NEW YORK STATE OF OPPORTUNITY. | Department of Environmental Conservation | Department of Health | Agriculture and Markets

# HARMFUL ALGAL BLOOM ACTION PLAN

# MONHAGEN-MIDDLETOWN RESERVOIR SYSTEM


www.dec.ny.gov

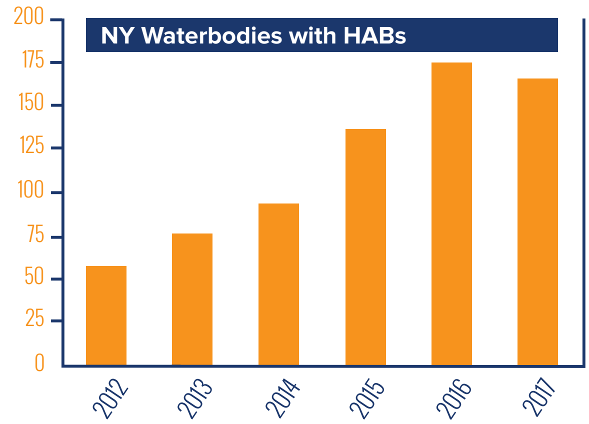
# EXECUTIVE SUMMARY

## SAFEGUARDING NEW YORK'S WATER

Protecting water quality is essential to healthy, vibrant communities, clean drinking water, and an array of recreational uses that benefit our local and regional economies.

Governor Cuomo recognizes that investments in water quality protection are critical to the future of our communities and the state. Under his direction, New York has launched an aggressive effort to protect state waters, including the landmark $2.5 billion Clean Water Infrastructure Act of 2017, and a first-of-its-kind, comprehensive initiative to reduce the frequency of harmful algal blooms (HABs).

New York recognizes the threat HABs pose to our drinking water, outdoor recreation, fish and animals, and human health. In 2017, more than 100 beaches were closed for at least part of the summer due to HABs, and some lakes that serve as the primary drinking water source for their communities were threatened by HABs for the first time.




## GOVERNOR CUOMO'S FOUR-POINT HARMFUL ALGAL BLOOM INITIATIVE

In his 2018 State of the State address, Governor Cuomo announced a $65 million, four-point initiative to aggressively combat HABs in Upstate New York, with the goal to identify contributing factors fueling HABs, and implement innovative strategies to address their causes and protect water quality.

Under this initiative, the Governor's Water Quality Rapid Response Team focused strategic planning efforts on 12 priority lakes across New York that have experienced or are vulnerable to HABs. The team brought together national, state, and local experts to discuss the science of HABs, and held four regional summits that focused on conditions that were potentially affecting the waters and contributing to HABs formation, and immediate and long-range actions to reduce the frequency and /or treat HABs.

Although the 12 selected lakes are unique and represent a wide range of conditions, the goal was to identify factors that lead to HABs in specific water bodies, and apply the information learned to other lakes facing similar threats. The Rapid Response Team, national stakeholders, and local steering committees worked together collaboratively to develop science-driven Action Plans for each of the 12 lakes to reduce the sources of pollution that spark algal blooms. The state will provide nearly $60 million in grant funding to implement the Action Plans, including new monitoring and treatment technologies.

## FOUR-POINT INITIATIVE

1. **PRIORITY LAKE IDENTIFICATION**
Identify 12 priority waterbodies that represent a wide range of conditions and vulnerabilities—the lessons learned will be applied to other impacted waterbodies in the future.

2. **REGIONAL SUMMITS**
Convene four Regional Summits to bring together nation-leading experts with Steering Committees of local stakeholders.

3. **ACTION PLAN DEVELOPMENT**
Continue to engage the nation-leading experts and local Steering Committees to complete Action Plans for each priority waterbody, identifying the unique factors fueling HABs—and recommending tailored strategies to reduce blooms.

4. **ACTION PLAN IMPLEMENTATION**
Provide nearly $60 million in grant funding to implement the Action Plans, including new monitoring and treatment technologies.

**TO LEARN MORE ABOUT HABs, VISIT:** on.ny.gov/hab www.health.ny.gov/HarmfulAlgae

# MONHAGEN-MIDDLETOWN RESERVOIR SYSTEM

## Orange County

Monhagen-Middletown Reservoir System includes five reservoirs covering 287 acres located in the Towns of Wallkill and Mount Hope, in Orange County. The Monhagen-Middletown Reservoir System is one of the 12 priority waterbodies impacted by HABs. The City of Middletown currently does not permit public access for recreational purposes, but at least one of the reservoirs, Mill Pond, has private landowners adjacent to the reservoir who have recreation access.

**The significant sources of phosphorus loading in the reservoir system are:**

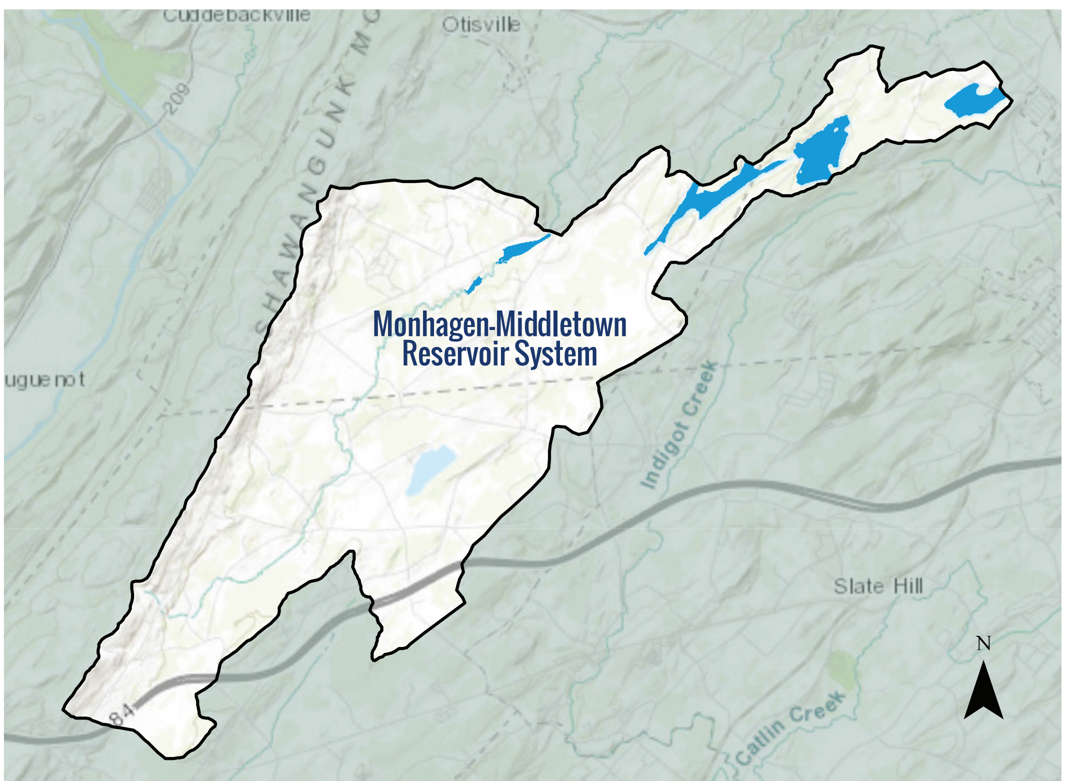
- Phosphorus inputs associated with wastewater treatment plant discharges; and
- Nonpoint sources and nutrient impacts from forested and agricultural runoff.

Monhagen-Middletown Reservoir System reportedly experiences periodic HABs, though HABs-specific data are not available for any of the waterbodies in the Monhagen-Middletown Reservoir System.

Although the causes of HABs vary from lake to lake, phosphorus pollution—from sources such as wastewater treatment plants, septic systems, and fertilizer runoff—is a major contributor. Other factors likely contributing to the uptick in HABs include higher temperatures, increased precipitation, and invasive species.

**With input from national and local experts, the Water Quality Rapid Response Team identified a suite of priority actions (see Section 13 of the Action Plan for the complete list) to address HABs in the Monhagen-Middletown Reservoir System, including the following:**

- Update land classification for the reservoir system watershed areas;
- Complete a feasibility study and cost estimate to upgrade Hidden Valley Estates wastewater treatment plant (WWTP);
- Research sources of algal blooms and cyanotoxins, conduct thermal and dissolved oxygen profiles to evaluate stratification, and complete a feasibility study to install aeration facilities;
- Purchase land and conservation easements, and enhance riparian buffers; and
- Pursue engineering studies to evaluate the efficacy of additional treatment at public water systems.




The black outline shows the lake's watershed area: all the land area where rain, snowmelt, streams or runoff flow into the lake. Land uses and activities on the land in this area have the potential to impact the lake.

# MONHAGEN-MIDDLETOWN RESERVOIR SYSTEM CONTINUED

## NEW YORK'S COMMITMENT TO PROTECTING OUR WATERS FROM HABS

New York is committed to addressing threats related to HABs, and will continue to monitor conditions in Monhagen-Middletown Reservoir System while working with researchers, scientists, and others who recognize the urgency of action to protect water quality.

Governor Cuomo is committed to providing nearly $60 million in grants to implement the priority actions included in these Action Plans, including new monitoring and treatment technologies. The New York State Water Quality Rapid Response Team has established a one-stop shop funding portal and stands ready to assist all partners in securing funding and expeditiously implementing priority projects. A description of the various funding streams available and links for applications can be found here: https://on.ny.gov/HABsAction.

This Action Plan is intended to be a 'living document' for Monhagen-Middletown Reservoir System and interested members of the public are encouraged to submit comments and ideas to DOWInformation@dec.ny.gov to assist with HABs prevention and treatment moving forward.

## NEW YORK STATE RESOURCES

**Drinking Water Monitoring and Technical Assistance:**

The state provides ongoing technical assistance for public water suppliers to optimize drinking water treatment when HABs and toxins might affect treated water. The U.S. EPA recommends a 10-day health advisory level of 0.3 micrograms per liter for HAB toxins, called microcystins, in drinking water for young children.

**Public Outreach and Education:**

The **Know It, Avoid It, Report It** campaign helps educate New Yorkers about recognizing HABs, taking steps to reduce exposure, and reporting HABs to state and local agencies. The state also requires regulated beaches to close swimming areas when HABs are observed and to test water before reopening.

