Water Quality Standards

The New Hampshire State Water Quality Standards for dissolved oxygen in Class A waters (Env-Wq 1703.07) are:

> Env-Wq 1703.07 (a): Class A waters shall have a dissolved oxygen content of at least 75% saturation, based on a daily average, and an instantaneous minimum of at least 6 mg/l at any place or time except as naturally occurs.
>
> Env-Wq 1703.07 (c): For the period from October 1st to May 14th, in areas identified by the fish and game department as cold water fish spawning areas of species whose early life stages are not directly exposed to the water, the 7 day mean dissolved oxygen concentration shall be at least 9.5 mg/l and the instantaneous minimum dissolved oxygen concentration shall be at least 8 mg/l. This period shall be extended to June 30 for a particular waterbody if the fish and game department determines it is necessary to protect spring spawners or late hatches of fall spawners, or both.
>
> Env-Wq 1703.07 (d): Unless naturally occurring or subject to (a) above, surface waters within the top 25 percent of depth of thermally unstratified lakes, ponds, impoundments and reservoirs or within the epilimnion shall contain a DO content of at least 75 percent saturation, based on a daily mean and an instantaneous minimum DO content of at least 5 mg/l. Unless naturally occurring, the DO content below those depths shall be consistent with that necessary to maintain and protect existing and designated uses.

The New Hampshire State Water Quality Standards for nutrients in Class A waters (Env-Wq 1703.14) are:

> Env-Wq 1703.14 (a): Class A waters shall contain no phosphorus or nitrogen unless naturally occurring.
>
> Env-Wq 1703.14 (c): Existing discharges containing either phosphorus or nitrogen that encourage cultural eutrophication shall be treated to remove phosphorus or nitrogen to ensure attainment and maintenance of water quality standards.
>
> Env-Wq 1703.14 (d): There shall be no new or increased discharge of phosphorus into lakes or ponds.
>
> Env-Wq 1703.14 (e): There shall be no new or increased discharge(s) containing phosphorus or nitrogen to tributaries of lakes or ponds that would contribute to cultural eutrophication or growth of weeds or algae in such lakes and ponds.

3.4 Anti-degradation Policy

In addition to the above water quality standards, NHDES has anti-degradation regulations designed to preserve and protect the existing beneficial uses of New Hampshire's surface waters and to limit the degradation allowed in receiving waters. Anti-degradation regulations are included in Part Env-Wq 1708 of the New Hampshire Surface Water Quality Regulations. According to Env-Wq 1708.02, anti-degradation applies to the following:

- All new or increased activity including point and nonpoint source discharges of pollutants that would lower water quality or affect the existing or designated uses;
- A proposed increase in loading to a waterbody when the proposal is associated with existing activities;
- An increase in flow alteration over an existing alteration; and
- All hydrologic modifications, such as dam construction and water withdrawals.

NHDES anti-degradation review is triggered for any development projects requiring any of the following permits or certificates: Water Quality Certification, the Alteration of Terrain (AoT) Permit; Wetland Permit; Shoreland Permit; and the National Pollutant Discharge Elimination System (NPDES) Program Permits.

The regulations outline limitations or reductions for future pollutant loading based on how a water body meets the water quality criteria for its designated use. These limitations are on a parameter by parameter basis and are based on an assimilative capacity analysis when adequate water quality data is available. The assimilative capacity analysis is used to determine whether or not the water body can accept additional pollutant loads and to what degree. This is described further in Section 6.0.

In cases where adequate water quality data is not available, NHDES has outlined options for meeting the anti-degradation provisions, including:

1. The applicant for the proposed development can demonstrate that it creates $\leq$10% effective impervious cover and maintains $\geq$65% undisturbed cover; or
2. The applicant for the proposed development can submit calculations showing that the project will not increase pollutant loading, will not increase the stormwater peak flow, and will maintain the groundwater recharge volume; or
3. The applicant for the proposed development can conduct a water quality analysis to determine the remaining assimilative capacity of the water body and provide calculations to show the development will not significantly degrade water quality based on the remaining capacity.

Lake Massabesic is currently listed as impaired for DO and cyanobacteria, with total phosphorus serving as a surrogate for measuring water quality. Although an assimilative capacity analysis was performed in Section 6.0 using the limited data for the lake, more

data would be needed to adequately demonstrate existing water quality and to use Option 3 above. Options 1 and 2 will most likely be applied by NHDES until more data can be collected.

3.5 Existing Water Quality Data

Manchester Water Works has been monitoring water quality in Lake Massabesic and its tributaries for a number of years. Refer to Appendix G for a map of historic sampling locations.

3.5.1 In-Lake Water Quality

In-lake sampling has included temperature, DO, conductivity and salinity profiles at five foot depth intervals at nine locations within the lake collected on an approximate weekly basis typically between June and October. This is the most extensive and consistent lake sampling data set collected by MWW. Four of the locations are within Lake Massabesic East, to represent water quality in various areas of the lake. The deep hole (ID: FRONTP – Front Park) is most representative of stratified conditions in the lake.

The other five locations are in Lake Massabesic West. Three of these are located near the intake and within the aeration bubbler system that was installed to help minimize manganese inputs into the treatment plant that occurs during turnover. The other two locations represent the other end of this portion of the lake, however, one is too shallow to see stratification in the lake and the other is in a somewhat stagnant cove, which may prevent it from providing representative water quality data.

Based on review of the DO and temperature profiles, the lake stratifies in the summer. Stratified conditions are defined by a steep temperature gradient with depth, marked by a warmer layer above (epilimnion) and cooler layer below (hypolimnion), in which the water is at different temperatures. This temperature gradient is known as the thermocline and is most prevalent during the summer when surface temperatures are much warmer than bottom temperatures. The thermocline in Lake Massabesic East is around 20 feet deep in the deep hole (Front Park). This is illustrated in Figure 3-1. A similar thermocline was observed in Lake Massabesic West near the intake (Firepoint), prior to the installation of the aeration system. Figure 3-2 shows the temperature and DO profiles at this location before and after the installation of the bubblers.

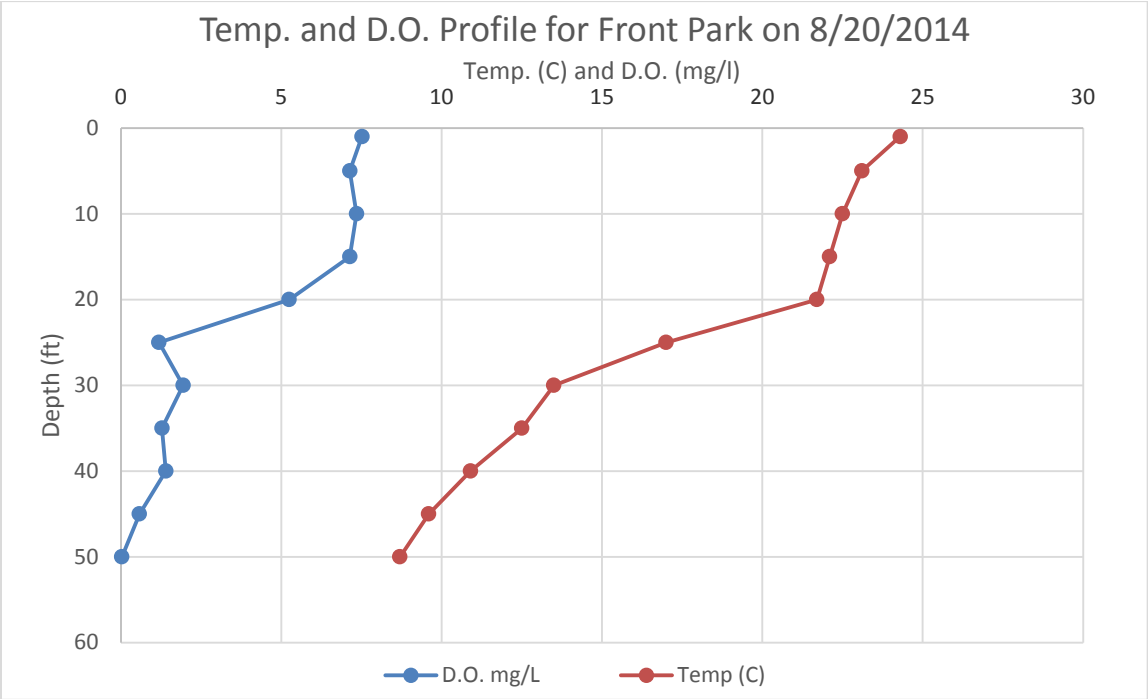


Figure 3-1. Temperature and DO Profile at Front Park in Lake Massabesic East

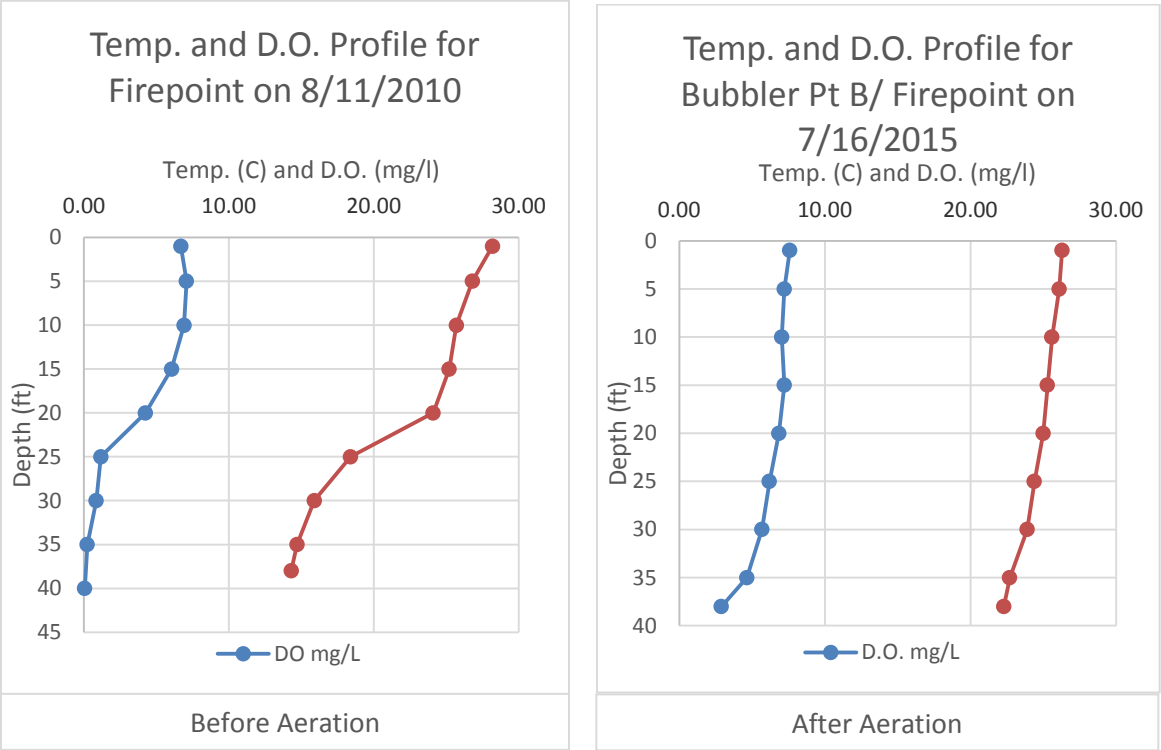


Figure 3-2. Temperature and DO Profiles at Firepoint in Lake Massabesic West – Before and After Aeration

The DO and temperature profiles are supplemented with periodic sampling and analysis of various water quality parameters (e.g., pH turbidity, color, orthophosphate, nitrate, total coliform, E. Coli, manganese, iron, and sodium). However, there is very limited data on total phosphorus, which is the targeted pollutant in freshwater lakes to limit algal blooms, including cyanobacteria, and improve dissolved oxygen levels. Appendix H provides the full phosphorus in-lake water quality data set available for Lake Massabesic East and West and includes summary tables of average concentrations for years data is available. This data set was collected from a combination of the NHDES OneStop Database (1980, 2000 and 2001 data), a report studying in-lake manganese control using aeration prepared by Ecosystem Consulting Services (ECS) (2005 data) and data collected from Manchester Water Works (2015). In each case, samples were limited to a few dates each year.

For pollutant modeling purposes (Section 5.0), the average and median total phosphorus concentration from all available data was used for calibration and comparison to modeling results. For Lake Massabesic East, the average total phosphorus concentration in the epilimnion layer is 7.5 ug/l and 8.8 ug/l in the hypolimnion layer. The median is 7.0 ug/l in the epilimnion and 8.0 ug/l in the hypolimnion.

For Lake Massabesic West, the average total phosphorus concentration in the epilimnion layer is 7.2 ug/l and also 7.2 ug/l in the hypolimnion layer. The median is 6.5 ug/l in the epilimnion and 7.0 ug/l in the hypolimnion.

In many lakes, dissolved oxygen concentrations in the bottom are typically lower than the surface due to the oxygen demand of the decomposing sediments (dead algae and plants) that lead to anoxic conditions and potential release of harmful constituents such as phosphorus and manganese. Mixing typically occurs in the spring and fall, at which time more uniform concentrations are typically seen at various depths. The limited data suggest this is occurring in Lake Massabesic to some degree with higher bottom average and median total phosphorus concentrations in the summer, particularly in Lake Massabesic East. Manganese concentrations have also been higher in the bottom samples historically for the same reasons (oxygen depletion and anaerobic respiration); however, have been improved in Lake Massabesic West through the installation and operation of an aeration system.

Although the limited data set indicates modest internal loading of phosphorus under anoxic (low oxygen) conditions, which is supported by minimal algal blooms in the lake (per conversation with MWW staff), continued growth and die off of plant matter (algal, invasives, etc.) in the lake can increase the accumulation of phosphorus in bottom sediments (phosphorus sink) for release in the future. Thus, it is important to have a program in place to monitor long-term total phosphorus concentrations in the lake and to limit phosphorus inputs to maintain lake health. Refer to monitoring recommendations in Section 7.0.

Additionally, Lake Massabesic is listed as impaired for low DO and cyanobacteria. To be removed from the list, DO levels must meet the criteria presented in Section 3.4. NHDES

is currently evaluating the process for delisting cyanobacteria impaired waters, which will include low total phosphorus, adequate DO levels and no blooms. The last documented cyanobacteria bloom was in 2004. It is unknown (e.g., no confirmed testing) whether later blooms included cyanobacteria.

3.5.2 Tributary Water Quality

The collection of tributary samples has focused on all reaches of the watershed, with up to 25 locations sampled for various water quality parameters (e.g., pH, turbidity, color, conductivity, orthophosphate, nitrate, total coliform, E. coli, manganese, iron, sodium) on a rotating basis during weekly watershed patrols. No flow data is collected during the tributary sampling events. Total phosphorus data was collected between 2009 and 2011, however, is not available for other years and cannot be correlated with flow.

Section 4 Potential Contamination Sources and Existing Protection Measures

Manchester Water Works regulates and patrols land activities and uses on MWW and watershed lands. Periodically, MWW also updates the state's Potential Contaminant Source (PCS) list to see what is shown by this state and federal database inventory of permits, listings and regulatory concerns. This section describes the pollutant source analysis performed to: 1) identify Potential Contamination Sources (PCSs) within the Lake Massabesic watershed that could potentially pose a risk to the lake's water quality; and 2) quantitatively identify total phosphorus loadings to the lake from various sources in the watershed. This section also outlines existing protection measures performed by MWW to protect the water supply and watershed.