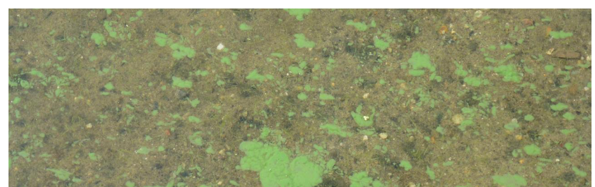
**Research, Surveillance, and Monitoring:**

Various state agencies, local authorities and organizations, and academic partners are working together to develop strategies to prevent and mitigate HABs. The state tracks HAB occurrences and illnesses related to exposure.

**Water Quality and Pollution Control:**

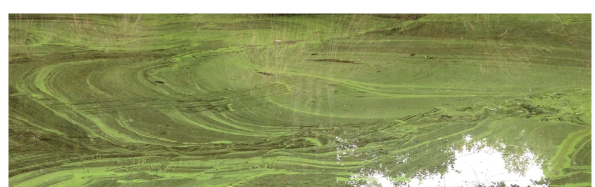
State laws and programs help control pollution and reduce nutrients from entering surface waters. State funding is available for municipalities, soil and water conservation districts, and non-profit organizations to implement projects that reduce nutrient runoff.

**Pea soup appearance**



**Floating dots or clumps**

**Spilled paint appearance**



**Streaks on the water's surface**

**CONTACT WITH HABs CAN CAUSE HEALTH EFFECTS**

Exposure to HABs can cause diarrhea, nausea, or vomiting; skin, eye or throat irritation; and allergic reactions or breathing difficulties.

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# 1. Introduction

## 1.1 Purpose

New York State's aquatic resources are among the best in the country. State residents benefit from the fact that these resources are not isolated, but can be found from the eastern tip of Long Island to the Niagara River in the west, and from the St. Lawrence River in the north to the Delaware River in the south.

These resources, and the plants and animals they harbor, provide both the State and the local communities a wealth of public health, economic, and ecological benefits including potable drinking water, tourism, water-based recreation, and other ecosystem services. Harmful algal blooms (HABs), primarily within ponded waters (i.e., lakes and ponds) of New York State, have become increasingly prevalent in recent years and have impacted the values and services that these resources provide.

This HABs Action Plan for the Monhagen-Middletown Reservoir System has been developed by the New York State Water Quality Rapid Response Team (WQRRT) to:

- Describe existing physical and biological conditions
- Summarize the research conducted to date and the data it has produced
- Identify the potential causative factors contributing to HABs
- Provide specific recommendations to minimize the frequency and duration of HABs to protect the health and livelihood of its residents and wildlife.

This Action Plan represents a key element in New York State's effort to combat HABs now and into the future.

## 1.2 Scope, Jurisdiction and Audience

The New York State HABs monitoring and surveillance program was developed to evaluate conditions for waterbodies with a variety of uses (public, private, public water supplies (PWSs), non-PWSs) throughout the State. The Governor's HABs initiative focuses on waterbodies that possess one or more of the following elements:

- Serve as a public drinking water supply
- Are publicly accessible
- Have regulated bathing beaches

Based on these criteria, the Governor's HABs initiative has selected 12 New York State waterbodies that are representative of waterbody types, lake conditions, and vulnerability to HABs throughout the State. The Monhagen-Middletown Reservoir System, with its use as a potable water source and a history of HABs, was selected as one of the priority waterbodies, and is the subject of this HABs Action Plan.

The intended audiences for this HABs Action Plan are as follows:

- New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health (NYSDOH), and New York State Department of Agriculture and Markets (NYSDAM) officials associated with the HABs initiative
- State agency staff who are directly involved in implementing or working with the NYS HABs monitoring and surveillance program
- Local and regional agencies involved in the oversight and management of the Monhagen-Middletown Reservoir System (e.g., Orange County Soil and Water Conservation District (SWCD), Orange County Department of Health (DOH), Orange County Water Authority (OCWA), and Orange County Planning Department)).
- Lake residents, managers, consultants, and others that are directly involved in the management of HABs in the Monhagen-Middletown Reservoir System, particularly the City of Middletown.
- Members of the public interested in background information about the development and implications of the HABs program.

Analyses conducted in this Action Plan provide insight into the processes that potentially influence the formation of HABs in the Monhagen-Middletown Reservoir System, and their spatial extents, durations, and intensities. Implementation of the mitigation actions recommended in this HABs Action Plan are expected to reduce the likelihood of blooms in the Monhagen-Middletown Reservoir System.

### 1.3 Background

Harmful algal blooms in freshwater generally consist of visible patches of cyanobacteria, also called blue-green algae (BGA). Cyanobacteria are naturally present in low numbers in most marine and freshwater systems. Under certain conditions, including adequate nutrient (e.g., phosphorus) availability, warm temperatures, and calm winds, cyanobacteria may multiply rapidly and form blooms that are visible on the surface of the affected waterbody. Several types of cyanobacteria can produce toxins and other harmful compounds that can pose a public health risk to people and animals through ingestion, skin contact, or inhalation. The NYSDEC has documented the occurrence of HABs in the Monhagen-Middletown Reservoir System and has produced this HABs Action Plan to identify the primary factors triggering HAB events, and to facilitate decision-making to minimize the frequency, intensity, and duration of HABs.

# 2. Lake Background

This Action Plan for the Monhagen-Middletown Reservoir System provides information on, and recommended actions for, five man-made reservoirs and one surface water intake that together serve as the drinking water supply for the City of Middletown as well as portions of the Towns of Wallkill and Wawayanda. As detailed below, these facilities are connected by both natural drainage and water system infrastructure (**Figure 1**). The Indigot Intake, Kinch Pond, Mill Pond, Shawangunk Reservoir and Highland Lake are treated herein as feeders to Monhagen Lake which is the ultimate receiving water (Note: Highland Lake is also a terminal reservoir but is treated herein as a feeder to Monhagen Lake due to their existing connection). The segment of Monhagen Brook which is downstream of Monhagen Lake is not part of this HABs initiative. Therefore, the primary focus of this Action Plan is on Monhagen Lake as the terminal reservoir, with discussion of the feeders because, collectively, they influence water quality within the Monhagen-Middletown Reservoir System (Hazen and Sawyer 2002; HDR 2009):

- Indigot Intake – An intake is located on the Shawangunk Kill that conveys up to 3,500 gallons per minute (GPM) to the Shawangunk Reservoir. A reservoir has been proposed in the location of the existing intake but has not been constructed to date
- Kinch Pond – a 20 million-gallon (MG) reservoir that flows into the Shawangunk Reservoir
- Mill Pond – a 25 MG reservoir with an 8-inch pipe through which water can be pumped to the Shawangunk Reservoir
- Shawangunk Reservoir – a 537 MG reservoir from which water either flows to Monhagen Lake or is pumped to Highland Lake
- Highland Lake – a 520 MG reservoir from which water is either routed to the Highland Treatment Plant, a standby system with a 1.5 MGD capacity, or is pumped to Monhagen Lake
- Monhagen Lake – a 283 MG reservoir, which serves as the terminal reservoir for the City of Middletown's drinking water supply.

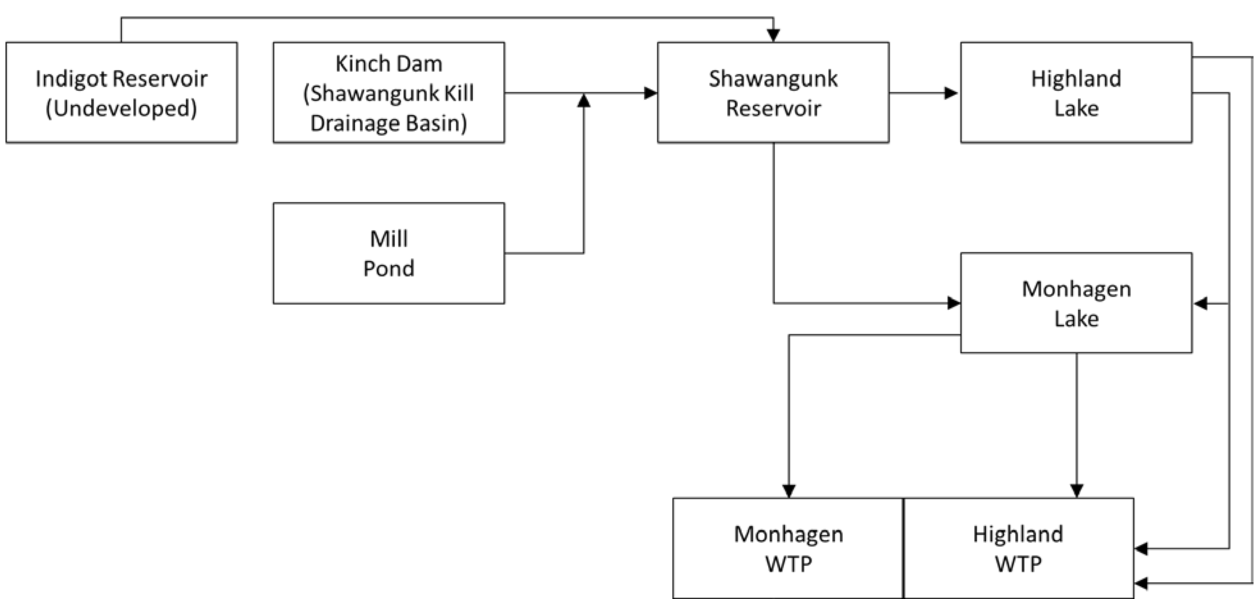


**Figure 1.** Schematic of existing water supply for the City of Middletown.

The Monhagen Water Treatment Facility was replaced with a new facility in 2010 that maintained the 5.1 MGD capacity that currently serves 30,000 residents (Hazen and Sawyer 2002; HDR 2009). In addition to Monhagen Lake water being sent to the Monhagen Water Treatment Plant for treatment, there is an emergency connection to Highland Water Treatment Plant. Water within Monhagen Lake that is not drawn into the water supply system discharges to Monhagen Brook in the northeast corner of the lake.

## 2.1 Geographic Location

Monhagen Lake is a 64-acre man-made lake located in the Town of Wallkill in Orange County, in the western portion of the Lower Hudson River region of New York State (**Figure 2**). The feeder resources associated with the Monhagen-Middletown Reservoir System are located southwest of Monhagen Lake (see **Figure 3**). Highland Lake has a surface area of 96 acres, and Shawangunk Reservoir has a surface area of 102 acres.

## 2.2 Basin Location

The watershed for the Monhagen-Middletown Reservoir System is located outside of the City of Middletown in the neighboring municipalities of Mount Hope, Greenville, and Wallkill (**Figure 4**). It is fed by ponds and streams of the Shawangunk Kill – specifically Mill Pond, Kinch Pond, Highland Lake and Shawangunk Reservoir.
Morphology


**Figure 2.** Location of Monhagen Lake within New York State (indicated by blue square).

Monhagen Lake has a mean depth of approximately 3.6 meters (11.8 feet) and a maximum depth of 6.8 meters (22.3 feet) (NYSDEC 2010a). The lake's relatively low surface area-to-depth ratio of approximately 5:1 makes it less susceptible to turbulence caused by wind and wave actions that promote internal mixing than lakes with higher ratios. In addition, the lake's relatively low watershed to surface area ratio of 6:1 is often associated with low rates of sedimentation and land-based loading of phosphorus and other nutrients (e.g., nitrogen).

For means of comparison, Highland Lake has a mean depth of 4.7 meters (15.4 feet) and a maximum depth of 5.8 meters (19.0 feet). Shawangunk Reservoir has a mean depth of 3.1 meters (10.2 feet) and a maximum depth of 8.8 meters (28.9 feet).

A wind rose for Monhagen Lake (**Appendix A**) indicates that the prevailing wind direction was from southwest and northeast during June through November from 2006 to 2017, as measured at the Orange County Airport. This pattern of prevailing winds generally results in a fetch of approximately 1,500 ft. (oriented southwest to northeast). Given these wind patterns for Monhagen Lake, buoyant cyanobacteria may accumulate in the northeastern portion of the water body if winds originate from the southwest, or the southwestern part of Monhagen Lake when stronger winds originated out of the northeast.

## 2.3 Hydrology

Monhagen Lake has a retention time, or the average amount of time it takes water to pass through the lake, of approximately one year. Monhagen Brook is a tributary to Monhagen Lake, and as described in **Section 2**, the lake is also hydrologically connected to Shawangunk Reservoir, Highland Lake, Kinch Pond, Mill Pond, and the Indigot Intake. Water from Kinch and Mill Ponds is conveyed to Shawangunk Reservoir (retention time of about 0.6 years), where it continues to Monhagen Lake or is pumped to Highland Lake (retention time of approximately 2 years). Water that is not transported to the Monhagen Water Treatment Plant from Monhagen Lake flows southeast into Monhagen Brook, the Wallkill River, and then to the Hudson River (NYSDEC 2010a, HDR 2009, EA Engineering 1994, Hazen and Sawyer 2002).

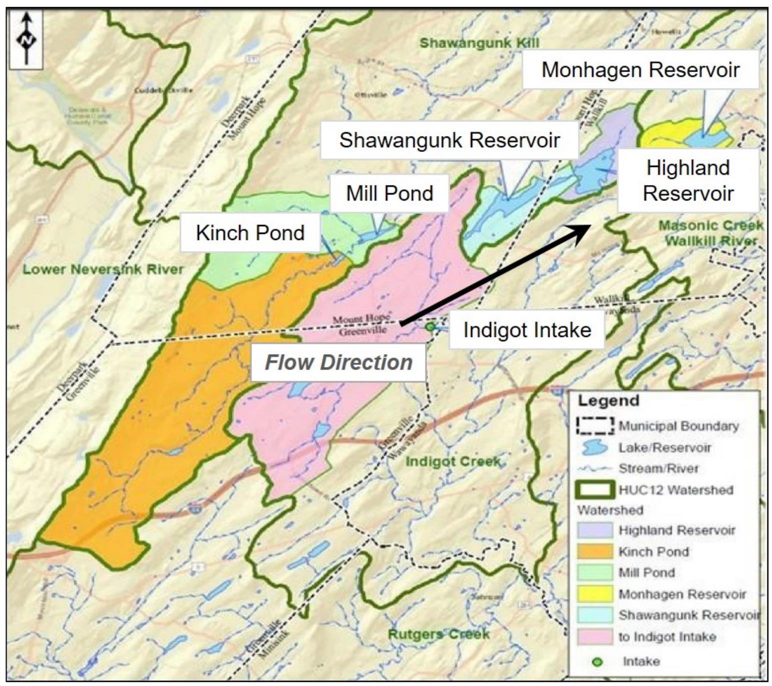


**Figure 3.** City of Middletown water source watersheds (Source: CDM Smith 2016)

## 2.4 Lake Origin

Monhagen Lake and the other reservoirs within the system are man-made. Monhagen Brook was dammed in the mid-1800s to create Monhagen Lake to create facilities that would provide potable water to the City of Middletown (Laskaris 1988). Each reservoir is owned and maintained by the City of Middletown.

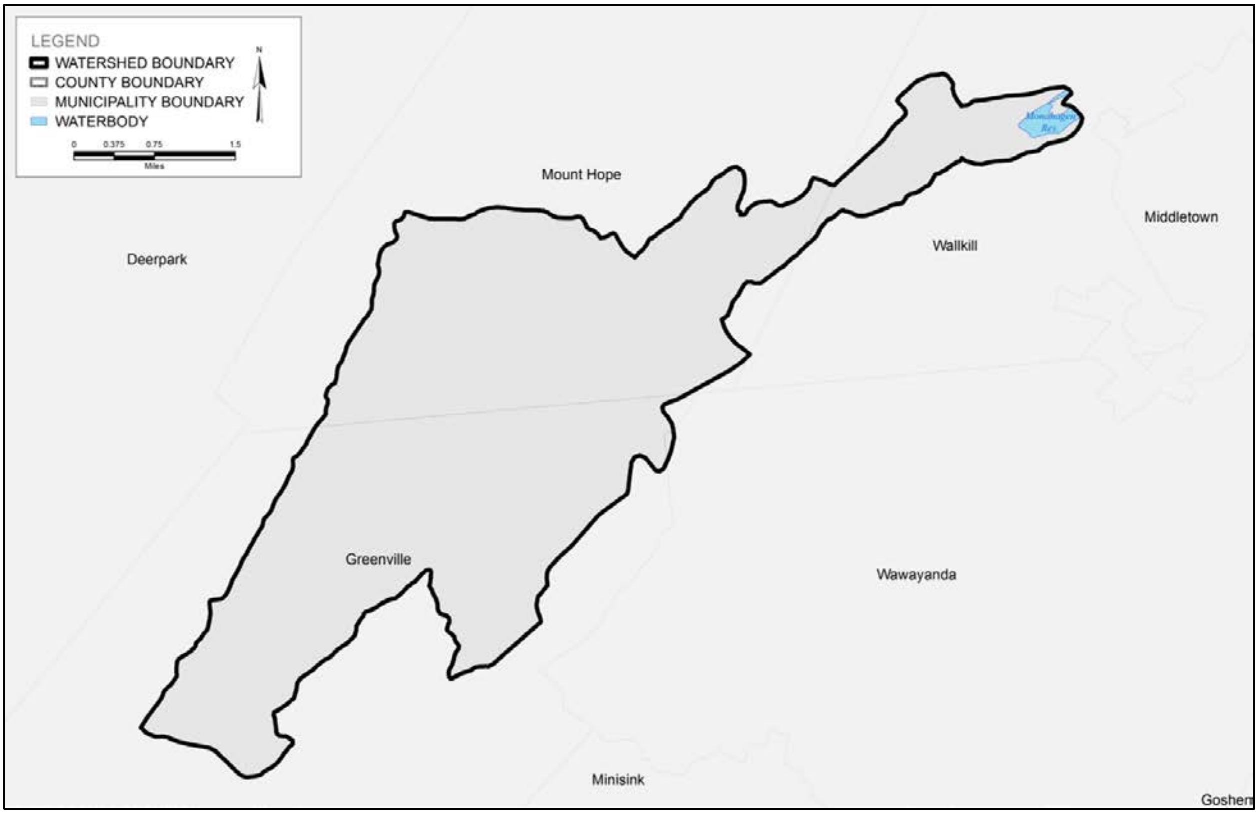


**Figure 4.** Political boundaries within the Monhagen-Middletown Reservoir System.

# 3. Designated Uses

## 3.1 Water Quality Classification – Lake and Major Tributaries

Monhagen Lake is classified as a Class AA waterbody under the New York Codes, Rules, and Regulations (6NYCRR Part 864.6), meaning it is suitable for use as a water supply for drinking (with approved disinfection treatments) and culinary or food processing purposes. The lake is also suitable for primary and secondary contact recreation, fishing, and fish propagation and survival (NYSDEC 2008). The New York state classification system is provided in **Appendix B**.

Shawangunk Reservoir and Highland Lake are also classified as Class AA waterbodies (NYSDEC 2008).

Kinch Pond is a Class A waterbody fed by a Class A tributary of the Shawangunk Kill, meaning they are suitable for use as potable water supplies (with approved coagulation, sedimentation, filtration, and disinfection treatments) and culinary or food processing purposes. They are also suitable for primary and secondary contact recreation, fishing, and fish propagation and survival.

Mill Pond and the tributaries of the Shawangunk Kill that feed this pond are a Class B waterbody and Class B streams (NYSDEC 2018b, NYSDEC 2008), meaning they are best used for primary and secondary contact recreation, fishing, and fish propagation and survival.

## 3.2 Potable Water Uses

The City of Middletown has 7,415 active metered water accounts that serve approximately 30,000 people. Of these accounts, 337 are located in the Town of Wallkill and a water district in the Town of Wawayanda (Middletown Water Department 2016).

The United States Environmental Protection Agency (USEPA) sets health advisories to protect people from being exposed to contaminants in drinking water. As described by the USEPA: "The Safe Drinking Water Act provides the authority for the USEPA to publish health advisories for contaminants not subject to any national primary drinking water regulation. Health advisories describe nonregulatory concentrations of drinking water contaminants at or below which adverse health effects are not anticipated to occur over specific exposure durations (e.g., one-day, 10-days, several years, and a lifetime). Health advisories are not legally enforceable federal standards and are subject to change as new information becomes available."

Health advisories are not bright lines between drinking water levels that cause health effects and those that do not. Health advisories are set at levels that consider animal studies, human studies, vulnerable populations, and the amount of exposure from drinking water. This information is used to establish a health protective advisory level that provides a wide margin of protection because it is set far below levels that cause health effects. When a health advisory is exceeded, it raises concerns not because health effects are likely to occur, but because it reduces the margin of protection provided by the health advisory. Consequently, exceedance of the health advisory serves as an indicator to reduce exposure, but it does not mean health effects will occur.