4.1 Inventory of Potential Contamination Sources

A PCS is a facility or property with activities that have the potential to contaminate the water supply. While virtually any human activity can be considered a PCS, NHDES has identified 20 types of activities that should be included in a PCS inventory (Table 4-1).

Table 4-1. Potential Contamination Sources (PCSs)*

- Vehicle service and repair shops
- General service and repair shops
- Metalworking shops
- Manufacturing facilities
- Underground and aboveground storage tanks
- Waste and scrap processing and storage
- Transportation corridors
- Septic systems (at commercial and industrial facilities)
- Laboratories and certain professional offices (medical, dental, veterinary)
- Use of agricultural chemicals
- Salt storage and use
- Snow dumps
- Stormwater infiltration ponds or leaching catch basins
- Cleaning services
- Food processing plants
- Fueling and maintenance of earth moving equipment
- Concrete, asphalt, and tar manufacture
- Cemeteries
- Hazardous waste facilities
- Farms

* "Potential Contamination Source" means, as specified in RSA 485-C:7, I, human activities or operations upon the land surface that pose a foreseeable risk of introducing regulated substances into the environment in such quantities as to degrade the natural groundwater quality. Examples of potential contamination sources are listed in RSA 485-C:7, II.

Table taken from NHDES Fact Sheet WD-DWGB-12-3.

An inventory of PCS locations within the Lake Massabesic watershed was developed with assistance from the NHDES OneStop database and through a windshield survey with the MWW forester. Figure 4-1 shows current PCS locations in the watershed that were compiled through the database review and windshield survey.

4.1.1 Database Review

An inventory of PCS locations within the Lake Massabesic watershed was developed using the NHDES Web Geographic Information System, which provides GIS mapping and database information for various PCSs, the following which were accessed for the Lake Massabesic watershed:

- Aboveground Storage Tank Facilities
- Tier II facilities
- Asbestos Disposal Sites
- Automobile Salvage Yards
- Environmental Monitoring Sites
- Hazardous Waste Generators
- Non-point Sources
- NPDES Outfalls
- Remediation Sites
- Surface Water Impairments with 1-Mile Buffer For Development Projects
- Underground Storage Tank Facilities

Additionally, NHDES provided a GIS data layer and database of "local potential contamination sources" that were identified as part of a previous Source Assessment Report. This consists of sites identified during a windshield survey that are not included in the above OneStop databases.

Table 4-2 includes the list of PCS locations found in each of the subwatershed areas. Appendix I includes more detailed information for each of the PCSs including addresses/locations.

4.1.2 Windshield Survey

A windshield survey was performed to identify new PCSs that may not be included in the current NHDES database and to update information for existing PCS locations included in the "local potential contamination sources" data layer provided by NHDES. New PCS locations identified during the windshield survey were primarily businesses related to automotive repair, small agricultural practices (e.g., hobby farms and horse farms) and a small commercial business (landscaping business and blasting company). The PCSs identified during the windshield survey are summarized in Table 4-2 and Appendix I.

Table 4-2. Potential Contamination Sources (PCSs) within Lake Massabesic Watershed

	Number of PCSs per Watershed																				
Subwatershed	**Clark Pond**	**Clay Pond**	**Dube's Pond**	**Fan Merrill**	**Hook Brook**	**Little Lake Massabesic**	**Massabesic East**	**Massabesic West**	**Kinnicum Pond**	**Murray Mill Brook**	**Neal Brook**	**Pine Hill Road**	**Preston Brook**	**Reed Brook**	**Severance Brook**	**Spring Valley**	**Spruce Pond**	**Sucker Brook**	**Tower Hill Pond**	**Total**	**Percent**
Underground Storage Tanks	0	0	0	0	1	0	1	5	0	6	0	0	0	12	0	5	0	2	1	33	12.3%
Aboveground Storage Tanks	0	0	1	6	0	0	0	2	0	2	6	0	1	0	0	4	0	1	1	24	8.9%
Hazardous Waste Generators	0	0	0	0	0	1	3	3	0	6	8	1	0	10	0	18	0	0	1	51	19.0%
Contaminated Sites	0	0	0	5	2	0	9	10	1	6	9	1	1	10	1	19	13	1	0	88	32.7%
Local Potential Contamination Sources	7	0	0	3	0	0	5	4	1	2	6	0	2	5	2	16	0	0	5	58	21.6%
PCS Identified during Windshield Survey	0	0	1	1	0	0	0	2	3	0	0	0	1	0	1	2	1	0	3	15	5.6%
Total PCSs	7	0	2	15	3	1	18	26	5	22	29	2	5	37	4	64	14	4	11	269	100%
Percent	3%	0%	1%	6%	1%	0%	7%	10%	2%	8%	11%	1%	2%	14%	1%	24%	5%	1%	4%	100%	

4.2 Other Water Quality Threats

In addition to the PCSs, certain activities may also pose a threat to water quality. Based on knowledge of MWW staff and field observations of the watershed during the windshield survey, additional potential threats include:

- Erosion – Erosion of soils can occur as a result of wind, precipitation, and wave action in the lake. Factors such as soil type, slope and vegetative cover can influence whether and the extent to which erosion occurs. Erosion of soils into the lake or its tributaries can increase turbidity, infilling and nutrient concentrations. Evidence of erosion was observed along road shoulders and shorelines. Refer to photos in Appendix J.
- Stormwater Runoff – Stormwater runoff can carry pollutants and warm water to the lake. This is of particular concern in developed areas with more impervious surfaces, where runoff is often collected and discharged without treatment. There are several developed areas within the watershed, a number of which are in close proximity to the lake and its tributaries, such as along Route 101. Direct discharges in these areas can carry pollutants such as hydrocarbons, heavy metals and nutrients directly to the lake and its tributaries. The number of and potential impacts of direct discharges to the lake and its tributaries was not evaluated as part of this study.
- Septic systems – On-site septic systems can contribute nutrients and bacteria to the lake and its tributaries depending on the proximity. MWW currently monitors 156 septic systems in the watershed. The number of and proximity of septic systems to the lake was not evaluated further as part of this study.
- Agricultural Activities – Active farming practices in the watershed are generally limited to hobby farms and boarding horses. These hobby farms have the potential to impact the water supply depending on their practices and proximity to the lake and its tributaries.
- Recreational Activities – Common recreational activities in the watershed include boating, fishing, hiking, jogging, biking, horse riding, dog walking and picnicking. Although MWW has rules pertaining to recreational uses in the watershed, they are not always followed and can be a challenge to enforce, as described in Section 2.0 and in Appendix F. Misuse of the watershed can result in disturbance of vegetated areas by people and animals creating new paths, deposition of fecal matter in or near waterways from animals using the watershed, and litter left behind by recreational users people.
- Roadways – There are several tributary roadway crossings throughout the watershed and several roadways are in close proximity to the lake. Sanding and salting operations on these roads can impact the lake and its tributaries by contributing increased sediment loads and salt.
- Logging – Logging activities have the potential to increase erosion in the watershed, however, these can be mitigated with the use of Best Management Practices. The impacts of logging were not evaluated under this study.

- Invasive Species – Variable milfoil, bladderwort and fanwort are present in the lake as shown on Figure 2-2.

4.3 Existing Protection Measures

MWW uses a combination of methods to protect Lake Massabesic and its watershed. These are described below.

4.3.1 Policy and Staffing

The MWW Water Supply Division is responsible for providing safe drinking water to the communities it serves. In addition to treating raw water for distribution and the laboratory analysis involved with this process, the MWW also regulates and patrols watershed lands to protect its raw water supply. All of these efforts involve a staff of laboratory technicians, treatment plant operators, and watershed patrol officers and equipment operators. Refer to Figure 1-3 for an organizational chart of the Water Supply Division. Section 4.3.2 provides information on the watershed rules and regulations and patrol staffing and responsibilities.

4.3.2 Watershed Regulations and Patrols

The New Hampshire Code of Administrative Rules Part Env-Dw 902 establishes rules to protect New Hampshire drinking water supplies. Part Env-Dw 902.23 is specific to Lake Massabesic and its tributaries. A copy of the rules is included in Appendix C. In summary, the rules:

- Allow the board of water commissioners and its representatives to enter any land or property within the Lake Massabesic watershed for the purpose of investigating watershed sanitation and other sources of potential water contamination;
- Prohibit the building of any privy, pigpen, stable, or other buildings or structures in which horses, cattle, swine or other animals or fowl are kept within 200 feet of Lake Massabesic or any pond, reservoir, or stream tributary thereto. Existing properly functioning septic systems may remain in place;
- Prohibit the deposition of potential pollutants within 200 feet of the waters of Lake Massabesic or any pond, reservoir, or stream tributary thereto;
- Prohibit water contact activities and deposition of pollutants within the water of Lake Massabesic or any pond, reservoir, or stream tributary;
- Set requirements for applying pesticides, conducting forestry activities, and handling agricultural compost, chemical fertilizer or manure within the watershed;
- Prohibit the use of all-terrain vehicles, with the exception of snowmobiles, on MWW property or waters of Lake Massabesic or any pond, reservoir, or stream tributary thereto;
- Prohibit human activity in specific areas of the lake and watershed;
- Prohibit the storage of specific compounds within 300 feet of Lake Massabesic or any pond, reservoir, or stream tributary thereto;

- Require control of pets on MWW property, including use of leashes and cleaning up pet waste;
- Prohibit feeding of waterfowl;
- Restrict boating activities.

The MWW Board of Water Commissioners developed and adopted local watershed protection rules on June 1, 2014. A copy is included in Appendix C. These rules pertain to the use of MWW property, specifically:

- Prohibition of alcoholic beverages and the sale of food, drink, or merchandise;
- Operation of motor vehicles;
- Managing pets;
- Horseback riding restrictions and requirements for collecting horse waste as it is produced;
- Approval for group activities;

MWW employs a staff of two full time and two part time watershed patrol officers who monitor all activity in the watershed and enforce the regulations pertaining to Lake Massabesic using their Standard Operating Procedures (SOPs) (Appendix D). Typical patrol duties include:

- Enforcement of rules;
- Inspecting Potential Contamination Sources, including septic systems;
- Checking for Ice In/Ice Out;
- Inspecting and marking boundary lines;
- Operating the Tower Hill gate;
- Reading gauges at five stations (Sucker Brook, Tower Hill Pond, Main Dam, Derryfield Station, Cohas Station);
- Inspecting specific areas in the watershed on a daily basis, weekly or monthly basis including dams and tanks; and
- Collecting water samples from tributaries, distribution system and monitoring wells for laboratory analysis.

MWW strives to protect its water supply and watershed while minimizing the impact on water rates. The existing level of staffing is inadequate to allow the performance of all of the watershed patrol duties to the level needed.

4.3.3 Land Acquisition

MWW has and continues to actively acquire land throughout the watershed to protect its water supply and currently owns over 8,000 acres (~30%) of the 9,200 acres protected through conservation easements, deed restrictions and fee ownership. Ownership allows MWW to control all activities that occur on their lands.

There still remains a significant amount of undeveloped land in the Lake Massabesic Watershed that is not protected and subject to future development. MWW still considers future land acquisition a priority to protect the water supply.

4.3.4 Forestry Practices

The MWW has a licensed professional forester on staff and manages the forests within the watershed in accordance with its Forest Management Plan (Appendix B). The program includes annual selective tree harvesting on approximately 300 acres of forested land. This has been determined to be a suitable level for the 8,000 acres of MWW owned land. The current Forest Management Plan was developed in 2008. It includes guidance and policies for sustainable forest management activities for the maintenance of a healthy watershed. All forest harvesting activities are performed by private contractors under the supervision of MWW's professional forester. The plan is slated to be updated every 5 years, however, the most recent plan is dated 2008.

4.3.5 Invasive Species Control

The MWW has an active invasive species control program to prevent the growth and spread of invasive plant species, with a focus on variable leaf milfoil (VLM), *Myriophyllum heterophullum*, in the lake. Terrestrial invasive species in the watershed also pose a concern, including oriental bittersweet (*Celastrus orbiculatus*), european buckthorn (*Rhamnus cathartica*), japanese barberry (*Berberis thunbergii*), purple loosestrife (*Lythrum salicaria*), and japanese knotweed (*Fallopia japonica*). The MWW does not use any herbicides on terrestrial or aquatic plant growth as part of its control program, rather relies on mechanical harvesting for control.

NHDES prepared a Long-Term Variable Milfoil Management and Control Plan for Lake Massabesic in April 2010 (Appendix J). The plan identifies the lake's beneficial use areas, provides a map of the native and exotic aquatic macrophyte species distribution, identifies short- and long-term exotic aquatic plant control goals, recommends exotic plant control actions, and recommends monitoring strategies to determine the success of the control practices over time.

Annual surveys have helped identify new areas of VLM and other invasive plants, allowing for rapid response and minimizing the spread of these plants outside of the established areas.

MWW currently uses a diver assisted suction harvesting (DASH) method to manage invasive plants in the lake. MWW notifies the public when work is to be performed. Divers hand pull plants and use a vacuum to transport the pulled plants to the surface. A silt screen is placed around the harvesting area prior to pulling the plants to minimize the transport of sediments. The work is performed by MWW staff and private contractors. All are licensed by NH DES. In addition to DASH methods, MWW uses benthic barrier mats in select areas to block light and prevent photosynthesis of invasive plants. MWW also ropes off large infestation areas to prevent boats from breaking up and making plants

mobile. MWW dedicates about $30,000 per year to these efforts with success rates varying by location.

The approach to date has focused on the prevention of VLM from spreading in the lake. Once VLM spreads to a large area removal becomes more difficult and expensive, and may require full harvesting with mechanical equipment and/or the application of herbicides to effectively control, both of which have negative impacts to water quality and habitat. Thus, continuation of current control measures is recommended in accordance with the existing actions taken.

Additional recommendations for tracking are included in Section 7.0.

4.3.6 City/Town Regulations

Local zoning ordinances and regulations were also reviewed in the communities of Manchester, Auburn, Candia and Hooksett to identify additional protection measures beyond the MWW rules.

<u>City of Manchester</u>

The City of Manchester Zoning Ordinance includes a Lake Massabesic Protection Overlay District (LMPOD), which was added in November 2006. The purpose of the overlay district is to protect the Lake Massabesic drinking water supply. It includes the entire Lake Massabesic watershed located in Manchester.

The following uses are prohibited in the LMPOD:

- Taxi, bus, rail terminal
- Sales or rental of motor vehicles
- Sales, rental, repair of boats, etc.
- Sales, rental, repair of heavy equipment
- Automotive repair
- Automotive service station
- Carwashes and car care centers
- Accessory outside storage for industrial or commercial use
- Accessory manufacturing use
- No impervious surfaces are allowed within 50 feet of waterways or wetlands with the exception of residential lots of 12,500 square feet or less and commercial/industrial lots of less than one acre in the B-2 Zoning District.