In 2015, the USEPA developed two 10-day drinking water health advisories for the HAB toxin microcystin: 0.3 micrograms per liter (μg/L) for infants and children under the age of 6, and 1.6 μg/L for older children and adults. (USEPA 2015). The 10-day health advisories are protective of exposures over a 10-day exposure period to microcystin in drinking water, and are set at levels that are 1,000-fold lower than levels that caused health effects in laboratory animals. The USEPA's lower 10-day health advisory of 0.3 μg/L is protective of people of all ages, including vulnerable populations such as infants, children, pregnant women, nursing mothers, and people with pre-existing health conditions. The NYSDOH has used the health advisory of 0.3 μg/L as the basis for recommendations, and a do not drink recommendation will be issued upon confirmation that microcystin levels exceeds this level in the finished drinking water delivered to customers.

In 2015, the USEPA also developed 10-day health advisories for the HAB toxin cylindrospermopsin (USEPA 2015). Although monitoring for cylindrospermopsin continues, it has not been detected in any of the extensive sampling performed in New

York State. New York State HAB response activities have focused on the blooms themselves and microcystin given it is by far the most commonly HAB toxin found.

Water system operators should conduct surveillance of their source water on a daily basis. If there is a sign of a HAB, they should confer with NYSDOH and NYSDEC as to whether a documented bloom is known. The water system operator, regardless of whether there is a visual presence of a bloom, should also be evaluating the daily measurements of their water system. If there is any evidence—such as an increase in turbidity, chlorine demand, and chlorophyll—then the water system operator should consult with the local health department about the need to do toxin measurement. The local health department should consult with NYSDOH central office on the need to sample and to seek additional guidance, such as how to optimize existing treatment to provide removal of potential toxins. If toxin is found then the results are compared to the USEPA 10-day health advisory of 0.3 µ/L, and that the results of any testing be immediately shared with the public. NYSDOH also recommends that if a concentration greater than the 0.3 µg/L is found in finished water, then a recommendation be made to not drink the water. NYSDOH has templates describing these recommendations that water system operators and local officials can use to share results with customers. Additionally, public water systems that serve over 3,300 people are required to submit Vulnerability Assessment /Emergency Response Plans (VA/ERP); in situations where a water system is using surface waters with a documented history of HABs, NYSDOH will require water system operators to account for HABs in their VA/ERP (which must be updated at least every five years).

## 3.3 Public Bathing Uses

Monhagen Lake and the other reservoirs do not currently offer public swimming opportunities (NYSDEC 2010a).

## 3.4 Recreation Uses

The Citizens Statewide Lake Assessment Program (CSLAP) data for Monhagen Lake suggest non-contact recreation (e.g., boating and fishing) should be fully supported (NYSDEC 2010a). However, the City of Middletown currently does not permit public access for recreational purposes. At least one of the reservoirs, Mill Pond, has private landowners adjacent to the reservoir who have recreation access. Recreation conditions within Shawangunk Reservoir and Highland Lake would likely be evaluated as excellent and excellent to slightly impacted, respectively, based on water quality conditions and associated recreational perception in similar lakes, if recreational uses were to be allowed (NYSDEC 2008).

## 3.5 Fish Consumption/Fishing Uses

Statewide fishing regulations are applicable in Monhagen Lake, Highland Lake, and Shawangunk Reservoir. However, it is likely that the lakes do not support active fishing due to the protection of the lake as a water supply (NYSDEC 2010a).

### 3.6 Aquatic Life Uses

While quantitative data of fish populations in the Monhagen-Middletown Reservoir System are not available, the qualitative fish species data suggests that the fish assemblage may exert cascading regulating ("top down") effects on lower trophic levels (e.g., zooplankton, benthic macroinvertebrate) that may contribute to HAB formations. For example, the feeding behavior of common carp, an invasive cyprinid that forages preferentially on benthic macroinvertebrates in lakebed sediments, can increase the suspension of sediment and nutrients into the water column. The increase in nutrient concentrations in the water column may be utilized by cyanobacteria, potentially leading to HABs.

# 4. User and Stakeholder Groups

Several citizen advocacy groups and county agencies exist with the shared goal of protecting the water resources of the Hudson Valley Region, including the Monhagen-Middletown Reservoir System. These include:

- The Orange County Water Authority (OCWA) was created to address the long-term water needs of Orange County by supporting local, intermunicipal, and regional planning and water projects and coordinating analysis of the county's water resources to provide a scientific basis for planning and decision-making. The OCWA focuses on water supply, water resource protection, watershed planning, and conservation (Orange County SWCD 2018).
- The Orange County Land Trust (OCLT) was founded in 1993 for the preservation of water resources, critical habitat, rural and urban farmland, scenic viewsheds, and ecosystems in and around Orange County. The OCLT has protected nearly 6,000 acres of land since it began, much of which is open to the public (OCLT 2018).
- The Lower Hudson Coalition of Conservation Districts (LHCCD) is composed of ten soil and water conservation districts with the goal of conserving water quality and natural resources in the Hudson River Estuary watershed. Participating counties include Albany, Greene, Columbia, Ulster, Dutchess, Orange, Putnam, Rockland, Westchester, and NYC (LHCCD 2018).
- Scenic Hudson was founded in 1963 with the goal of preserving land and farms, creating parks, and addressing issues faced by the Hudson River and its natural resources. The group works with residents, elected officials, developers, and regional and state entities to promote planning and design standards that protect scenic views, limit urban sprawl, revitalize community centers, and mitigate environmental impacts of new development (Scenic Hudson 2018, Orange County SWCD 2018).

- The Hudson River Estuary Program was created in 1987 through the Hudson River Estuary Management Act and focuses on the tidal Hudson and adjacent watershed from the federal dam at Troy to the Verrazano Narrows in New York City. The program promotes the use, protection, and revitalization of the Hudson River and its valley (NYSDEC 2018c).
- The Wallkill River Watershed Alliance (WRWA) was created in 2015 with a mission to restore the Wallkill River to its prime, to act as the voice of the River, and to advocate for the restoration of its entire watershed, using whatever means necessary. Its three main goals are to improve water quality, increase public engagement, and build capacity to protect and restore the Wallkill River and its watershed (WRWA 2018).
- The Hudson River Fishermen’s Association, now known as Riverkeeper, was formed in 1966 by a group of fishermen to address impacts to the River’s natural resources, fish, drinking water supplies, and recreational opportunities. Riverkeeper’s mission is to protect the environmental, recreational and commercial integrity of the Hudson River and its tributaries, and safeguard the drinking water of nine million New York City and Hudson Valley residents (Riverkeeper 2018).
- Clearwater was founded in 1966 by the musician and environmentalist Pete Seeger in response to the same issues observed by the Hudson River Fishermen’s Association. In 1969, the sloop Clearwater was launched to collect scientific data, raise awareness, and educate the public on environmental conditions within the Hudson River. The Hudson River Sloop Clearwater, Inc. now partners with Hudson Valley schools and community leaders to continue to educate the public and encourage youth to become active stewards of their environment and the Hudson River (Clearwater 2018).

# 5. Monitoring Efforts

## 5.1 Lake Monitoring Activities

Monhagen Lake has reportedly experienced algae levels high enough to impact its quality as a potable water source (NYSDEC 2010a). Studies have been conducted on Monhagen Lake to identify potential factors that may be contributing to the perceived decrease in water quality, including the following:

- Monhagen Lake was first sampled as part of CSLAP in 2003. **Section 6** details the physical, chemical, and biological condition of Monhagen Lake based on data collected through the CSLAP program. Water quality monitoring has been conducted through CSLAP from 2003 to 2005 and 2008 to 2009 (NYSDEC 2010a).

- Monhagen Lake was sampled in 1987 as part of the Adirondack Lake Survey Corporation (ALSC) survey of more than 1500 lakes in the Adirondacks and Catskill region to evaluate lake acidification. These results suggest better water quality conditions than those measured through CSLAP, as water clarity was higher, and nutrient levels were lower (suggesting that algae levels were also lower, although chlorophyll-a was not measured through the ALSC program) (NYSDEC 2010a).

Both Highland Lake and Shawangunk Reservoir also were sampled as part of the CSLAP program from 2003 to 2005 and 2008 to 2009 (NYSDEC 2010b, 2010c). Generally, CSLAP reports for Highland Lake, Shawangunk Reservoir, and Monhagen Lake indicate similar conditions, particularly as it relates to eutrophication and susceptibility for HABs.

## 5.2 Tributary Monitoring Activities

There are no historical NYSDEC Rotating Intensive Basins (RIBS) monitoring sites on or near Monhagen Lake (NYSDEC 2010a). However, Monhagen Brook has been sampled at various locations downstream of the lake as part of the NYSDEC's Stream Biomonitoring program between 1992 – 2012. Results of this monitoring suggest slight to moderate water quality impacts on aquatic life. More recent sampling in 2017 occurred at a single site on Monhagen Brook at river mile 0.4. Both biological and water chemistry monitoring occurred. Biological monitoring results suggest slight water quality impacts to aquatic life. Water chemistry monitoring suggests water quality below standards but with elevated nutrients, especially total phosphorus. Monitoring of this location continues in 2018 with the addition of another site upstream at river mile 4.1.

The NYSDEC Stream Monitoring and Assessment Section and the Hudson River Estuary Program plan to conduct water quality sampling in summer 2018 for several tributaries to Kinch Pond, Mill Pond and Shawangunk Reservoir. Samples will be analyzed for biological indicators of stream health (benthic macroinvertebrates), water chemistry parameters and harmful algal bloom information including chlorophyll concentration, algal community composition and testing for a suite of algal toxins.

# 6. Water Quality Conditions

Trends in water quality for Monhagen Lake, Highland Lake and Shawangunk Reservoir were assessed using CSLAP data from 2003 to 2005 and 2008 to 2009. However, since the focus on this evaluation is on the terminal reservoir (Monhagen Lake), the detailed results for Monhagen Lake are presented here. Statistical significance of time trends was evaluated with Kendall's tau trend test using annual average values. This nonparametric correlation coefficient determines if trends over time were significantly different than zero, or there was no trend. A significant difference was assumed for p-values less than 0.05. Water quality data used in this analysis were limited to those that were collected under a State-approved Quality Assurance Project Plan (QAPP), and analyzed at an Environmental Laboratory Accredited Program (ELAP) certified laboratory. Note that long-term trends presented below are intended to provide an overview of water quality conditions, and that continued sampling will better inform trend analyses over time.

**Table 1** provides a regional summary of surface TP concentrations from Monhagen Lake compared to New York State lakes. In freshwater lakes, phosphorus is typically the nutrient that limits plant growth; therefore, when excess phosphorus becomes available from point sources or nonpoint sources, primary production can continue unchecked leading to algal blooms. Note that phosphorus form is an important consideration when evaluating management alternatives (**Section 13**).