The City also has a Stormwater Ordinance for construction projects disturbing 1-acre or more of land. The ordinance was developed for compliance with the National Pollutant Discharge Elimination System (NPDES) Phase II Program (2003 Municipal Separate Storm Sewer System (MS4) Permit) and requires applicants to prepare and submit a Notice of Intent (NOI) and Stormwater Pollution Prevention Plan (SWPPP) for submission to EPA and the City Highway Department. The SWPPP must include a site map showing surface waters, disturbed areas, and best management practices (BMPs) and

requires inspection of all erosion and sediment control BMPs and maintenance performed. The focus of the SWPPP is on stormwater control measures to be used during construction activities and stabilization of the site upon completion of construction activities. It does not require the development of control measures to treat stormwater runoff from the completed site.

The subdivision and site plan review regulations require applicants to maintain pre-development runoff rates (peak rate control); however, do not have requirements for the treatment of stormwater runoff from the site.

EPA is in the process of revising and renewing the 2003 MS4 permit, which will include more prescriptive stormwater treatment requirements for regulated MS4 to incorporate into their local regulations. As a Phase II community, Manchester will be required to update its regulations to comply with the new permit. This will offer additional protection to surface waters throughout the City, including Lake Massabesic, and can serve as a model for other watershed communities to consider.

Town of Auburn

The Town of Auburn is also designated as an MS4 community under EPA's NPDES Phase II Program.

Auburn's Zoning Ordinance includes a Wetlands and Watershed Protection Area (WWPA) overlay district that requires a buffer zone of 125 feet setback from the edge of certain wetlands, all bodies of water, brooks and streams and all vernal pools. No septic system, lawn, yard, parking lot or landscaping shall be constructed within the WWPA and no structure shall be constructed within the WWPA, except for minor accessory structures expressly permitted. In addition, no storage of petroleum products, hazardous chemicals or material shall occur within the WWPA. No chemical fertilizers, pesticides, insecticides, or herbicides shall be used within the WWPA.

Subdivision regulations requires applicants to submit a stormwater management and erosion and sedimentation control plan for any tract of land being subdivided where the cumulative disturbed area exceeds 20,000 square feet; construction or reconstruction of a street or road; a subdivision of more than three building lots; and/or disturbed critical areas. All measures in the plan must meet the Best Management Practices set forth in the "Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire." Rockingham County Conservation District, NH Department of Environmental Services, Soil Conservation Service, August 1992, as amended, a copy of which is available in the Planning Board office. BMPs must be used to provide 80% removal of total suspended solids (TSS) from paved surfaces. A minimum 10% of the differential between the volume of the pre-development and post-development must be held or infiltrated on site for the duration of the 10-year storm event.

Site plan regulations require that Major Site Plans (a cumulative disturbed area exceeding 20,000 square feet; construction or reconstruction of a street or road; or disturbed critical

areas) include plans for managing stormwater and controlling erosion and sedimentation with the same design requirements as the Subdivision regulations outlined above. No more than 40% of a lot may be covered by impervious material.

The Site Plan regulations also offer an incentive bonus for additional stormwater controls. If the Applicant can demonstrate through accepted engineering practices that the stormwater system design for a project is providing additional stormwater controls resulting in additional pollution reduction of total suspended solids in excess of eighty (80%) percent, the amount of allowable impervious lot coverage can be increased (up to 70% from an otherwise maximum of 40%).

Town of Candia

The Town of Candia Zoning Ordinance has a Wetlands Conservation District that includes all areas of very poorly drained soils; areas of poorly drained soils ½ acre or more in size; and areas of poorly drained soils of any size if contiguous to surface waters such as lakes, ponds and streams subjected to high water tables for extended periods of time. Structures, dredging and filling are prohibited in these areas. Septic systems may not be installed within 75 feet of the edge of any wetland.

The Zoning Ordinance also includes a Groundwater Protection District, which is an overlay district that is superimposed over the existing underlying zoning of the entire Town of Candia. The regulations require:

- Preparation of a Stormwater Management Plan for any use that will render impervious more than 15% or more than 10,000 square feet of any lot, whichever is greater. The plan must be prepared in a manner consistent with Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire, Rockingham County Conservation District, August 1992 and Best Management Practices for Urban Stormwater Runoff, NH Department of Environmental Services, January 1996. The Stormwater Management Plan must demonstrate that the stormwater recharged to groundwater will not result in violation of Ambient Groundwater Quality Standards at the property boundary.
- Animal manures, fertilizers, and compost must be stored in accordance with the Manual of Best Management Practices for Agriculture in New Hampshire, NH Department of Agriculture, Markets, and Food, August, 1998, and subsequent revisions.
- Requirements for the storage of regulated substances, including secondary containment of substances if an aggregate of 275 gallons or more are stored outdoors.
- All land cleared and graded for the purpose of establishing lawns must be finish graded with at least 4 inches of good quality loam or topsoil.
- The following uses are prohibited: hazardous waste disposal facilities; solid waste landfills; wastewater or septage lagoon, sludge monofill or sludge composting facility; storage of regulated substances, unless in a free-standing container within a building, or aboveground with secondary containment; storage

of commercial fertilizers unless within a structure designed to prevent the generation and escape of runoff or leachate; and junkyards, unless certified by the NH DES as a Green Yards. Some exemptions apply.

The Subdivision Regulations require applicants to submit a Sediment and Erosion Control Plan. Subdivision grading and drainage plans must include final drawings and specifications for each proposed soil erosion and sediment control measure and for proposed stormwater retention facilities for groundwater recharge.

The Site Plan Review Regulations require that storm drainage design be based on a 25-year storm design flow.

Town of Hooksett

The Town of Hooksett is also designated as an MS4 community under EPA's NPDES Phase II Program.

The Town of Hooksett Zoning Ordinance has a Wetlands Conservation Overlay District that includes all wetland areas within Town. Structures, dredging and filling are prohibited in these areas.

The Zoning Ordinance also includes a Groundwater Resource Conservation District, which encompasses areas that have been designated as wellhead protection areas and stratified drift aquifers. The regulations prohibit specific uses and activities that could contaminate the groundwater aquifer and require:

- Restriction on the amount of impervious area (no more than 10% for a single lot or building site or more than 2,500 square feet of any lot or building site) unless certain provisions are provided as outlined in a stormwater management plan submitted to the planning board. The stormwater management plan must include best management practices designed to retain or percolate all development generated stormwater runoff for the 2-year, 10-year, 50-year and 100-year storm events for the site. It must also provide for removal of oil and gasoline from parking lot runoff prior to retention and percolation.
- There are requirements for the storage and security of regulated substances.
- Storm drainage shall be designed to maintain infiltration to groundwater.
- Buffers must be maintained around Pinnacle Pond and along Brickyard Brook.

Septic systems may not be installed within 75 feet of the edge of a public water body and/or a well.

The Town of Hooksett Development Regulations include general development regulations (Part I), subdivision regulations (Part II) and site plan regulations (Part III). Some of the requirements pertaining to stormwater management include:

- Section 6.08 of Part I references NHDES Rule Env-Ws 415.11(a) through (h) and Env-Ws 386.47(r), which pertains to Lake Massabesic calls for a 300-foot or 200-

foot buffer respectively, prohibits certain high-risk land uses, limits impervious areas, and requires stormwater treatment.

- Section 11.12 of Part I outlines drainage design criteria for development plans and requires all drainage design to adhere to the latest editions of Volume 1, Volume 2 and Volume 3 of the NHDES Alteration of Terrain program and the local Development Regulations. Specifically, all proposed projects must meet the requirements for stormwater quality as required in the NHDES Alteration of Terrain (AoT) Design Volume 1. If no AoT permit is required, no detention is proposed, and/or the site is a redevelopment, approved BMPs shall be used to provide 80% removal of total suspended solids. All projects, regardless of amount of proposed impervious coverage must follow the recharge and site stormwater retention criteria requirements of the AoT Stormwater Manuals.
- Section 14 of Part I requires development of an Erosion Prevention Plan (EPP) for an site involving one acre or more of impact.

4.3.7 Public Education

School Education Program

MWW has a comprehensive public education program that targets 3rd and 4th grade students in the City of Manchester. The program began in 1994 and includes classroom presentations, a 3rd grade poster contest and a 4th grade science fair. MWW staff introduce third graders to the source of drinking water, how it is treated and the water cycle and invite them to participate in a theme based poster contest. Fourth grade classes are introduced to water pollution, watersheds and water conservation and students are invited to participate in a water science fair. MWW provides small prizes to all poster contest and science fair participants. The winners and their families are invited to MWW's "Water Fun Day and City Wide Science Fair Finals" to enjoy food, games, and festivities and receive awards.

Educating children brings the public education process full circle. Children bring home and share information and concerns with their parents. Parents will learn more and likely reinforce the lessons taught to children at school through example. As children mature into young adults, the hope is that they will retain the lessons and habits instilled by teachers and parents and pass these along to their children.

Other Education Activities

In addition to the school education program, the MWW forester gives historical presentations on MWW and Lake Massabesic and also does forestry and green landscape presentations. These are often through local civic groups and the Audubon Center.

4.3.8 Water Quality Monitoring

Manchester Water Works has been monitoring Lake Massabesic and its tributaries for a number of years. In-lake sampling has included temperature, DO, conductivity and salinity profiles at five foot depth intervals at nine locations within the lake collected on

an approximate weekly basis typically between June and October. This is the most extensive and consistent lake sampling data set collected by MWW. Four of the locations are within Lake Massabesic East, to represent water quality in various areas of the lake. The deep hole (ID: FRONTP – Front Park) is most representative of stratified conditions in the lake.

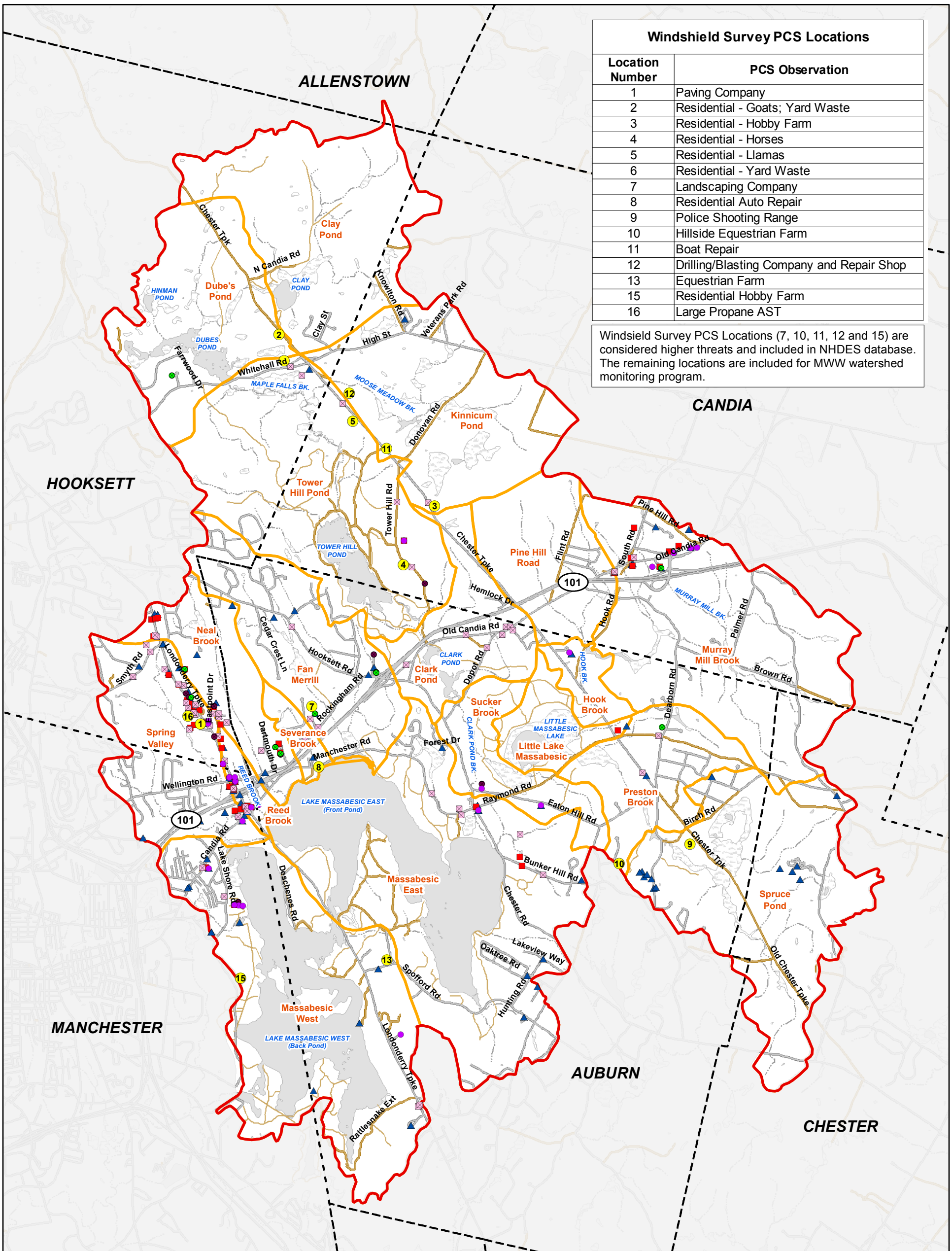
The other five locations are in Lake Massabesic West. Three of these are located near the intake and within the aeration bubbler system that was installed to help minimize manganese inputs into the treatment plant that occurs during turnover. The other two locations represent the other end of this portion of the lake, however, one is too shallow to see stratification in the lake and the other is in a fairly stagnant cove, which may prevent it from providing representative water quality data.

The DO and temperature profiles are supplemented with periodic sampling and analysis of various water quality parameters (e.g., pH turbidity, color, orthophosphate, nitrate, total coliform, E. Coli, manganese, iron, and sodium). However, there is very limited data on some of the most important parameters, which include total phosphorus and Chlorophyll-a measurement.

The collection of tributary samples has focused on all reaches of the watershed, with up to 25 locations sampled for various water quality parameters (e.g., pH, turbidity, color, conductivity, orthophosphate, nitrate, total coliform, e. Coli, manganese, iron, sodium) on a rotating basis during weekly watershed patrols. No flow data is collected during the tributary sampling events.

Again, however, the most important parameter Total Phosphorus, is not often sampled (it must go out to a lab). Total phosphorus data was collected between 2009 and 2011, however, is not available for other years and cannot be correlated with flow. In addition, no Dissolved Oxygen or temperature data is taken, which should be collected with a multi meter. These could all be quite meaningful data if collected, so a few recommendations for modifications to the program are described below.

Recommendations to the monitoring program are included in Section 7.0.



Windshield Survey PCS Locations

Location Number	PCS Observation
1	Paving Company
2	Residential - Goats; Yard Waste
3	Residential - Hobby Farm
4	Residential - Horses
5	Residential - Llamas
6	Residential - Yard Waste
7	Landscaping Company
8	Residential Auto Repair
9	Police Shooting Range
10	Hillside Equestrian Farm
11	Boat Repair
12	Drilling/Blasting Company and Repair Shop
13	Equestrian Farm
15	Residential Hobby Farm
16	Large Propane AST

Windsield Survey PCS Locations (7, 10, 11, 12 and 15) are considered higher threats and included in NHDES database. The remaining locations are included for MWW watershed monitoring program.