**Table 1. Regional summary of surface total phosphorus (TP) concentrations (mg/L, ± standard error) for New York State lakes (2012-2017, CSLAP and LCI), and the average TP concentration (± standard error) in Monhagen Lake (2003-2005, 2008-2009, CSLAP).**

| Region | Number of Lakes | Average TP (mg/L) | Average TP Monhagen Lake (mg/L) 2003-2005; 2008-2009 |
|---|---|---|---|
| **NYS** | 521 | 0.034 (± 0.003) | - |
| **NYC-LI** | 27 | 0.123 (± 0.033) | - |
| **Lower Hudson** | 49 | 0.040 (± 0.005) | 0.031 (± 0.003) |
| **Mid-Hudson** | 53 | 0.033 (± 0.008) | - |
| **Mohawk** | 29 | 0.040 (± 0.009) | - |
| **Eastern Adirondack** | 112 | 0.010 (± 0.0004) | - |
| **Western Adirondack** | 88 | 0.012 (± 0.001) | - |
| **Central NY** | 60 | 0.024 (± 0.005) | - |
| **Finger Lakes region** | 45 | 0.077 (± 0.022) | |
| **Finger Lakes** | 11 | 0.015 (± 0.003) | - |
| **Western NY** | 47 | 0.045 (± 0.008) | - |

The data provided in **Table 1** indicate that the average TP concentration in Monhagen Lake is about 25% lower than the average concentration found throughout the Lower Hudson region. Further, the average TP concentration is 50% greater than the New York State water quality guidance value of 0.02 mg/L, which suggests that future management actions to protect water quality should likely focus on reducing TP concentrations.

Water clarity (based on Secchi depth, m), TP (mg/L) and chlorophyll-a (µg/L) concentrations are used to assess trophic state using New York State criteria (**Table 2**). Based on water quality sampling, these indicators suggest Monhagen Lake and Shawangunk Reservoir were eutrophic (highly productive), while Highland Lake was mesoeutrophic.

| **Table 2. New York State criteria for trophic classifications (NYSFOLA 2009) compared to average values (± standard error) in Monhagen and Highland Lakes, and Shawangunk Reservoir (CSLAP).** | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **Oligotrophic** | **Mesotrophic** | **Eutrophic** | **Monhagen Lake** 2003-2005; 2008-2009 | **Highland Lake** 2003-2005; 2008-2009 | **Shawangunk Reservoir** 2003-2005; 2008-2009 |
| **Transparency (m)** | >5 | 2-5 | <2 | 2.0 (± 0.13) | 2.2 (± 0.14) | 2.3 (± 0.13) |
| **TP (mg/L)** | <0.010 | 0.010-0.020 | >0.020 | 0.031 (± 0.003) | 0.038 (± 0.005) | 0.029 (± 0.002) |
| **Chlorophyll-a (µg/L)** | <2 | 2-8 | >8 | 8.4 (± 1.1) | 4.0 (± 0.46) | 9.1 (± 1.9) |

## 6.1 Physical Conditions

Water clarity, as represented by Secchi depth, showed no statistical trend over time ($p$ = 0.327, $\tau$ = -0.400); however, Secchi depth was notably lower in 2008 and 2009 (**Figure 5**). The minimum Secchi depth, or the shallowest recorded value for a given year, has also shown no trend ($p$ = 0.327, $\tau$ = -0.400). Water clarity in Highland Lake and Shawangunk Reservoir also showed no trend over time (p-values > 0.05). Secchi disk transparency readings regularly exceeded the New York State Sanitary Code requirements for siting new bathing beaches (1.2-meter, or 4 ft., minimum, NYSDOH 2018b, NYSDOH 2018), although as noted above, these lakes do not support this use. These trophic indicators should continue to be monitored for changes.

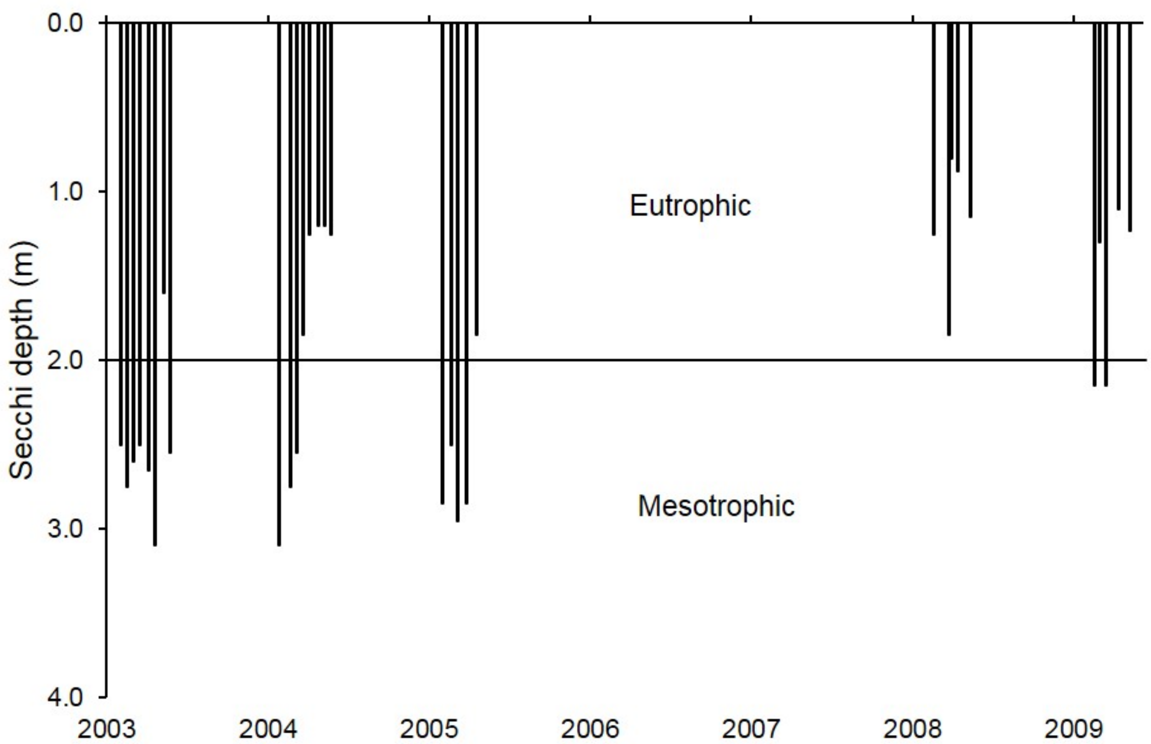


**Figure 5.** Monhagen Lake water clarity, measured as Secchi depth (m), from 2003-2005 and 2008-2009 (CSLAP).

Understanding temperature changes within a waterbody seasonally, as well as annually, is important in understanding HABs. Most cyanobacteria taxa grow better at higher temperatures than other phytoplankton which give them a competitive advantage at higher temperatures (typically above 25°C) (Paerl and Huisman 2008). Surface water temperatures have been observed to exceed 25°C in Monhagen Lake during summer (**Figure 6**). Available water temperature (°C) data indicate there were no long-term trends in Monhagen Lake (**Figure 6**):

- Average annual temperature - $p = 0.624$, $\tau = 0.200$
- Number of temperature readings above 20°C - $p = 0.296$, $\tau = 0.447$
- Maximum annual temperature - $p = 0.405$, $\tau = -0.359$

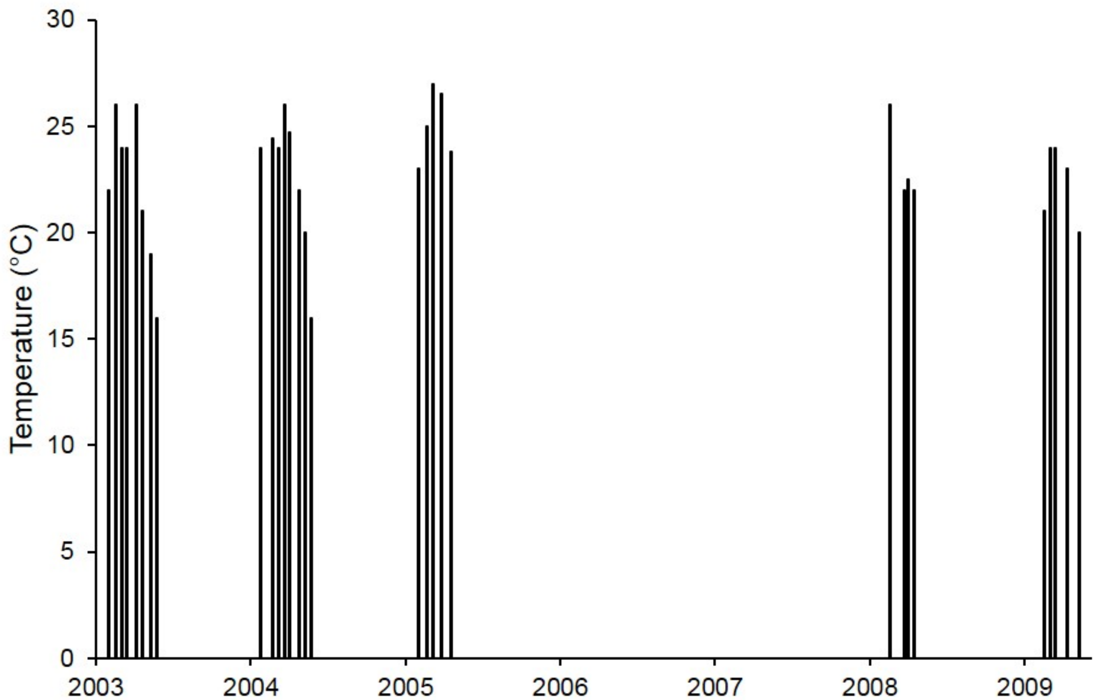


**Figure 6.** Surface water temperatures (°C) in Monhagen Lake from 2003-2005 and 2008-2009 (CSLAP).

Similarly, no long-term trends in average annual temperature, temperatures exceeding 20°C, or maximum annual temperature were identified in Highland Lake or Shawangunk Reservoir over the five years of available data.

## 6.2 Chemical Conditions

*Results from Past Studies*

As discussed in **Section 5**, the sampling of Monhagen Lake in 1987 as part of the ALSC survey suggested that water clarity was higher, and nutrient levels were lower, than the more recent CSLAP data indicate. This suggests that algae levels were also lower (NYSDEC 2010a).