Legend

Potential Contamination Sources (PCS)

- Underground Storage Tanks
- Aboveground Storage Tanks
- Local Potential Contamination Sources
- Hazardous Waste Generators
- Contaminated Sites
- Windshield Survey PCS Locations

- Subwatershed Boundaries
- Lake Massabesic Watershed
- Town Boundary

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

Note: Aboveground Storage Tanks locations include EPCRA Tier II Facilities
PCS Data Sources: MWW, NHDES

0 2,500 5,000 10,000 15,000 Feet

Figure 4-1

Lake Massabesic Watershed Management Plan

NHDES Potential Contamination Sources (PCS) and Windshield Survey PCS Observations

Manchester Water Works

Comprehensive Environmental Inc.

Section 5 Pollutant Load Analysis

5.1 Introduction

Pollutant modeling was performed to evaluate and identify total phosphorus loads to Lake Massabesic from various sources within the watershed. While there is not enough in-lake and tributary phosphorus data available to accurately calibrate the model, it does provide a first step that can be used to comparatively evaluate sources and sets the model up for future calibration as data is collected.

As currently set up, the model shows that the upper ponds and wetland network provide a large amount of phosphorus attenuation, with higher loads associated with the closest subwatershed to the Lake. Figure 5-1 shows the pollutant load distribution by sources, including atmospheric, septic systems, internal loading and subwatershed loads (e.g., from stormwater runoff and baseflow). A more detailed description of the modeling process is provided in the following sections.

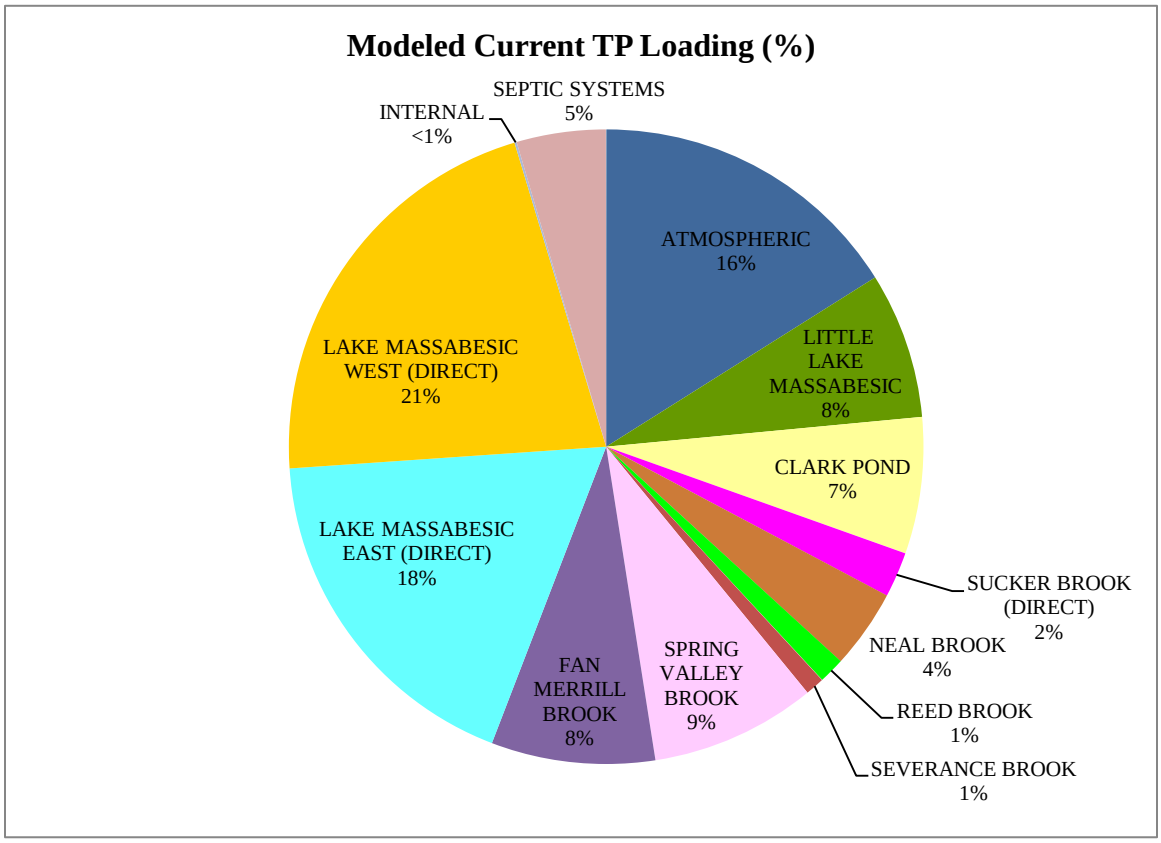


Figure 5-1. Modeled Total Phosphorus Loads to Lake Massabesic West by Source

5.2 Pollutant Loads

Total phosphorus (TP) loadings to Lake Massabesic were assessed using a land use export coefficient model[1] developed for use in New England and modified for New Hampshire lakes by incorporating New Hampshire land use TP export coefficients when available and adding septic system loading into the model.

The direct and indirect nonpoint sources of TP to Lake Massabesic evaluated within the model include:

- Atmospheric deposition (through direct precipitation to the lake);
- Surface water base flow (dry weather tributary flows, including any groundwater seepage into streams from groundwater);
- Stormwater runoff (runoff draining to tributaries or directly to the lake);
- Internal recycling (release from sediment by chemical interaction);
- Waterfowl (direct input from waterfowl); and
- Direct groundwater seepage including septic system inputs from shorefront residences.

Temporary construction discharge and impacts are not incorporated into the model due to their variability and short-term impacts. Construction activities that disturb greater than one acre of land and convey stormwater to surface water require a federal General Permit for Stormwater Discharge from Construction Activities, which requires the use of controls to reduce pollution from these sources.

TP loads were estimated for each of the nineteen subwatersheds on runoff and groundwater land use export coefficients. The TP loads were then attenuated such that the predicted in-lake TP concentrations matched observed in-lake TP concentrations. All basins were given the same attenuation factor at this time due to the limited TP water quality data. These should be refined in the future to incorporate TP concentrations observed in tributaries and in the lake, and to account for comparative slope, soils and wetlands attenuation between basins.

Loads from the watershed as well as direct sources were then used to predict in-lake concentrations of TP, chlorophyll-a, Secchi Disk Transparency, and algal bloom probability. The estimated load and in-lake predictions were then compared against measured in-lake concentrations with further adjustment of attenuation factors to achieve a close agreement between predicted in-lake TP and observed mean/median TP.

5.2.1 Hydrologic Inputs and Water Loading

Calculating total phosphorus loads to Lake Massabesic requires estimation of the hydrologic budget or quantity of water flowing into the lake. The three primary sources of water are: 1) direct precipitation onto the lake surface; 2) stormwater runoff from the watershed, which enters tributaries to the lake and/or drains directly to the lake; and 3)

[1] Lake Loading Response Model (LLRM)

baseflow, which includes all precipitation that infiltrates and is then subsequently released to surface water in the tributaries or directly to the lake (i.e., groundwater). Baseflow typically represents the minimum flows to the tributaries and lake during dry weather. The water budget is broken down into its components in Table 5-1, with further description of each of these components provided below:

1. Direct precipitation – Mean annual precipitation was assumed to be representative of a typical hydrologic period for the watershed. The annual precipitation value was obtained from the NOAA National Climatic Data Center's *Current Results, Weather and Science Facts* website[2], which provides an annual precipitation average for Lake Massabesic based on weather data collected from 1981 to 2010. For the Lake Massabesic watershed, 1.07 meters (42 inches) of annual precipitation was used.
2. Runoff – For each land use category, annual runoff was calculated by multiplying mean annual precipitation by basin area and a land use specific runoff fraction. The runoff fraction represents the portion of rainfall converted to overland flow.
3. Baseflow – The baseflow calculation was calculated in a manner similar to runoff. However, a baseflow fraction was used in place of a runoff fraction for each land use. The baseflow fraction represents the portion of rainfall converted to baseflow.

Table 5-1. Lake Massabesic Water Budget

	Lake Massabesic East	Lake Massabesic West
Water Budget	**M^3/Yr**	**M^3/Yr**
Direct Precipitation	5,994,300	10,684,361
Watershed Runoff	27,348,378	28,627,622
Watershed Baseflow	34,522,437	36,136,814
Total	67,865,115	75,448,797

The hydrologic water budget was further broken down by major contributing drainage area and is presented as Figure 5-2.

Runoff and baseflow fractions[3] were assumed to be representative for NH land uses and are listed in Tables A-1 and A-2 in Appendix A. The hydrologic budget was calibrated to a representative standard water yield for New England[4], verified by assessment of yield from various New England USGS flow gauging stations). Calibration was achieved by attenuating (reducing) the water load in each subwatershed to achieve better agreement

[2] Current Results. 2015. Retrieved October 2015. Average Annual Precipitation for New Hampshire. < http://www.currentresults.com/Weather/New-Hampshire/average-yearly-precipitation.php >

[3] Dunn, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, San Francisco, CA

[4] Sopper, W.E. and H.W. Lull. 1970. Streamflow Characteristics of the Northeastern United States. Bulletin 766. Penn State Agricultural Experiment Station, University Park, PA

with the standard water yield for New England. More detail on the methodology for hydrologic budget estimation and calibration is presented in Appendix L.

5.2.2 Phosphorus Inputs

Land Use Export

Land uses within the watershed were determined using Geographic Information System (GIS) data.

The TP load for each subwatershed was calculated using export coefficients for each land use type. The watershed load (baseflow and runoff) was combined with direct loads (atmospheric, internal load, septic system, and waterfowl) to calculate TP loading. The generated load to the lake was then input into a series of empirical models that provided predictions of in-lake TP concentrations, chlorophyll-a concentrations, algal bloom frequency and water clarity. Details on model input parameters and major assumptions used to estimate the baseline loading (i.e., existing conditions) for Lake Massabesic are described below.

- Areal land use estimates were generated from land use and land cover GIS data layers from the Southern New Hampshire Planning Commission (SNHPC) (Figure 2-4). Land use categories were matched with the LLRM land use categories and their respective TP export coefficients. Table 2-2 provides land use areas by subwatershed as used in the model. Table A-3 in Appendix A lists LLRM land use categories in which the GRANIT categories were matched.
- TP export coefficient ranges were derived from values summarized by Reckhow et al.[5] and Schloss and Connor[6]. Table A-4 (Appendix A) provides ranges for export coefficients and the runoff and baseflow export coefficient for each land use category in the Lake Massabesic watershed and the sources for each export coefficient.
- Annual areal loading of TP from the watershed (nineteen subwatersheds) is estimated to be 541 kg/yr., which represents 79% of the total load to Lake Massabesic West.

Atmospheric Deposition

TP inputs from atmospheric deposition were estimated based on a TP coefficient for direct precipitation. The atmospheric load of 0.25 kg/ha/yr. includes both the mass of TP in rainfall and the mass in dryfall[7]. The sum of these masses is carried by rainfall. As a

[5] Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011, US-EPA, Washington, D.C.

[6] Schloss, J.A. and J. Connor. 2000. Development of Statewide Nutrient Loading Coefficients through Geographic Information System Aided Analysis. University of New Hampshire, Water Resources Research Center, project summary.

[7] Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems. Academic Press: Boston.

result, the concentration calculated for use in the loading estimate (23 ug/l) is comparable to the mean concentration (25 ug/l) observed in rainfall in Concord, NH. The coefficient was then multiplied by the lake area (ha) in order to obtain an annual atmospheric deposition TP load. The contribution of atmospheric deposition to the annual TP load to Lake Massabesic West was estimated to be 110 kg/yr. or 16% of the total load.

Internal Loading

Internal TP loading was estimated as the difference between the hypolimnetic and epilimnetic TP concentrations in late summer for the years when TP data was available, multiplied by the volume of the hypolimnion (Table A-5 in Appendix A). Internal loading of TP to Lake Massabesic East was estimated at about 13 kg/yr and to Massabesic West, 0.78 kg/yr. Massabesic West has a smaller area and volume exposed to anoxic (low DO) conditions and the aeration system helps to keep TP levels low in the hypolimnion layer. These values are based on the hypolimnion at an average depth of 20 feet (6.1 meters) and only represent <1-2% of the total TP load. Additional data collection and analysis of temperature, DO and TP in the deep spots of both lakes, can be used to refine and provide a range for these estimations in the future, as the area of soils subject to anoxic conditions can fluctuate from year to year with the elevation that the hypolimnion starts. Additional data collected in the fall can also be used to assess the mixing of layers and changes in TP in the epilimnion. Low DO may also occur over the winter, releasing phosphorus to the water column, making it readily available for spring blooms.

Septic Systems

TP export loading from residential septic systems was estimated for the 156 septic systems that MWW monitors, assuming all were proximate enough to contribute some phosphorus load to the lake. Septic systems were not mapped to determine proximity to the shoreline. A more detailed analysis can be performed in the future to refine TP loadings from septic systems.

The TP load was calculated by multiplying a TP export coefficient (based on literature values for wastewater TP concentrations and expected water use), the number of dwellings, the mean number of people per dwelling, the number of days occupied per year, and an attenuation coefficient. In Lake Massabesic, the TP loading from septic systems was estimated to be 31 kg/yr. (5%) of the TP load to Lake Massabesic West.

The following assumptions were used in estimating the TP load from septic systems.

- All were assumed to be year round.
- 2.77 people were estimated to reside in each dwelling (Auburn, NH household population). It was estimated that each resident uses 65 gallons per day for 365 days per year.

- The TP coefficients were calculated based on mean TP concentration in domestic wastewater of 8 mg/l and mean household water uses[8].
- All septic loads to Lake Massabesic were attenuated 90%[9&10] to account for TP uptake in the soil between the septic systems and the lake.

Waterfowl

Records for most waterfowl populations are not kept by MWW, however field staff report the number of waterfowl observed on the lake are typically low and have not observed any water quality impacts associated with waterfowl. Typical waterfowl identified on the lake include loons and wood ducks. Canadian geese have been observed near the water treatment plant and a small flock of seagulls (approximately 30-50 seagulls) have been observed congregating near the intake. Loons are the only waterfowl population that is monitored. The Loon Preservation Society maintains several floating nests in the lake and has documented the presence of nine pairs of loons on the lake.

Due to low waterfowl populations, the TP load was assumed to be negligible. However, should waterfowl populations increase, the model should be refined to account for it.

5.2.3 Phosphorus Loading Assessment Summary

The current TP load to Lake Massabesic West was estimated to be 683 kg/yr. from all sources as shown in Table 5-2. Phosphorous loading from the watershed, which includes stormwater runoff and groundwater, was overwhelmingly the largest source at 541 kg/yr. (approximately 78% of the TP load). This is the total TP load considering attenuation throughout the watershed. Table 5-3 provides a breakdown of phosphorus loads by subwatershed. The loads in this table represent the TP loads that reach the lake from each subwatershed after considering all downgradient attenuation factors.

For comparison to the hydrologic budget, the total phosphorus loads were broken down by major drainage area/tributary to the lake as shown in Table 5-4 and Figure 5-1.