*Current Analysis*

While current water quality data are not available to the NYSDEC, average summer TP concentrations suggest that Monhagen Lake is eutrophic (highly productive) (**Figure 7**). There was not a statistically significant trend in annual average TP concentrations in Monhagen Lake ($p$ = 0.624, $\tau$ = -0.200); however, TP concentrations were markedly higher in 2008 when the average was 0.04 mg/L (± 0.02). The annual average TP levels met or exceeded the New York State guidance value for protection of recreational uses of 0.20 mg/L in 2003, 2004, 2008, and 2009, but not in 2005, further suggesting a eutrophic condition.

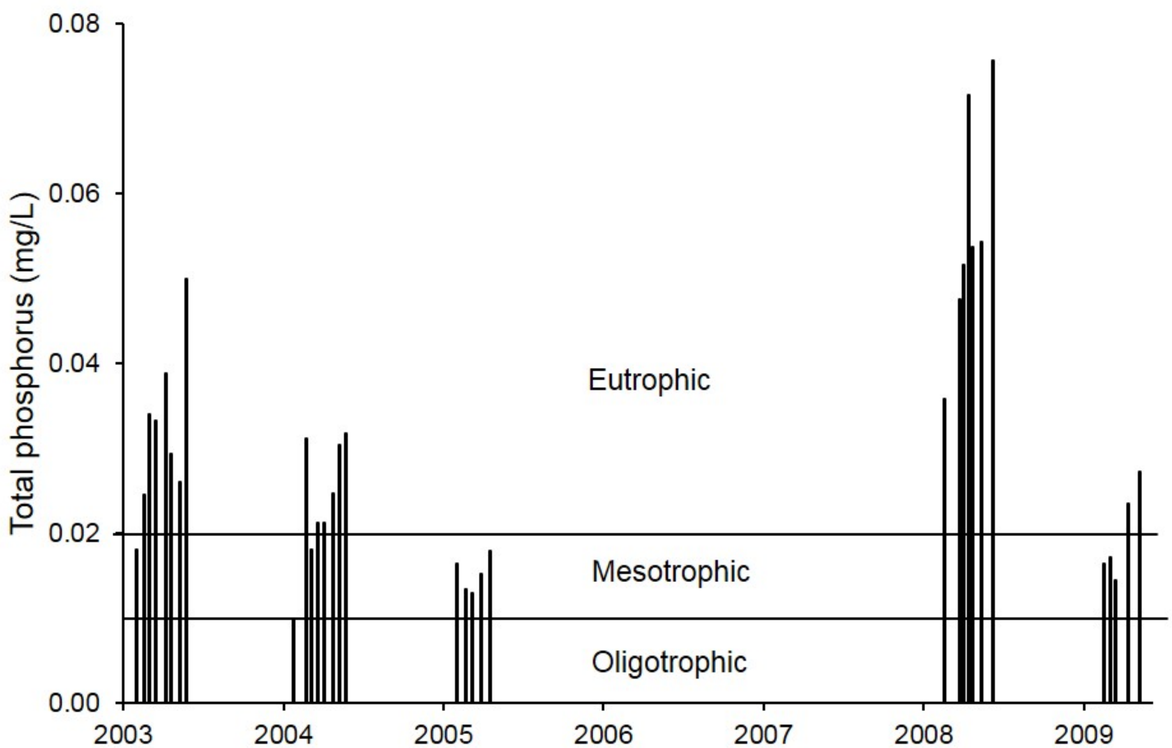


**Figure 7.** Total phosphorus (TP) concentrations (mg/L) in Monhagen Lake from 2003-2005 and 2008-2009 (CSLAP).

Annual average concentrations of total nitrogen (TN) in Monhagen Lake were not indicative of eutrophic conditions (> 0.6 mg/L, Canfield et al. 1983) (**Figure 8**) in 2008 (average = 0.51 mg/L ± 0.09) or 2009 (average = 0.33 mg/L ± 0.07). Trends of TN could not be analyzed (two years of data), however, the following non-significant trends were observed for ammonia and NOx:

- The average annual ammonia concentration has remained constant ($p$ = 1.0, $\tau$ = 0.000). Further, no trend in the annual maximum ammonia concentration was observed ($p$ = 0.327, $\tau$ = -0.400)

- There was not a trend over time in either annual average ($p$ = 0.624, $\tau$ = -0.200) or maximum concentration ($p$ = 0.327, -0.400) of NOx (mg/L), which is a measure of the sum of nitrate ($NO^-_3$) and nitrite ($NO^-_2$)
- Significant ammonia and NOx trends were not observed in Shawangunk Reservoir and Highland Lake; limited TN data for these waterbodies prevented trend analysis for this water quality parameter.

The relative concentrations of nitrogen and phosphorus can influence algal community composition and the abundance of cyanobacteria. Ratios of TN:TP in lakes can be used as a suitable index to determine if algal growth is limited by the availability of nitrogen or phosphorus (Lv et al. 2011). The ratio of TN:TP may determine whether HABs occur; cyanobacteria blooms are typically rare in lakes where mass based TN:TP ratios are greater than 29:1 (Smith 1983, Filstrup et al. 2016). Certain cyanobacteria taxa (e.g. *Aphanizomenon, Dolichospermum*) can utilize atmospheric dinitrogen ($N_2$), which is unavailable to other phytoplankton, providing a competitive advantage to N-fixing cyanobacteria when nitrogen becomes limiting. Unfortunately, each of these reservoirs was sampled through CSLAP or other NYSDEC monitoring programs before cyanobacteria taxa (or other measures of bloom content or cyanotoxins) were routinely surveyed. Therefore, any connections between TN:TP ratios and cyanobacteria content cannot be evaluated through the CSLAP dataset.

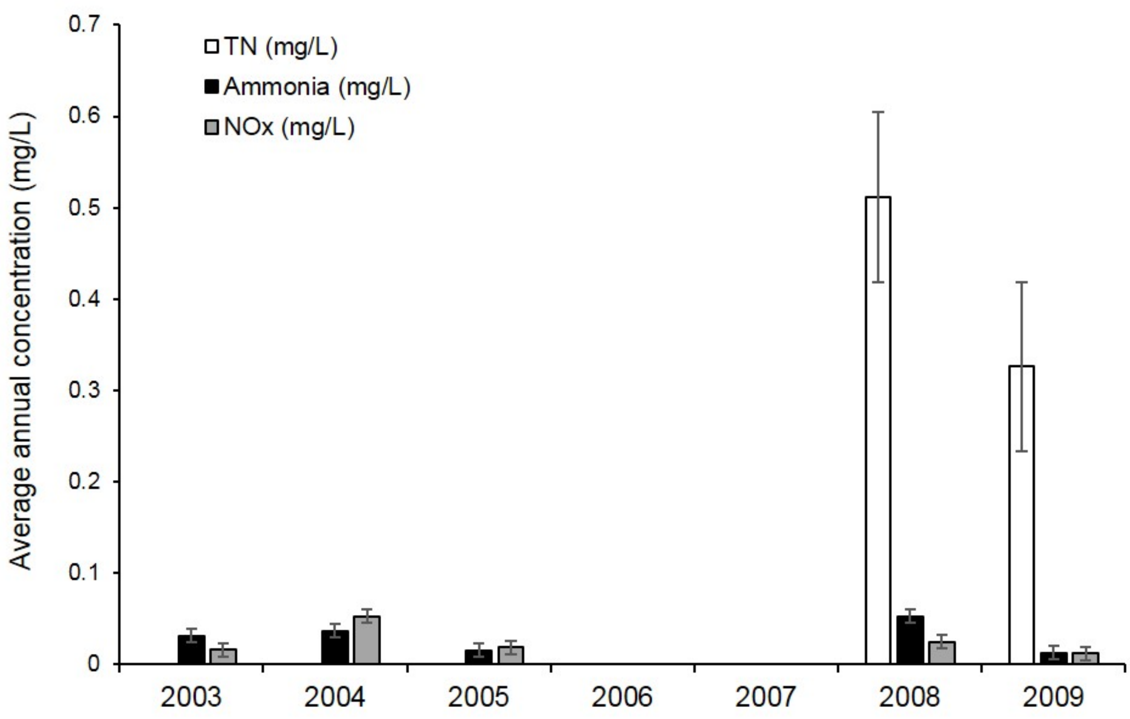


**Figure 8.** Average annual total nitrogen (TN), ammonia, and nitrogen oxide (NOx) concentrations (mg/L) in Monhagen Lake from 2003-2005 and 2008-2009 (CSLAP).

Ratios (by mass) of TN:TP in Monhagen Lake in 2008 and 2009 ranged between 8 and 30 (**Figure 9**). Average TN:TP ratios for Highland Lake were from 5.3 in 2008 and 34.6

in 2009; for Shawangunk Reservoir, ratios ranged from 10.5 in 2008 to 15.8 in 2009. These TN:TP ratios indicate that algal biomass, including cyanobacteria, may be limited by nitrogen (TN:TP < 10**)** for short periods in these waterbodies during the growing season, but phosphorus concentrations likely limit algal growth for much of this period. While these data show a marked increase from 2008 to 2009 in each of these waterbodies, a trend analysis could not be performed as a minimum of five years of data is required for statistical analysis.