TP loading from the Lake Massabesic West subwatershed was the highest at 146 kg/yr. (Table 5-4), followed by the Lake Massabesic East subwatershed at 123 kg/yr. These represent direct contributions to the lake, therefore receive less cumulative attenuation than subwatersheds located further upgradient.

The next largest TP source other than the watershed loads is atmospheric deposition, followed by septic systems with the internal loading representing the smallest load.

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[8] Metcalf & Eddy, Inc. 1991. 3rd ed. Wastewater Engineering Treatment, Disposal and Reuse. Tchobanoglous, G. and F.L. Burton. McGraw-Hill, Inc.: New York.

[9] Dudley, J.G. and D.A. Stephenson. 1973. Nutrient Enrichment of Ground Water from Septic Tank Disposal Systems. Upper Great Lakes Regional Commission.

[10] Brown and Associates. 1980. An assessment of the impact of septic leach fields, home lawn fertilization and agricultural activities on groundwater quality. Prepared for NJ Pinelands Commission. K.W. Brown and Associates, College Station, TX.

Table 5-2. Modeled Total Phosphorus Loads to Lake Massabesic (kg/yr)		
	Lake Massabesic East	**Lake Massabesic West**
Atmospheric (Direct Precipitation to Lake)	140	110
Internal	13	0.8
Watershed Runoff	647	532
Watershed Baseflow	11	9
Septic Systems[1]	31	31
Total	842	683

Table 5-3. Total Phosphorus Loads by Subwatershed[1] (kg/yr)		
Basin	**TP Loads to Lake Massabesic East**	**TP Loads to Lake Massabesic West**
Clark Pond	25	15
Clay Pond	5	3
Dubes Pond	9	6
Fan Merrill Brook	95	57
Hook Brook	5	3
Little Lake Massabesic	6	3
Lake Massabesic West	-	146
Lake Massabesic East	205	123
Kinnicum Pond	15	9
Murray mill Brook	30	18
Neal Brook	46	27
Pine Hill Road	10	6
Preston Brook	18	11
Reed Brook	15	9
Severance Brook	11	7
Spring Valley Brook	96	58
Spruce Pond	16	10
Sucker Brook	26	16
Tower Hill Pond	25	15
Total	**658**	**541**

Notes:
[1]All loads represent the amount of TP that reaches the lake from each subwatershed after accounting for attenuation factors for downgradient subwatersheds it flows through. The attenuation factors retain some of the phosphorus loads in the watershed due to wetlands, waterbodies, etc. and are cumulative. Thus, a particular subwatershed may have a higher initial load that is decreased through attenuation before it reaches the lake. Attenuation factors can be adjusted when additional data is collected and used to calibrate the model.

Table 5-4. Modeled Total Phosphorus Loads to Lake Massabesic by Major Drainage Area				
	Lake Massabesic East		Lake Massabesic West	
Phosphorus Budget	Kg/yr	% Load	Kg/yr	% Load
Atmospheric	140	17%	110	16%
Internal	13	2%	1	<1%
Septic	31	4%	31	5%
Little Lake Massabesic (Cumulative)	85	10%	51	7%
Clark Pond (Cumulative)	79	9%	47	7%
Sucker Brook (Direct)	26	3%	16	2%
Neal Brook	46	5%	27	4%
Reed Brook	15	2%	9	1%
Severance Brook	11	1%	7	1%
Spring Valley Brook	96	11%	58	8%
Fan Merrill Brook	95	11%	57	8%
Lake Massabesic East (Direct)	205	24%	123	18%
Lake Massabesic West (Direct)			146	21%
Total	**842**	**100%**	**683**	**100%**
Watershed Total	**658**		**541**	

Note: The direct and cumulative loads in this table represent the amount of TP reaching the lake after all attenuation factors are applied.

5.2.4 Lake Response to Current Loads

TP load outputs from the LLRM Methodology were used to predict in-lake TP concentrations using five empirical models. The models include: Kirchner-Dillon[11], Vollenweider[12], Reckhow[13], Larsen-Mercier[14], and Jones-Bachmann[15]. These empirical models estimate TP from system features, such as depth and detention time of the waterbody. The load generated from the export portion of the model was used in these equations to predict in-lake TP. The mean predicted TP concentration from these models was compared to measured (observed) values. Input factors in the export portion of the model, such as export coefficients and attenuation, were adjusted to yield an acceptable agreement between measured and average predicted TP. Because these empirical models account for a degree of TP loss to the lake sediments, the in-lake concentrations predicted

[11] Kirchner, W. and P. Dillon. 1975. An Empirical Method of Estimating the Retention of Phosphorus in Lakes. Water Resource. Res. 11:182-183.

[12] Vollenweider, R.A. 1975. Input-output models with special references to the phosphorus loading concept in limnology. Schweiz. Z. Hydrol. 37:53-62.

[13] Reckhow, K. 1977. Phosphorus Models for Lake Management. Ph.D. Dissertation, Harvard University, Cambridge, MA.

[14] Larsen, D. and H. Mercier. 1976. Phosphorus Retention Capacity of Lakes. J. Fish. Res. Bd. Can. 33:1742-1750.

[15] Jones, J. and R. Bachmann. 1976. Prediction of Phosphorus and Chlorophyll Levels in Lakes. JWPCF 48:2176-2184.

by the empirical models are lower than those predicted by a straight mass-balance where the mass of TP entering the lake is equal to the mass exiting the lake without any retention. Also, the empirical models are based on relationships derived from many other lakes. As such, they may not apply accurately to any one lake, but provide an approximation of predicted in-lake TP concentrations and a reasonable estimate of the direction and magnitude of change that might be expected if loading is altered.

The predicted in-lake phosphorus concentration compared to historic observed concentrations is provided in Table 5-5.

The TP load estimated using the modeling methodology translates to predicted mean in-lake concentrations ranging from 6 to 9 ug/l for Lake Massabesic East with a mean of 7.5, and ranging from 5 to 8 ug/l for Lake Massabesic West with a mean of 6.5. The mean epilimnetic TP concentration from observed in-lake data was 7.5 ug/l for Lake Massabesic East and 7.2 ug/l for Lake Massabesic West (median of 6.5 ug/l). The empirical models all predict mean annual TP concentrations assuming fully mixed conditions. Further calibration should be performed upon the collection of additional tributary and in-lake data to reflect current observed conditions.

Once TP estimates were derived, annual mean chlorophyll-a and Secchi Disk Transparency (SDT) can be predicted based on another set of empirical equations: Carlson[16], Dillon and Rigler[17], Jones and Bachman[18], Oglesby and Schaffner[19], Vollenweider[20], and Jones, Rast and Lee[21]. Algae bloom frequency (leading to an increase in chlorophyll-a in the water) was also calculated based on equations developed by Walker[22][23] (1984, 2000) using a natural log mean chlorophyll-a standard deviation of 0.5. These predictions are presented in Table 5-6; however, additional data collection/compilation is needed to compare to real data.

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[16] Carlson, R. 1977. A Trophic State Index for Lakes. *Limnol. and Oceanogr*. 22:261-369 Mifflin Co., NY.

[17] Dillon, P.J. and F.H. Rigler. 1974. The Phosphorus-Chlorophyll Relationship in Lakes. Limnol. Oceanogr. 19:767-773.

[18] Jones, J. and R. Bachmann. 1976. Prediction of Phosphorus and Chlorophyll Levels in Lakes. JWPCF 48:2176-2184.

[19] Oglesby, R.T. and W.R. Schaffner. 1978. Phosphorus Loadings to Lakes and some of their responses. Part 2. Regression Models of Summer Phytoplankton Standing Crops, Winter Total P, and Transparency of New York Lakes with Phosphorus Loadings. Limnol. Oceanogr. 23:135-145.

[20] Vollenweider, R. 1982. Eutrophication of Waters: Monitoring, Assessment and Control. OECD, Paris.

[21] Jones, R.A., W. Rast and G.F. Lee. 1979. Relationship between summer mean and summer maximum chlorophyll *a* concentrations in lakes. Env. Sci. & Technol. 13:869-870.

[22] Walker. W.W. 1984. Statistical bases for mean chlorophyll *a* criteria. Pages 57-62 in Lake and Reservoir Management – Practical Applications. Proceedings of the 4th annual NALMS symposium. US EPA, Washington, DC.

[23] Walker. W.W. 2000. Quantifying uncertainty in phosphorus TMDLs for lakes. Prepared for NEIWPCC and US EPA Region I. Concord, MA.

Table 5-5. Predicted In-Lake Total Phosphorus Concentration Using Empirical Models			
Empirical Equation	**Equation**	**Predicted TP (ug/l)**	
		Lake Massabesic East	**Lake Massabesic West**
Mass Balance	TP=L/(Z(F))*1000	12	9
Kirchner-Dillon 1975 Vollenweider 1975 Larsen-Mercier 1976 Jones-Bachmann 1976 Reckhow General 1977 Average of Above 5 Model Values	TP=L(1-Rp)/(Z(F))*1000 TP=L/(Z(S+F))*1000 TP=L(1-Rlm)/(Z(F))*1000 TP=0.84(L)/(Z(0.65+F))*1000 TP=L/(11.6+1.2(Z(F)))*1000	7 9 7 8 6 *7.5*	6 8 6 7 5 *6.5*
Observed Epilimnion Mean		*7.5*	*7.2*
Observed Epilimnion Median		*7.0*	*6.5*

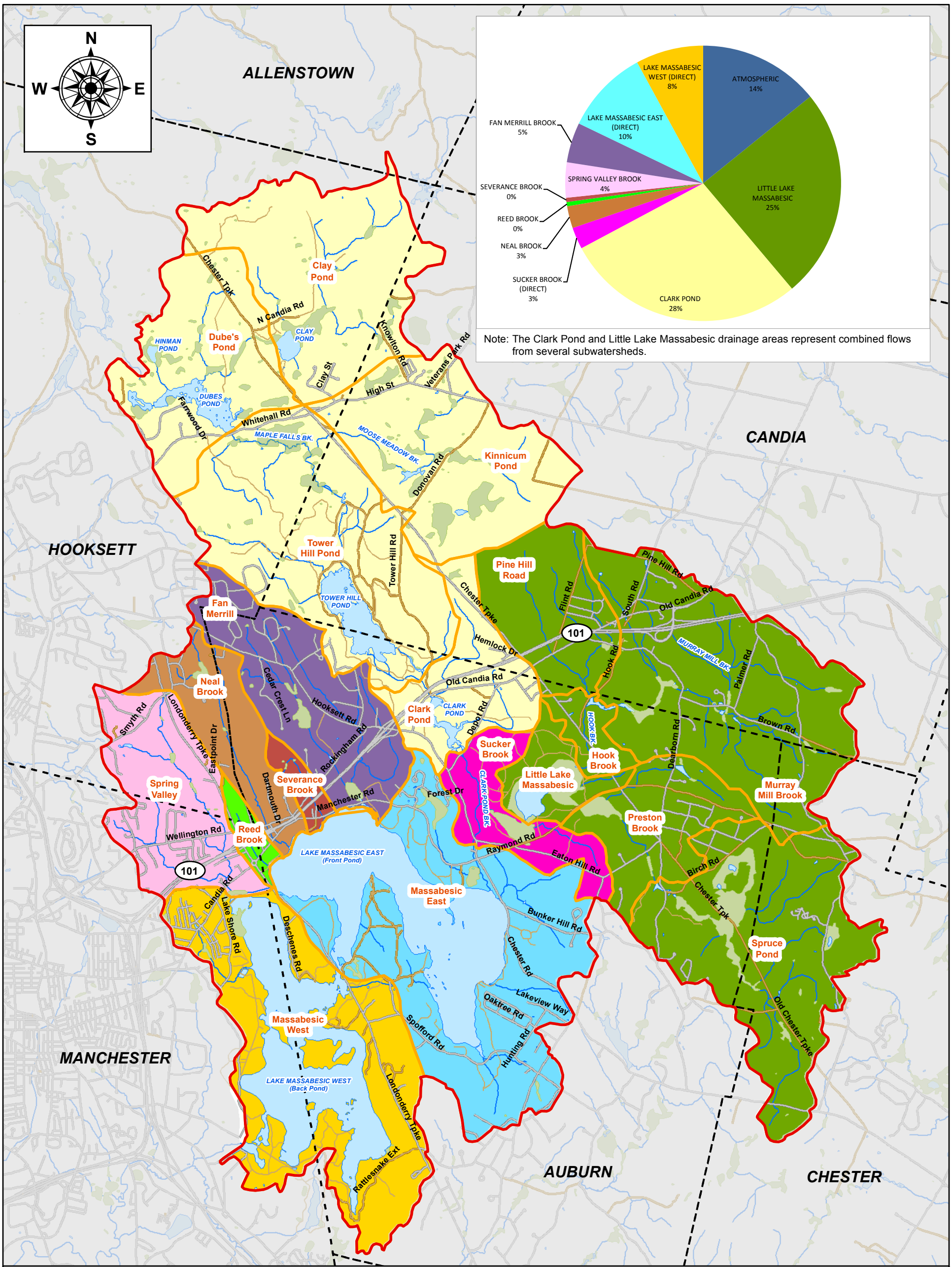
Variable	Description	Units	Equation
L	Phosphorus Load to Lake	g P/m2/yr.	
Z	Mean Depth	m	Volume/area
F	Flushing Rate	flushings/yr.	Inflow/volume
S	Suspended Fraction	no units	Effluent TP/Influent TP
Qs	Areal Water Load	m/yr.	Z(F)
Vs	Settling Velocity	m	Z(S)
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)

Table 5-6. Predicted In-Lake Chlorophyll a and Secchi Disk Transparency for Lake Massabesic			
Empirical Equation	**Equation**	**Predicted Value**	
		East	**West**
Mean Chlorophyll		***ug/l***	***ug/l***
Carlson 1977	Chl=0.087*(Pred TP)^1.45	1.6	1.3
Dillon and Rigler 1974	Chl=10^(1.449*LOG(Pred TP)-1.136)	1.4	1.1
Jones and Bachmann 1976	Chl=10^(1.46*LOG(Pred TP)-1.09)	1.5	1.2
Oglesby and Schaffner 1978	Chl=0.574*(Pred TP)-2.9	1.4	0.8
Modified Vollenweider 1982	Chl=2*0.28*(Pred TP)^0.96	3.9	3.4
Average of Model Values		**2.0**	**1.6**
Observed Summer Mean			
Peak Chlorophyll		***ug/l***	***ug/l***
Modified Vollenweider (TP) 1982	Chl=2*0.64*(Pred TP)^1.05	10.6	9.1
Vollenweider (CHL) 1982	Chl=2.6*(AVERAGE(Pred Chl))^1.06	5.3	4.2
Modified Jones, Rast and Lee 1979	Chl=2*1.7*(AVERAGE(Pred Chl))+0.2	6.8	5.5
Average of Model Values		**8**	**6**
Observed Summer Maximum*			
Bloom Probability		***% of Summer***	***% of Summer***
Probability of Chl >15 *ug*/l	See Walker 1984 & 2000	0%	0%
Secchi Transparency		***m***	***m***
Mean: Oglesby and Schaffner 1978	Chl=10^(1.36-0.764*LOG(Pred TP))	4.9	5.5
Max: Modified Vollenweider 1982	Chl=9.77*Pred TP^-0.28	5.6	5.8
Observed Summer Mean			
Observed Summer Maximum			
Variable	**Description**		**Units**
"Pred TP"	The average TP calculated from the 5 predictive equation models in Table 5-5		*ug*/l
"Pred Chl"	The average of the 3 predictive equations calculating mean chlorophyll		*ug*/l

5.3 Phosphorus Loading Assessment Limitations

While the analysis presented above provides a reasonable accounting of sources of TP loading to Lake Massabesic, there are several limitations to the analysis:

- Precipitation varies among years and hence hydrologic loading will vary. This may greatly influence TP loads in any given year, given the importance of runoff to loading.
- Spatial analysis has innate limitations related to the resolution and timeliness of the underlying data. Data layers were not 100% verified on the ground. In addition, land uses were aggregated into classes which were then assigned export coefficients; variability in export within classes was not evaluated or expressed.
- TP export coefficients were limited as they were based on regional estimates for runoff.
- The TP loading estimate from septic systems was limited by the assumptions associated with this calculation (described in Section 5.2 above in the "Septic Systems" subsection) and the assumptions made about the proximity of the systems to the lake and their influence on the total loading.
- Water quality data for Lake Massabesic and its tributaries are limited, restricting calibration of the model.
- The loading estimate for the waterfowl was limited by the assumptions made in Section 5.2.
- The internal phosphorus loading estimate was limited by the assumptions made in Section 5.2.
- The loadings represent existing loadings only. A buildout analysis was not performed to determine potential future loadings.