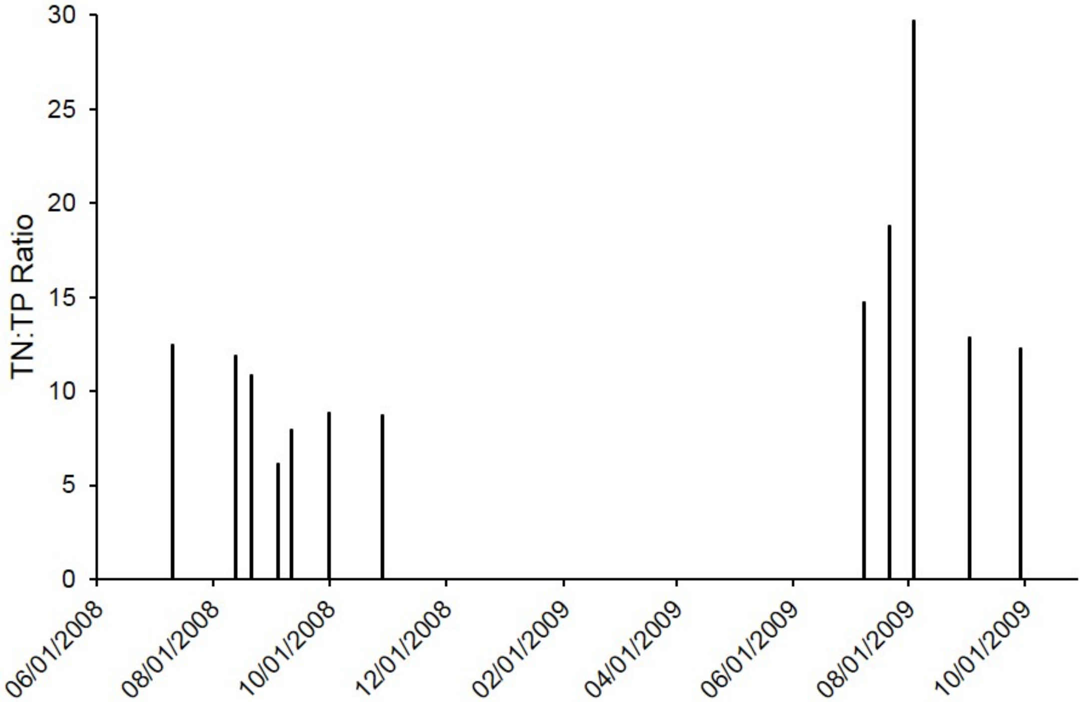


**Figure 9.** Ratios of total nitrogen (TN) to total phosphorus (TP) in Monhagen Lake from 2008 and 2009 (CSLAP).

Additional monitoring of each water quality parameter (e.g., TP, TN, dissolved oxygen) is recommended in Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System to better inform long-term trends indicative of water quality (e.g., seasonal and annual concentrations of water quality parameters throughout the water column). Until those data are available, identification of significant long-term trends for individual parameters and potential correlations amongst constituents is not practicable. Understanding these trends and correlations could play a significant role in informing future management strategies to minimize HABs.

## 6.3 Biological Conditions

Annual concentrations of chlorophyll-a (photosynthetic pigment present in algae, including cyanobacteria) suggest that Monhagen Lake is meso-eutrophic (moderate to high productivity) (**Figure 10**). Chlorophyll-a concentrations generally follow a seasonal pattern, with increased concentrations during the mid- to late-growing season (**Figure**

10). Trends in annual average and maximum chlorophyll-a concentrations were not observed (*p* = 0.624, $\tau$ = 0.200; *p* = 0.327, 0.400). Chlorophyll-a concentration trends in Highland Lake and Shawangunk Reservoir were also not observed (p-values > 0.05).

Additional, and more recent, monitoring of chlorophyll-a concentrations will supplement the relatively limited temporal coverage of the water quality data for the lake and can be used to evaluate the effectiveness of recommended actions (see **Section 13**).

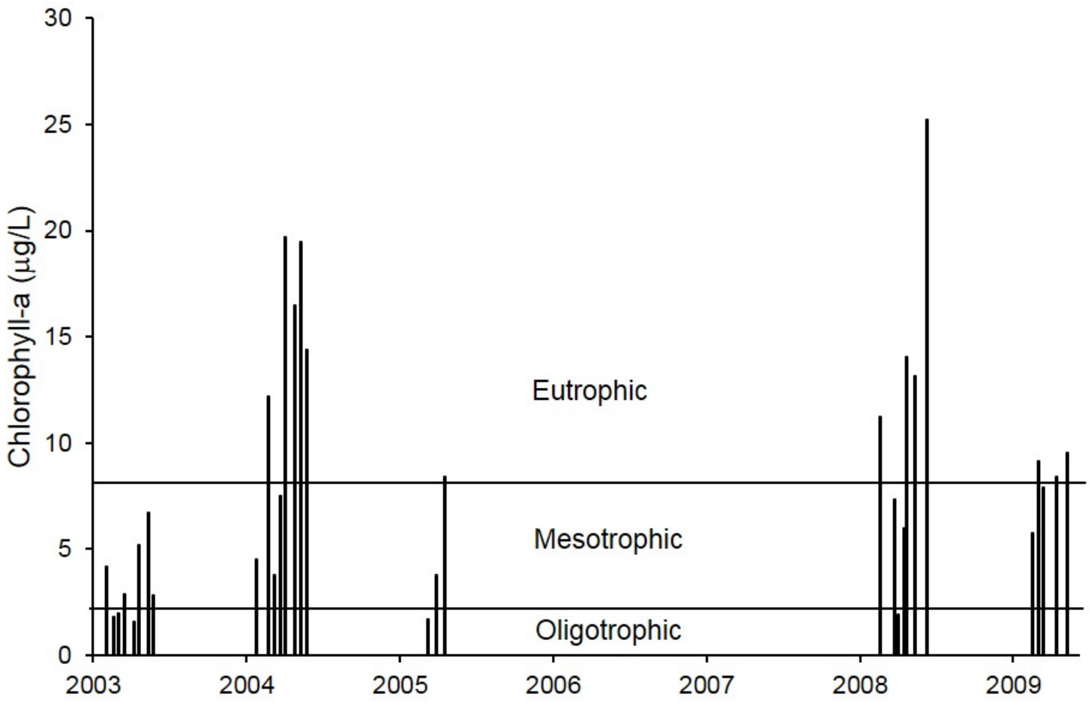


**Figure 10.** Chlorophyll-a concentrations (extracted, µg/L) in Monhagen Lake from 2003-2005 and 2008-2009 (CSLAP).

## 6.4 Other Conditions

Aquatic macrophyte coverage was reported as lower than normal in Monhagen Lake during the 2009 CSLAP assessment (NYSDEC 2010a), perhaps as part of a longer-term trend. Seasonal drawdown of the reservoir for drinking water use could limit macrophyte growth. The macrophyte community profile (i.e., species composition, percent of natives vs. exotics) is unknown since aquatic plant surveys have not been conducted through CSLAP at any of the Middletown reservoirs. Recreational assessments were reported as unchanged, likely due to the lack of recreational uses of the lake. Additional data regarding the macrophyte community in Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System could be useful regarding lake dynamics that influence HABs.

# 7. Summary of HABs

New York State possesses one of, if not the most comprehensive HABs monitoring and notification programs in the country. The NYSDEC and NYSDOH collaborate to document and communicate with New Yorkers regarding HABs. Within NYSDEC, staff in the Division of Water, Lake Monitoring and Assessment Section oversee HAB monitoring and surveillance activities, identify bloom status, communicate public health risks, and conduct outreach, education, and research regarding HABs. As part of the HABs Program, the NYSDEC has adopted a combination of visual surveillance, algal concentration measurements, and toxin concentration to determine bloom status. This process is unique to New York State and has been used consistently since 2012.

The NYSDEC HABs Program has established four levels of bloom status:

- **No Bloom**: evaluation of a bloom report indicates low likelihood that a cyanobacteria bloom (HAB) is present
- **Suspicious Bloom**: NYSDEC staff determined that conditions fit the description of a HAB, based on visual observations and/or digital photographs. Laboratory analysis has not been done to confirm if this is a HAB. It is not known if there are toxins in the water.
- **Confirmed Bloom**: Water sampling results have confirmed the presence of a HAB which may produce toxins or other harmful compounds (BGA chlorophyll levels ≥ 25 µg/L and/or microscopic confirmation that majority of sample is cyanobacteria and present in bloom-like densities). For the purposes of evaluating HABs sample, chlorophyll-a is quantified with a Fluoroprobe (bbe Moldaenke) which can effectively differentiate relative contributions to total chlorophyll-a by phytoplankton taxonomic group (Kring et al. 2014). BGA chlorophyll-a concentrations (attributed to most types of cyanobacteria) are utilized by the NYSDEC HABs Program for determining bloom status. This method provides an accurate assessment of cyanobacteria density and can be accomplished more quickly and cost effectively than traditional cell counts.
- **Confirmed with High Toxins Bloom**: Water sampling results have confirmed that there are toxins present in sufficient quantities to potentially cause health effects if people and animals come in contact with the water through swimming or drinking (microcystin ≥ 20 µg/L (shoreline samples) or microcystin ≥ 10 µg/L (open water samples).

The spatial extent of HABs are categorized as follows:

- **Small Localized**: Bloom affects a small area of the waterbody, limited from one to several neighboring properties.
- **Large Localized**: Bloom affects many properties within an entire cove, along a large segment of the shoreline, or in a specific region of the waterbody.

- **Widespread/Lakewide**: Bloom affects the entire waterbody, a large portion of the lake, or most to all of the shoreline.
- **Open Water**: Sample was collected near the center of the lake and may indicate that the bloom is widespread and conditions may be worse along shorelines or within recreational areas.

## 7.1 HABs History

Monhagen Lake is a eutrophic lake that reportedly experiences periodic HABs, though HABs-specific data are not available for any of the waterbodies in the Monhagen-Middletown Reservoirs System. Data regarding HABs in Monhagen Lake and the other resources within the Monhagen-Middletown Reservoir System should be collected to provide insight into conditions that lead to blooms with undesirable toxin concentrations (see **Section 13**).

NYSDOH sampled raw (particulate and dissolved microcystin) from Monhagen Lake and finished drinking water on 6/17/16 due to a reported bloom. All samples were non-detect (ND).

NYSDEC and NYSDOH believe that all cyanobacteria blooms should be avoided, even if measured microcystin levels are less than the recommended threshold level. Other toxins may be present, and illness is possible even in the absence of toxins.

## 7.2 Drinking Water and Swimming Beach HABs History

Across New York, NYSDOH first sampled ambient water for toxin measurement in 2001, and raw and finished drinking water samples beginning in 2010. Two public water supplies were sampled in a 2012 pilot study that included both fixed interval and bloom based event criteria. While microcystin has been detected in pre-treatment water occasionally, rarely have any detects been found in finished water. To date, no samples of finished water have exceeded the 0.3 µg/L microcystin health advisory limit (HAL). Many different water systems using different source waters have been sampled, and drinking water HABs toxin sampling has increased substantially since 2015 when the EPA released the microcystin and cylindrospermopsin HALs. The information gained from this work and a review of the scientific literature was used to create the current NYSDOH HABs drinking water response protocol. This document contains background information on HABs and toxins, when and how water supplies should be sampled, drinking water treatment optimization, and steps to be taken if health advisories are exceeded (which has not yet occurred in New York State).

In 2018 the USEPA started monitoring for their Unregulated Contaminant Monitoring Rule 4 (UCMR 4) which includes several HAB toxins. In 2018 the USEPA will sample 32 public water systems in New York State. The UCMR 4 is expected to bring further attention to this issue leading to a greater demand for monitoring at PWSs. To help with the increasing demand for laboratory analysis of microcystin, the NYSDOH ELAP is offering certification for laboratories performing HAB toxin analysis, starting in spring

2018, and public water supplies should only use ELAP-certified labs and consult with local health departments (with the support of NYSDOH) prior to beginning HAB toxin monitoring and response actions.