Legend

- Lake Massabesic Watershed
- Subwatershed Boundaries
- Town Boundary

Roads

- Paved
- Unpaved

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

Data Sources: GRANIT, MWW, City of Manchester

0 2,500 5,000 10,000 15,000 Feet

Figure 5-2

Lake Massabesic Watershed Management Plan

Lake Massabesic Watershed Budget

Manchester Water Works

Comprehensive Environmental Inc.

Section 6 Assimilative Capacity Analysis and Water Quality Goals

Assimilative capacity refers to the amount of a pollutant that can be safely released to a waterbody without causing violations of applicable water quality criteria or negatively impacting uses (Env-Wq 1702.03). As discussed in Section 3.0, Lake Massabesic is listed as impaired for dissolved oxygen (aquatic life uses) and cyanobacteria (primary contact recreation). Since high levels of phosphorus can contribute to both cyanobacteria blooms and low DO levels, it has been selected as the pollutant with the greatest direct impact on the water quality of Lake Massabesic, thus, the assimilative capacity analysis and water quality goals will be performed for total phosphorus.

6.1 Assimilative Capacity Analysis

An assimilative capacity analysis was performed on Lake Massabesic East and Lake Massabesic West using the limited total phosphorus data available for the lake. The analysis provides an indication of the remaining assimilative capacity of the lake, assuming the water quality is similar to historic data. More recent data is needed to perform an accurate assimilative capacity analysis that can be used for the purposes of anti-degradation review as outlined in Section 3.0. Based on the available data, the median total phosphorus concentration from each portion of the lake was used to calculate the total, reserve, and remaining assimilative capacity for each side of the lake following the procedures described in the Standard Operating Procedures for Assimilative Capacity Analysis for New Hampshire Waters (NHDES, 2008). Using this process, waterbodies are classified into one of three categories:

- Impaired – does not meet the water quality standard with a negative assimilative capacity. This requires reductions in pollutant loading to restore the waterbody to meet the standard.
- Tier 1 – meets water quality standard but is within the 10% reserve assimilative capacity.
- Tier 2 – meets the water quality standard with some assimilative capacity remaining.

As discussed in Section 3.0, the Consolidated Assessment and Listing Methodology (CALM) for Class A surface waters defines phosphorus thresholds by trophic class. The oligotrophic status of <8 ug/l is applied to both sides of Lake Massabesic. The results of this analysis are included in Table 6-1.

Table 6-1. Assimilative Capacity Analysis					
Lake	**Existing Median TP (ug/l)**	**TP WQ Threshold (ug/l)**	**Assimilative Capacity Reserve (10%) (ug/l)**	**Remaining Assimilative Capacity (ug/l)**	**Category**
Lake Massabesic East	7.0	8.0	0.8	0.2	Tier 2
Lake Massabesic West	6.5	8.0	0.8	0.7	Tier 2

The Assimilative Capacity Analysis indicates that Lake Massabesic is a Tier 2 or High Quality Water for phosphorus since there is remaining assimilative capacity. However, this is based on a very limited water quality data set. While MWW has indicated that they do not experience significant or frequent algal blooms, recent water quality data continues to show low DO levels at the bottom of the lake. Additional in-lake and tributary monitoring is recommended (outlined in Section 7.0) to represent current in-lake water quality for incorporation into the modeling and assimilative capacity analysis.

6.2 Water Quality Goals

The overall goal is to maintain high quality water status in regards to phosphorus, to improve the DO levels in the lake and to protect the lake from future, unaccounted-for inputs of TP from recreation or from new development in the watershed. Watershed loads account for the largest TP inputs (78%) into the lake, and as such should be the focus of management activities to maintain water quality. However, recreational activities have a more direct impact on water quality and also need to be the focus of continued vigilance and enforcement.

Existing and new development in the watershed needs to be carefully managed to prevent the introduction of additional phosphorus loads to the lake. Any increase in loads from new activities and/or development should be offset with a reduction to existing loads to maintain a net zero increase over time.

The pollutant load model, assimilative capacity analysis and water quality goals should be re-evaluated every 5 years as additional water quality data is collected that is reflective of current conditions.

Section 7 Recommendations

7.1 Introduction

Because of the extensive efforts of the Manchester Water Works, water quality continues to be good to excellent. However, there has been some degradation over time in that oxygen levels at the bottom of the lake are problematic.

This is a common phenomenon in freshwater lakes such as Lake Massabesic because organic sediments from dead aquatic vegetation and turbid inflows tend to settle out and accumulate in the bottom of the lake. Over time, these materials decompose and consume oxygen from the water column during that decomposition. Lakes that are shallow and have a large surface area may stay mixed by wind action, but lakes that are deep have less mixing and a greater tendency to stratify with cooler temperature layers at the bottom. Lake Massabesic has some shallower areas where mixing is likely good, but the downside of shallow water is more opportunity for aquatic weed growth and die-off. It also has deeper, stratified areas that are subject to low oxygen.

As the oxygen in the lower layers of the lakes is depleted, certain compounds including phosphorus and manganese may be released from the sediments back into the water column. This can create a cycle of phosphorus and manganese being released from the sediments into the water column where they are available for algae and other organisms.

Unfortunately, this cycle can accelerate and lead to rapid eutrophication. The term 'eutrophic' means well-nourished; thus, 'eutrophication' refers to natural or artificial addition of nutrients to bodies of water and to the effects of the added nutrients. Lake Massabesic has a history of low oxygen in the two deepest locations: near the intakes and on the East side of the lake at the Front Park sampling station. NHDES lists the lake as oxygen deficient and mesotrophic, i.e., on the sliding scale towards eutrophic. The intake area of the lake does have aeration, which is one of the best methods to stop the phosphorus cycling. However, data is lacking to determine at this point in time whether oxygenation is also needed on the East side of the lake.

Although there are only a few samples of phosphorus in this bottom layer, some of the concentrations are higher than those samples in upper layers, suggesting that internal recycling of phosphorus may already be or could become an issue at some point in the future.

This section describes an implementation program that will help track and maintain the water quality in Lake Massabesic. Section 7.2 presents recommendations in a standardized format, including a description of the action, statement of its objectives, implementing partners, and costs of implementation. Table 7-1 summarizes the recommendations.

The success of the recommendations in achieving watershed quality improvements must be measurable to ensure the plan is working and to make adjustments as needed to achieve the desired results. Section 7.3 concludes with a discussion of the recommended monitoring program and success indicators.

Table 7-1. Summary of Recommendations			
Priority	**Recommendation**	**Objective**	**Schedule**
1	Revise the in-lake monitoring program to include phosphorus at a low detection limit	To understand the lake's cycle and prevent future problems, keep costs level	2016 – Incorporate revisions
2	Revise the tributary monitoring program to include flow data and phosphorus at a low detection limit and to collect data on a consistent basis	To understand and compare watershed loads to help focus management efforts and prevent future problems	2016 – Incorporate revisions
3	Develop a Recreational Management Plan and stronger recreational program to include additional boundary markers and enforcement "examples"	To develop a more enforceable, useable program to prevent issues as recreational pressures increase over time and to document current practices	2016
4	Update forest management program to include diversity of stands as related to future invasive pests	To prevent wholesale erosion and death of large swaths of forest due to plantation style plantings	2016 & every 5 years
5	Bathymetric mapping of all upper storage ponds and Lake Massabesic	To avoid overflow of sediments under major storm event conditions and to evaluate infilling storage capacity of the supply	2016 & every 5 years
6	Assess culverts for stability and/or need for modification	To avoid road washouts that could negatively impact the lake's status	2016
7	Populate and maintain Access database	To track watershed and water quality trends	Annually
8	Map stormdrain network in the watershed and encourage stormwater standards for new and redevelopment projects	To understand and limit risks associated with spills and stormwater runoff from developed areas	2017
9	Explore increasing in-house GIS capabilities as a management tool	To provide MWW staff with the tools, resources and geodatabase to manage watershed patrol & forestry data	2018
10	Update public outreach program	To reach a broader audience on the importance of water supply and watershed protection & to target shoreline owners	2016 & every five years
11	Manage property lines & encroachments	To protect MWW property & water supply	Annually
12	Investigate when seagulls become problematic	To protect the water supply from fecal and nutrient contamination from seagulls	2018
13	Calibrate the phosphorus load model with new water quality data	Refine phosphorus loads and distribution throughout the watershed and update management actions accordingly to maintain the best protection of the source	2020 & every 5 years
14	Manage watershed lands for resiliency	To protect the supply under drought and flood conditions	Ongoing
15	Continue with ongoing watershed and water supply protection efforts -Land acquisition & conservation -Update PCS inventory -Visit & talk with PCSs & others -Aquatic weed control & map updates -Regular patrols & inspections	To provide continued long-term protection of the waters supply	 -Ongoing -Every 5 years -Annually -Annually -Weekly

7.2 Recommendations

#1. Revise In-Lake Monitoring Program

MWW has been monitoring Lake Massabesic for a number of years and has an extensive data set showing in-lake temperature, DO, conductivity and salinity profiles. However, there is very limited data on total phosphorus and Chlorophyll-a within the lake, data which is important for assessing the potential for algal blooms within the lake and for managing phosphorus loads from the watershed. Excess phosphorus can result in an overabundance of aquatic plants which in turn can deplete oxygen from the water through the decay process and result in taste and odor problems.

Recommendation: Revise the existing in-lake monitoring program to include total phosphorus and chlorophyll-a samples important for evaluating and managing watershed loads.

Locations and Schedule:
Sample the following locations once a month April through October and once during the winter under ice cover (January/February). Refer to Figure 7-1 for sampling locations.

- Front Park (FRONTP)
- Bubbler Point B (BUBB)
- Raw Water Intake in the Plant

In-Lake Locations: Temperature, DO, conductivity and salinity (if available on YSI) should be measured at 5 foot intervals throughout the water column. Collect a sample from the metalimnion or thermocline (when an obvious layer is present), three feet below the surface, and a sample three feet above the bottom for analysis of remaining parameters (except secchi disk, which is a one time reading at each location and Chlorophyll-a, which only needs to be collected from the surface samples). Collect top and bottom samples even if the lake is not stratified. Refer to Appendix M for Standard Operating Procedures (SOPs) for collecting in-lake water quality samples.

Raw Water Intake: Collect a single sample from the raw water intake in the plant and analyze for everything but secchi disk transparency.

Sampling Parameters:

Total Phosphorus*	pH
Total Nitrogen	Temperature**
Turbidity	Dissolved Oxygen (DO)**
Manganese	Conductivity
Iron	Salinity
E. Coli	Color
Chlorophyll-a	Secchi Disc Transparency (SDT)

**Request a detection limit of 0.01 mg/l when ordering bottles and when filling out the chain of custody – use EPA Method 365.1 or equivalent method that can achieve the 0.01 mg/l detection limit.*
***Continue collecting data with in-house multi-meter*

Actions:

1) Revise the in-lake monitoring program to include total phosphorus and chlorophyll-a analysis.
2) Sample lake in accordance with the outlined schedule.
3) Add the sampling results to the water quality database.
4) Evaluate long-term water quality trends to help direct future watershed management actions.

Objectives: To better understand the lake's cycle and prevent future increases in in-lake phosphorus loadings.

Partners: NH DES Watershed Management Bureau for impaired water status and updates.

#2. Revise Tributary Monitoring Program

MWW has been monitoring tributaries to Lake Massabesic for a number of years, with up to 25 locations sampled for various water quality parameters on a rotating basis during weekly watershed patrols. Flow data are not collected during the tributary sampling events. Total phosphorus data are not often sampled and cannot be correlated with flow. In addition, DO and temperature data are not taken.

Tributary sampling is useful to monitor water quality and quantity impacts to the streams from various areas of the watershed and can help identify which areas of the watershed require closer evaluation and attention to minimize pollutant loads into the lake. To better compare water quality data from one tributary to another, flow measurements are also needed. This allows for evaluation of the total pollutant load of each tributary, rather than just a concentration. For example, a very large tributary may have a very low phosphorus concentration when compared to a smaller stream; however, due to the large volume of water in the larger stream, it may carry a higher mass of phosphorus to the lake than the smaller stream with the higher concentration. Applying the flows allows for this more accurate comparison to help better define problem areas. Flow measurements can also help develop trendlines that show how streams respond to precipitation and how this is changing over time in response to changes in the watershed.

Recommendation: Revise the existing tributary monitoring program to allow for the collection of more consistent data (e.g., all locations sampled during the same day) from the major tributaries to the lake.

Sample eight tributaries monthly under dry weather conditions. The locations selected represent the major tributary flows directly into Lake Massabesic East and Lake Massabesic West.

Sample three tributaries annually under dry weather conditions. The locations selected represent outlets to various ponds in the upper watershed, which likely act as detention basins for flow from the upper watershed. Periodically sampling these locations, along with checking bathymetry, will help track the quality and filling of these ponds so they can be addressed when needed.

Measure both water quality and flow volume. Measurement of flow will require the installation of staff gages and preparation of stage-discharge curves. Following outlines the recommended sampling locations, schedule and parameters.

Locations and Schedule:

Monthly Sampling – Sample the following locations once a month throughout the year during dry weather. Sample all locations on the same day each monitoring round. Refer to Figure 7-1 for sampling locations.

- Massabesic Lake @ RAW Water Station (MLRWS) – this discharges close to the intake in Lake Massabesic West and is surrounded by residential, commercial and air transportation land uses.
- Little Massabesic Brook (LMASSB) – this is the outlet from Little Massabesic Pond, which connects with the tributary discharge from Clark Pond. This represents flow to the lake from the Little Lake Massabesic, Murray Mill Brook, Pine Hill Road, Preston Brook and Spruce Pond Subwatersheds.
- Clarks Brook (CLARKB) – this is the outlet from Clark Pond, which connects with the tributary discharge from Little Massabesic Pond. This represents flow to the lake from Clay Pond, Dube's Pond, Kinnicum Pond, and Tower Hill Pond Subwatersheds.
- Fan Merrill Brook (FANM) – this represents flow to the lake from the Fan Merrill Subwatershed.
- Severence Brook (SEVERB) – this represents flow to the lake from the Severence Brook Subwatershed. While small, it does collect runoff from residential development and a portion of Route 101 runs through it.
- Neal Brook (NEALBO) – this represents flow to the lake from the Neal Brook Subwatershed and contains some commercial and residential development along Route 101.
- Reed Brook (REEDB) – this represents flow to the lake from Reed Brook Subwatershed and contains a portion of Route 101 and some commercial, industrial and residential development.
- Spring Valley Brook @ Rte 28 (SPV28) – this represents flow to the lake from the Spring Valley Brook Subwatershed and contains a portion of Route 101, residential, commercial and industrial development.

Annual Sampling – Sample the following locations once a year during the summer during dry weather. Sample all locations on the same day each monitoring round.

- Maple Falls Brook (MAPLEB)
- Dube's Pond (DUPO)
- Tower Hill Pond Outlet (THPO)

Sampling Parameters:

All samples should be analyzed for:

Total Phosphorus*	pH**
Total Nitrogen	Temperature**
Turbidity	Dissolved Oxygen (DO)**
Manganese	Conductivity**
Iron	Salinity
E. Coli	Color

**Request a detection limit of 0.01 mg/l when ordering bottles and when filling out the chain of custody – use EPA Method 365.1 or equivalent method that can achieve the 0.01 mg/l detection limit.*
*** Recommend the use of a YSI 556 or similar meter capable of measuring temperature, DO, pH and conductivity.*

Actions:

1) Revise the tributary sampling program to focus efforts on the major tributaries to the lake and to incorporate total phosphorus and DO analysis.
2) Develop stage-discharge curves for each tributary sampling location to relate flow to water level. Purchase data loggers to continuously measure tributary water level at each of the tributary sampling locations. At a minimum, install a staff gage to record water levels during sampling events, which can then be converted to flow.
3) Sample tributaries in accordance with the outlined schedule.
4) Add the sampling results to the water quality database.
5) Evaluate long-term water quality trends to help direct future watershed management actions. Correlate with watershed activities.

Objectives: To understand and compare watershed loads to help focus management efforts towards areas of largest water quality impacts and to help prevent future unexpected water quality degradation. The data will be used to help manage watershed activities to limit phosphorus inputs and improve low DO in the lake.

Partners: NH DES Watershed Management Bureau for impaired water status and updates.

#3. Develop Stronger Recreational Program

MWW had adopted rules to regulate recreational use activities in the watershed and employs watershed patrol staff to monitor the watershed and enforce these regulations. However, despite these efforts, MWW still faces many challenges associated with passive recreation of their lands (refer to Appendix F), including:

- Recreational Usage: has increased over the years and at times the need for enforcement overwhelms the existing patrol staff since recreational users often do not follow signage.
- Animals: horses enter backcountry areas or sensitive areas, and although the regulations call for diapers to be used, it does not always happen. In addition, dogs off leash go in the water and their owners are not removing waste or leave the bags behind.
- Trash and waste: continue to be a problem including by trail users and hunters.

- Entrance in prohibited areas: fishermen, geocachers and hunters often go into restricted areas.
- Rule changes: take a long time and are sometimes ineffective.

Further action is needed to address these challenges.

Recommendation: Develop a stronger recreational program to include additional trail and boundary marking and provide enforcement examples. Document current and future recreational activities and management in a Recreational Management Plan.

Actions:

1) Update the "Manchester Water Works Watershed Land" map included on the City's website to include a summary of Posted Rules and to clearly mark trails and designated uses. People looking to print trail maps will be introduced to the rules and restrictions at the same time. Include examples of potential consequences for violating the rules.
2) Identify areas where recurring problems most often occur and evaluate the need for additional signage including trail signs, boundary markers, and posted rules.
3) Evaluate watershed patrol activities and schedules and evaluate the need for adjustments based on violation trends identified in the watershed.
4) Work with local horseback riding, biking, hiking and fishing groups to increase awareness and distribution of rules and regulations.
5) Prepare a Recreational Management Plan to document current and future recreational activities and management.

Objectives: To develop a more enforceable, useable program to prevent issues as recreational pressures increase over time.

Partners: NH DES for potential funding, NH Division of Parks and Recreation, recreational user groups, watershed communities.

#4. Update Forest Management Program

MWW has a Forest Management Plan used to manage forests within the watershed. The plan outlines a timber harvest program that focuses on removing over mature and diseased trees to stimulate growth and regeneration of desirable species. The plan is slated for update on a five year cycle, however, the most recent plan is dated May 2008.

The last forest inventory was completed in 1986. An updated inventory of the tree species, number of trees, condition and location of stands will allow the forester to better evaluate areas to perform selective harvesting and reforestation and should be incorporated into future plan revisions.

In light of the recent infestation of the Red Pine Scale Insect in New Hampshire, which has led to MWW removing stands of Red Pine Timber, the Forest Management Plan should be updated to include diversity of stands as related to future invasive pests.

Recommendation: Update the tree inventory and Forest Management Plan. Include diversity of stands as related to future invasive pests and encouragement of water production by selective removal of hardwoods.

Actions:

1) Perform tree inventory and record it in a GIS format for future use and updating.
2) Update the Forestry Management Plan to include the new inventory, project harvesting schedules, selective removal of hardwoods to encourage water production and reforestation to include diversity of stands as related to future invasive pests.
3) Track future forestry efforts (e.g., harvesting and reforestation) in GIS. Monitor annual forest growth such that it at least meets, and preferably exceeds, the amount harvested. This may indicate more systemic problems in the forest ecosystem.

Objectives: To prevent wholesale erosion and death of large swaths of forest due to plantation style plantings.

Partners: NH DES for potential funding, NH Division of Forests and Lands, Society for the Protection of NH Forests (SPNHF), United States Department of Agriculture (USDA).

#5. Prepare Bathymetric Maps

Bathymetric mapping provides information on the available water storage in a pond or lake. When performed periodically, it can be used to evaluate sedimentation and infill in the water body by comparing current and past bottom contours and remaining water storage.
The ponds located in the upper watershed will act as detention basins, collecting and settling sediments that discharge from stormwater runoff and the contributing tributaries. Under major storm events, these sediments have the potential to overflow and discharge into Lake Massabesic, particularly if sediment levels are high in these ponds. If sediment levels are known, proactive measures can be taken to remove the sediments before they become problematic for Lake Massabesic.

Bathymetric mapping of the bottom contours in these ponds should be performed to obtain a baseline sediment level and then repeated every 5 years to evaluate the rate of infilling and potential for washout.

An updated bathymetric map should also be generated for Lake Massabesic to evaluate infilling and the storage capacity of the supply. The existing map was completed in 2003.

Mapping can be completed using acoustic echosounding (sonar) measurement of bottom sediments. Using this method, the water level of the lake/pond is measured in relation to a fixed reference point. In the case of Lake Massabesic, this could be the spillway elevation. In the case of the upper ponds, a fixed reference point would need to be established from the surrounding area. The sonar and GPS unit are attached to a boat and used to obtain point by point location coordinates and depths in a grid fine enough to yield a map of resolution similar to the 2003

baseline map for Lake Massabesic. The data can then be input into GIS to develop and elevation model.

In the smaller upper ponds, sediment depths should also be collected at the same time using a secchi disk and rod method. The secchi disk is used to measure the depth to the top of sediment at each location and a rod is used to measure the thickness of sediment by pushing the rod into the sediment until refusal. This would be beneficial during the first mapping effort of the upper ponds since there is currently no baseline bathymetric map which to compare infill. This would provide an approximation of the amount of sediment that has filled the pond to date.

Recommendation: Prepare bathymetric maps for Lake Massabesic and upper storage ponds including Clay Pond, Dube's Pond, Tower Hill Pond, Clark Pond and Little Massabesic Lake. Bathymetric mapping of the upper storage ponds should start with the ponds closest to Lake Massabesic and then work upwards as follows: 1) Little Massabesic Lake; 2) Clark Pond; 3) Tower Hill Pond; 4) Dube's Pond; and 5) Clay Pond.

Actions:

1) Identify/create fixed reference points to relate water levels for each waterbody.
2) Identify grid spacing for each waterbody.
3) Collect point by point location coordinates and water depths in each waterbody using sonar and GPS equipment.
4) Collect sediment depth information at each point in the upper ponds.
5) Input data into GIS and create bathymetric maps of bottom contours for each waterbody and estimates of sediment volumes for the upper ponds.

Objectives: To avoid overflow of sediments under major storm event or hurricane conditions and to evaluate infilling storage capacity of the supply.

Partners: NH DES for potential funding, NH Fish and Game.

#6. Assess Culverts for Stability

According to the report "Trends in Extreme Precipitation Events for the Northeastern United States, 1948-2007," Susan G. Spierre and Cameron Wake, Ph.D., University of New Hampshire, 2010, 92 percent of the New England monitoring stations show increasingly large 2-inch storms, many statistically significant. The 2-inch storm is significant because it is considered a "scouring event". Stream banks are scoured causing erosion and sedimentation to occur, and with these come pollutants such as nutrients and total suspended solids (TSS) that can be detrimental to surface water supplies of drinking water like Lake Massabesic.

These increased precipitation events can also wash out culverts and road crossings, potentially causing long-stored sediments behind these structures to be flushed from contributing tributaries and ponds into the water supply lake. In a lake such as Massabesic, these events may over time and throughout many events, result in huge volumes of sediments displaced into the

water body. This can result in potentially serious consequences on water quality of the raw water. Once there is a large volume of nutrient-rich sediments in a limnologic system, the influx of additional nutrients such as nitrogen and phosphorous bound within the sediments can contribute to increased cyanobacteria blooms, as well as accelerating the cycle of aquatic vegetation growth and die-off. This can create anaerobic conditions in the lake, particularly along the bottom where organic materials accumulate and break down, causing a resultant phosphorus release back into the water column, further adding to the cycle of oxygen demand from the decomposition of organic compounds.

One positive step that can be done to prevent future sedimentation in extreme events is to inventory culverts that directly enter the water body and identify which ones are likely to wash out and carry huge volumes of sediments. These vulnerable culverts can then be replaced over time in order of priority since each one may be a significant project on its' own.

Today, culverts proximal to raw water supply lakes (as well as other locations) are one component of an aging infrastructure, increasingly vulnerable to compromise, likely to be undersized, and unable to meet modern design standards. In many cases, the entire roadway may be washed out along with tons of bedding materials along with the stream bank. The damage to Lake Massabesic could be significant, so it is prudent to inventory the culverts that discharge directly into the lake to prioritize them for improvements over time. According to the original Normandeau[1] report, several culverts are undersized and potentially inadequate. There may also be an opportunity for increasing the treatment value of wetlands and stream banks along with the culvert replacement or rehabilitation in order to ensure a resilient infrastructure improvement.

Recommendation: Inventory culverts that discharge directly into Lake Massabesic and prioritize them for improvements over time.

Actions:

1) Assess culvert conditions through field reconnaissance and available records.
2) Prioritize culverts and road crossings based on their potential for washing out with consequences to Lake Massabesic.

Objectives: To avoid road washouts that could negatively impact the lake's status.

Partners: NH DES Drinking Water Source Protection Program for potential funding, Manchester Department of Public Works (DPW), Manchester Environmental Protection Division (EPD).

[1] Normandeau Associates Inc. 1999. Lake Massabesic Watershed Management Plan.

#7. Populate and Maintain Access Database

A Microsoft Access database was recently developed to organize and store watershed and water quality monitoring data collected by MWW staff. A copy of the database user guide is included in Appendix N. MWW staff can update and add information to the database with basic training and generate reports to summarize data, identify trends and indicate when parameter thresholds have been exceeded.

The Access database should be populated with existing information that is currently housed in multiple locations and formats to organize and make it easier to access the data.

Recommendation: Populate and manage Access database.

Actions:

1) Populate database with existing records.
2) Update Access as new monitoring data is collected.
3) Identify data trends and coordinate future monitoring efforts based on the analysis results.

Objectives: To house monitoring data in Access database to make data management more efficient and easier to access. To track watershed and water quality trends.

Partners: NH DES Drinking Water Source Protection Program for potential funding.

#8. Map Stormdrain Network in Watershed and Encourage Stormwater Standards for New and Redevelopment

There is a significant amount of undeveloped land within the watershed. The development of these lands can drastically impact the water quality of Lake Massabesic if not controlled. Land disturbances during development can wash large quantities of sediments and soils into waterways. The increase in impervious surfaces associated with development changes the hydrology of the watershed, producing greater volumes and peak rates of runoff that carry greater quantities of pollutants such as sediments and phosphorus than predeveloped uses. The runoff is also warmer since it heats up as it travels across hot paved surfaces during summer months. The result is increased flooding and degradation of water quality in receiving waters.

It is important for MWW to understand where stormwater runoff is entering the water supply and its tributaries and the associated threats to water quality, including spills from roadway accidents and stormwater runoff from existing or new development. An updated drainage system map should be completed for systems within the watershed and updated annually to keep abreast of this potential threat.

The implementation of consistent watershed protection and stormwater management regulations is also an important element of watershed management. Development will occur; the key is to control the impacts from it by establishing protective design standards. A small increase in

phosphorus loads could have a profound impact on the water quality of the lake. As such, MWW should work with the City of Manchester to develop stormwater design standards that result in no net increase of phosphorus load to Lake Massabesic. These requirements can be incorporated into the Lake Massabesic Protection Overlay District (LMPOD). However, since it only applies to the small portion of the watershed in the City of Manchester, MWW should seek to work in cooperation with the other watershed communities to promote a similar overlay district using the LMPOD as a template.

Recommendation: Create an updated map of the stormwater drainage network system within the watershed. Work with the City of Manchester to develop stormwater design standards that result in no net increase of phosphorus load to Lake Massabesic. Incorporate into the LMPOD and Manchester Stormwater Ordinance as appropriate. Reach out to watershed communities to encourage adoption of a similar LMPOD.

Actions:

1) Compile existing maps/records through coordination with watershed communities.
2) Prepare an updated map in GIS.
3) Inspect stormwater outfalls to determine the need for stormwater BMPs.
4) Work with City of Manchester to develop stormwater design standards that result in no net increase of phosphorus load to Lake Massabesic and incorporate into LMPOD and Manchester Stormwater Ordinance as appropriate.
5) Contact and meet with planning boards and public works in Candia, Hooksett, Auburn and Chester to encourage development of a LMPOD consistent with Manchester's. Allenstown is not included due to the extremely small watershed area located within the Town.

Objectives: To understand and limit risks associated with spills and stormwater runoff from developed areas.

Partners: NH DES Drinking Water Drinking Water Source Protection Program for potential funding, Manchester EPD, watershed communities.

#9. Explore Increasing In-house GIS Capabilities

GIS can be a powerful tool for tracking and managing watershed management efforts, such as forestry practices (tree stands and cutting) and land use changes through the use of visual maps and databases.

While the City of Manchester does have GIS capabilities and staff, an MWW-managed overlay district for the lake would be highly advantageous to MWW's staff and watershed program.

Recommendation: Explore increasing in-house GIS capabilities to allow MWW staff to use GIS as a geodatabase to manage its watershed protection efforts.

Actions:

1) Evaluate GIS software needs and costs.
2) Evaluate employee training options and costs.
3) Decide if feasible to manage GIS in-house and if so, develop data management standards for maintaining GIS database.

Objectives: To provide MWW staff with the capabilities to use GIS to spatially manage watershed maps and management activities.

Partners: NHDES for potential funding, City of Manchester, GRANIT, watershed communities.

#10. Update Public Outreach Program

Public education and outreach is an important component of any watershed management program. It connects residents and businesses to the lake and watershed protection efforts. With this connection and knowledge, individuals are more likely to make good decisions regarding their habits and practices to help protect the Lake. They also may be more likely to support watershed friendly policies and to cooperate with the MWW and watershed communities in protecting Lake Massabesic.

MWW currently has an excellent public outreach program geared towards elementary school students in the City of Manchester. Expansion of this program is recommenced to reach a broader audience.

Recommendation: Expand the current education program to include the following components:

1) Update the MWW website to include more information on pollution prevention and how residents can help protect water quality. This can include links to outside resources available through EPA and NHDES.
2) Update trail maps posted on the website to include more detail on trail uses and a posted summary of rules. See recommendation #3.
3) Develop an educational video or series of short video clips that can be included on MWW's website and shown at school presentations. The videos can focus on threats to the water supply that residents can control, such as fertilizer use, yard waste management, good pet waste management, reducing impervious surfaces and stormwater runoff, and other related topics. Emphasis should be placed on reducing phosphorus, which is a key element in watershed protection.
4) Perform targeted outreach to shoreline property owners on the lake. Focus on lawn care and property care to protect the lake and water supply and generate materials that can be left with each property owner.
5) Perform targeted outreach to identified potential contamination sources (PCSs). See recommendation #11.

Actions:

1) Gather information and outside links for inclusion on MWW's website.
2) Update website to include new information and resource links.
3) Update trail maps on MWW owned lands to include more information on allowed and restricted uses and rules.
4) Develop video series on the water supply and watershed protection. This will involve development of video scripts, compilation of existing videos and images, producing videos with a professional videographer, and publishing the videos on MWW's website.
5) Perform targeted outreach of shoreline property owners and PCSs to include annual visits if needed.

Objectives: To reach a broader audience on the importance of water supply and watershed protection.

Partners: NHDES for potential funding, watershed communities.

#11. Manage Property Lines and Encroachments

It is part of MWWs legal obligation to protect and preserve the land it owns for the purposes of water supply protection. As part of this effort, MWW is responsible for ensuring that its lands are maintained and used as intended. This includes delineation and maintenance of property lines and addressing encroachments from abutting properties.

Encroachments are intrusions and alternations on MWW land and may include:

- Extension of lawns or gardens
- Clearing/cutting of underbrush or trees
- Erection of sheds, fences, or play sets
- Dumping of yard waste and debris

Encroachments can result in degraded water resources, reduced wildlife habitat value and diminished public access.

While MWW watershed patrols currently monitor land uses and activities in the watershed, the management of property lines and addressing encroachments has not been a priority.

Recommendation: Evaluate abutting properties to MWW land for encroachments and take actions to address these encroachments.

Actions:

1) Prioritize lands abutting MWW property for inspection and establish an inspection schedule.
2) Inspect lands abutting MWW property for encroachment.
3) Work with property owners to address/correct encroachments.

4) Document inspections, identified encroachments, correspondence with abutters and final corrective actions taken. This will serve as a baseline to track reoccurring problems and need for additional measures.

Objectives: To preserve MWW lands for the protection of the water supply.

Partners: NHDES for potential funding (e.g., inspections, surveying, corrective measures), abutters

#12. Investigate When Seagulls/Birds Could Become Problematic

A small flock of seagulls (30-50 seagulls) have been observed congregating near the water supply intake. Large flocks of birds may increase bacteria levels in water supplies and may contribute nutrients such as phosphorus to the water supply. While the existing population of gulls has not resulted in a known water quality problem at Lake Massabesic, increases in gull populations could be problematic at some point in the future. MWW should track gull and other bird populations and take proactive measures if they become problematic. These measures usually include various tactics to scare the birds away, such as loud noises. Such measures may also disturb neighbors so the work must be planned ahead of time and notice given to neighbors.

Recommendation: Track seagull and bird populations on the lake and investigate when populations could potentially become problematic to water quality so that proactive measures can be taken.

Actions:

1) Begin tracking seagull and bird counts on Lake Massabesic to determine if populations are increasing over time.
2) Investigate the best measures to reduce populations at Lake Massabesic.
3) Monitor and track bacteria and phosphorus concentrations in the lake for increasing trends.
4) Develop protocols with triggers for when to take corrective actions.
5) Take corrective actions to control gull populations as needed.

Objectives: To prevent negative water quality impacts associated with seagull and bird populations on the lake.

Partners: NH DES for potential funding, United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services

#13. Update Water Quality Model

As cited in Section 5.0, there are limitations with the methodology used to estimate phosphorus loads to the lake, in many cases associated with limitations in water quality data. For example, there is not enough phosphorus data to assess the current water quality of the lake and tributaries to adequately calibrate the model. As more data is collected, the model should be updated to more accurately define phosphorus loads and target goals for watershed management.

Recommendation: Update the model after additional data has been collected. The results should be used to refine the assimilative capacity assessment and phosphorus management goals.

Actions:

1) Update and calibrate the LLRM model with new water quality data when it becomes available, preferably after collection of five years of data. Incorporate tributary and in-lake water quality data to provide better calibration of the model.
2) Update assimilative capacity and water quality goals based on modeling results.
3) Update watershed management plan with new modeling results, water quality goals and modify or refine recommendations for watershed-specific actions to address the new goals.

Objectives: Adjust the model and management plan to reflect actual water quality conditions and to establish a plan to meet water quality goals to advance the protection of the water supply. A current plan also supports future funding of recommendations through NHDES.

Partners: NH DES for potential funding.

#14. Manage Watershed Lands for Resiliency

Protecting Lake Massabesic from contamination threats has been a priority of MWW for many years – a large focus of their protection program has been on the acquisition and management of lands within the watershed, both from a forestry and recreational stance. These efforts should be expanded to include management for resiliency.

Recommendation: Assess and incorporate resiliency factors into the management of watershed lands that consider drought and flood related protection measures.

Actions:

1) Expand and protect wetlands as a source of water supply storage. Prioritize wetland areas in land acquisition activities.
2) Promote and diversify riparian buffers on streams/drainage to Lake Massabesic.
    a. Encourage water production by selective removals of hardwoods, which can be incorporated into the Forestry Management Plan (refer to Recommendation #4).
    b. Diversify tree plantings to protect from invasive pests, which can be incorporated into the Forestry Management Plan (refer to Recommendation #4).
3) Inventory problem areas using a GIS layer specific for the watershed for the purpose of climate change proofing (e.g., problem areas during droughts and floods).

4) Monitor annual forest growth such that it at least meets, and preferably exceeds, the amount harvested. This may indicate more systemic problems in the forest ecosystem.

Objectives: To protect the supply under drought and flood conditions.

Partners: NH DES for potential funding for inventories and plan updates.

#15. Continue with Ongoing Water Supply Watershed and Watershed Protection Efforts

In addition to the monitoring, forestry practices and public education discussed in recommendations #1, #2, #4 and #9, MWW currently engages in several other water supply and watershed protection efforts that should continue. These include:

1) Considering future land acquisitions and pursuing collaborative efforts for conservation of land;
2) Visiting and talking with PCSs and other properties of concern in the watershed;
3) Aquatic weed control practices;
4) Regular patrols & inspections of the watershed.

Recommendation: Continue with other ongoing watershed and water supply protection efforts as outlined above.

Actions:

1) Prioritize and consider future land acquisition opportunities in the watershed. Pursue collaborative efforts for the conservation of watershed land, in addition to outright purchase by MWW.
2) Update PCS inventory every five years. Perform targeted outreach, including site visits to evaluate and discuss operations and best management practices, on an annual basis.
3) Continue with annual surveys of invasive species in the lake and the active control program. Track invasive plant populations in the Water Quality Database using quadrant designations (East A, East B, West A and West B) to provide spatial reference. Update the aquatic weed map annually.
4) Continue with regular patrols and inspections of the watershed. Enter findings in the Water Quality Database and prepare monthly incident reports.

Objectives: To provide continued long-term protection of the water supply.

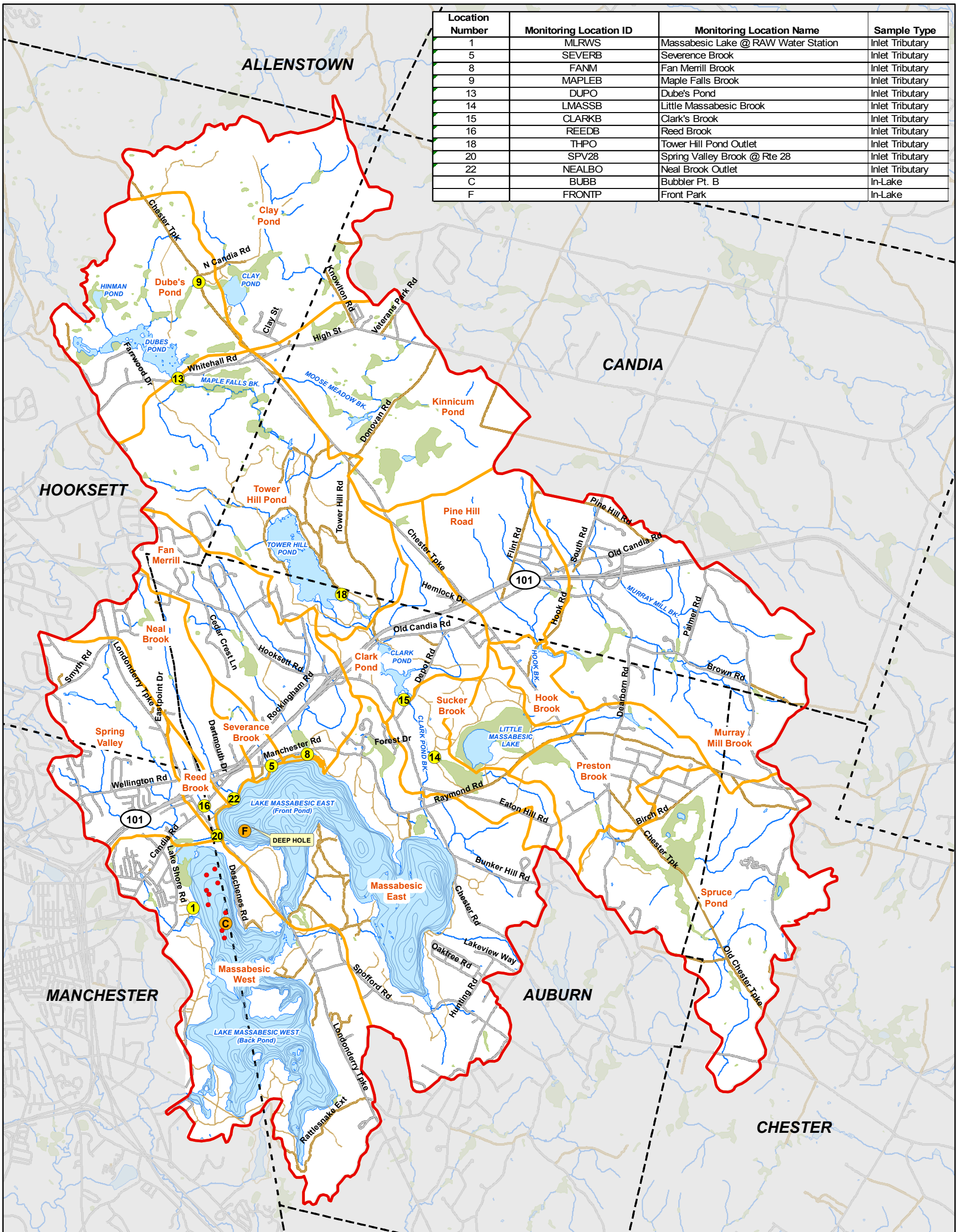
Partners: NH DES for potential funding.

7.3 Overall Plan Success Indicators

The success of the implementation of the recommendations must be measurable to ensure they are working and to make adjustments as needed to achieve the desired results. The following success indicators are proposed:

1) Data collected from the proposed long-term monitoring program will be used to assess long-term trend lines within the lake. Phosphorus and chlorophyll-a levels will be compared with oligotrophic thresholds of <8 ug/l and <3.3 ug/l, respectively and bottom DO levels will be compared with the threshold of 6 mg/l. Water quality data will be the primary measurement of success since it reflects actual water quality and habitat improvements.
2) The number of new and redevelopment projects constructed should be tracked by the watershed communities including the total and impervious acreage of the site, the "effective impervious coverage" (accounting for infiltration BMPs and disconnection practices), and the controls implemented at each site with estimated phosphorus removals. This information would provide a tally of watershed changes that can be compared with the in-lake monitoring program results to draw a correlation between development and water quality.
3) The condition and maintenance of septic systems within the 125 foot shoreland buffer should be continually tracked through direct contact by watershed patrol staff.
4) Track and document all watershed management actions performed by MWW and others over the 10-year implementation period to allow correlation with noted water quality changes.

Location Number	Monitoring Location ID	Monitoring Location Name	Sample Type
1	MLRWS	Massabesic Lake @ RAW Water Station	Inlet Tributary
5	SEVERB	Severence Brook	Inlet Tributary
8	FANM	Fan Merrill Brook	Inlet Tributary
9	MAPLEB	Maple Falls Brook	Inlet Tributary
13	DUPO	Dube's Pond	Inlet Tributary
14	LMASSB	Little Massabesic Brook	Inlet Tributary
15	CLARKB	Clark's Brook	Inlet Tributary
16	REEDB	Reed Brook	Inlet Tributary
18	THPO	Tower Hill Pond Outlet	Inlet Tributary
20	SPV28	Spring Valley Brook @ Rte 28	Inlet Tributary
22	NEALBO	Neal Brook Outlet	Inlet Tributary
C	BUBB	Bubbler Pt. B	In-Lake
F	FRONTP	Front Park	In-Lake



Legend

- Bubbler Locations

Water Monitoring Locations

- In-Lake
- Inlet Tributary
- Bathymetric Contours
- Lake Massabesic Watershed
- Subwatershed Boundaries
- Town Boundary

Roads

- Paved
- Unpaved

Hydrography

- Lake/Pond
- Wetland/Swamp
- Stream/Brook

Data Sources: GRANIT, MWW, City of Manchester

0 2,500 5,000 10,000 15,000 Feet

Figure 7-1

Lake Massabesic Watershed Management Plan

Proposed Water Quality Monitoring Locations

Manchester Water Works

Comprehensive Environmental Inc.