As recommended by the NYSDOH, it is never advisable to drink water from a surface source unless it has been treated by a public drinking water system regardless of the presence HABs. Surface waters may contain other bacteria, parasites or viruses that can cause illness. If you choose to explore in-home treatment systems, you are living with some risk of exposure to blue-green algae and their toxins and other contaminants. Those who desire to use an intake for non-potable use, and treat their water for contaminants including HABS, should work with a water treatment professional who should evaluate for credible third-party certifications such as National Sanitation Foundation standards (NSF P477; NYSDOH 2017).

While elevated algae levels and/or disinfection by-product (DBP) compounds can result in human health effects, there are no reports of impacts to potable water drawn from Monhagen Lake or other waterbodies comprising the Monhagen-Middletown Reservoir System. As discussed in **Section 3.3**, Monhagen Lake and the other resources within the Monhagen-Middletown Reservoir System are not open to public swimming.

While these waterbodies are not open to public swimming, bathing beaches are regulated by NYSDOH District Offices, County Health Departments and the New York City Department of Health and Mental Hygiene in accordance with the State Sanitary Code (SSC). The SSC contains qualitative water quality requirements for protection from HABs. NYSDOH developed an interactive intranet tool that provides guidance to County, City and State District DOH staff to standardize the process for identifying blooms, closing beaches, sampling, reopening beaches and reporting activities. The protocol uses a visual assessment to initiate beach closures as it affords a more rapid response than sampling and analysis. Beaches are reopened when a bloom dissipates (visually) and samples collected the following day confirm the bloom has dissipated and show toxin levels are below the latest guidance value for microcystins. Sample analysis is performed by local health departments, the Wadsworth Laboratory in Albany or academic institutions.

**Table 3** provides a summary of the guidance criteria that the NYSDEC and NYSDOH use to advise local beach operators.

| Table 3. HABs guidance criteria. | | | |
|---|---|---|---|
| ***NYSDEC Bloom Categories*** | | | |
| **Confirmed** | **Confirmed w/ high toxins** | | **Suspicious** |
| | **Open water** | **Shoreline** | |
| [BGA Chlorophyll-a] >25 µg/L | [Microcystin] > 10 µg/L | [Microcystin] > 20 µg/L | Visual evidence w/out sampling results |
| | | | |
| ***NYSDOH Guidelines*** | | | |
| **Closure** | | **Re-open** | |
| Visual evidence (sampling results not needed). | | Bloom has dissipated (based on visual evidence); confirmatory samples 1 day after dissipation w/ microcystin < 10 µg/l or < 4 µg/l (USEPA 2016) in 2017. | |

# 8. Waterbody Assessment

The Waterbody Inventory/Priority Waterbodies List (WI/PWL) is an inventory of water quality assessments that characterize known/and or suspected water quality issues and determine the level of designated use support in a waterbody. It is instrumental in directing water quality management efforts to address water quality impacts and for tracking progress toward their resolution. In addition, the WI/PWL provides the foundation for the development of the state Section 303(d) List of Impaired Waters Requiring a TMDL.

The WIPWL assessments reflect data and information drawn from numerous NYSDEC programs (e.g. CSLAP) as well as other federal, state and local government agencies, and citizen organizations. All data and information used in these assessments has been evaluated for adequacy and quality as per the NYSDEC Consolidated Assessment and Listing Methodology (CALM).

## 8.1 WI/PWL Assessment

The current WI/PWL Assessment for Monhagen Lake (**Appendix D**) reflects monitoring data collected in 2009. Monhagen Lake is required to support use as a water supply source for drinking, primary and secondary contact recreation uses, and fishing use.

Monhagen Lake is assessed as a threatened waterbody due elevated chlorophyll levels that could impacts its use as a drinking water supply source. Elevated nutrient and chlorophyll levels in the lake result in the increased risk of disinfection by-products formation in finished drinking water and make treatment to meet drinking water standards more difficult. In addition, primary and secondary contact recreation uses may be stressed by the excessive nutrients and resulting algae growth and poor water clarity.

| Table 4. WI/PWL severity of use impact categorization (Source: NYSDEC 2008). | |
|---|---|
| **Impairment Classification** | **Description** |
| **Precluded** | *Frequent/persistent* water quality, or quantity, conditions and/or associated habitat degradation prevents *all aspects* of a specific waterbody use. |
| **Impaired** | *Occasional* water quality, or quantity, conditions and/or habitat characteristics *periodically prevent* specific uses of the waterbody, or;<br>Waterbody uses are not precluded, but some aspects of the use are *limited or restricted*, or;<br>Waterbody uses are not precluded, but *frequent/persistent* water quality, or quantity, conditions and/or associated habitat degradation *discourage* the use of the waterbody, or;<br>Support of the waterbody use requires *additional/advanced* measures or treatment. |
| **Stressed** | Waterbody uses are not significantly limited or restricted (i.e. uses are *Fully Supported*), but *occasional* water quality, or quantity, conditions and/or associated habitat degradation *periodically discourage* specific uses of the waterbody. |
| **Threatened** | Water quality supports waterbody uses and ecosystem exhibits no obvious signs of stress, however *existing or changing land use patterns* may result in restricted use or ecosystem disruption, or;<br>*Data reveals decreases in water quality* or presence of toxics below the level of concern. |

## 8.2 Source Water Protection Program (SWPP)

The NYSDOH Source Waters Assessment Program (SWAP) was completed in 2004 to compile, organize, and evaluate information regarding possible and actual threats to the quality of public water supply (PWS) sources based on information available at the time. Each assessment included a watershed delineation prioritizing the area closest to the PWS source, an inventory of potential contaminant sources based on land cover and the regulated potential pollutant source facilities present, a waterbody type sensitivity rating, and susceptibility ratings for contaminant categories. The information included in these analyses included: GIS analyses of land cover, types and location of facilities, discharge permits, Concentrated Animal Feeding Operations (CAFOs), NYSDEC WI/PWL listings, local health department drinking water history and concerns, and existing lake/watershed reports. A SWAP for the Monhagen-Middletown Reservoir System public drinking supply sources was completed. Although the information provides a historical perspective, the drinking water systems and/or land uses may have changed. Monhagen-Middletown Reservoir System public drinking supply sources need updated assessments to understand the current impacts to best protect water quality. NYSDEC and NYSDOH are working with stakeholders to build a sustainable statewide program to assist and encourage municipalities to develop and implement Source Water Protection Programs (SWPP) in their communities.

The 2004 SWAP assessment of the Monhagen-Middletown Reservoir System indicated an elevated susceptibility to protozoa and pesticides from agricultural runoff. The relatively high density of sanitary wastewater discharges within the watershed was also identified as a source of elevated susceptibility to all contaminant categories, particularly protozoa. The assessment noted that the hydrologic characteristics (e.g., basin morphology and flushing rates) of reservoirs like those in the Monhagen-Middletown Reservoir System inherently make these waterbodies highly sensitive to existing and new sources of phosphorus and microbial contamination (Middletown Water Department 2016).

Currently, the State is meeting with a working group of stakeholders to develop the SWPP structure and potential tools (e.g., templates, data sets, guidance and other resources) that will be pilot tested in municipalities. Following the pilot, the state will roll out the program and work with municipalities as they develop and implement their individual SWPP and associated implementation program. The goal of the SWPP is for municipalities to not merely assess threats to their public water supply but to take action at the local level to protect public drinking water.

## 8.3 CSLAP Scorecard

Results from CSLAP activities are forwarded to the New York State Federation of Lake Associations (NYSFOLA) and NYSDEC and are combined into a scorecard detailing potential lake use impact levels and stresses. The scorecards represent a preliminary assessment of one source of data, in this case CSLAP. The WI/PWL updates include the evaluation of multiple data sources, including the CSLAP scorecard preliminary evaluations.

Monhagen Lake was not sampled as part of CSLAP in 2017 (**Figure 11**).

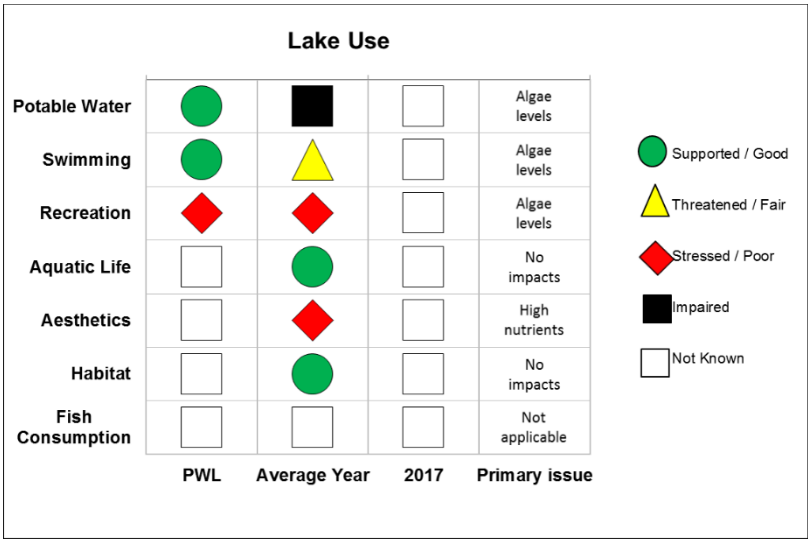


**Figure 11.** Monhagen Lake's 2017 CSLAP scorecard. Note: Monhagen Lake was not sampled in 2017; scorecard will be updated following the next sampling event.

# 9. Conditions triggering HABs

Resilience is an important factor in determining an ecosystem's ability to respond to and overcome negative impacts (Zhou et al. 2010), including the occurrence and prevalence of HABs. Certain lakes may not experience HABs even though factors hypothesized to be "triggers" (e.g., elevated P concentrations) are realized (Mantzouki et al. 2016), and conversely, lakes that have historically been subject to HABs may still be negatively affected even after one or more triggers have been reduced. Thus, the pattern by which an outcome (presence or absence of HABs) lags behind changes in the properties causing it (triggers) has been observed for ecological phenomena, including phytoplankton dynamics (Faassen et al. 2015). Further, unusual climatic events (*e.g.*, high TP input from spring runoff and hot calm weather in fall) may create unique conditions that contribute to a HAB despite implementation of management strategies to prevent them (Reichwaldt and Ghadouani 2012).

Ecosystems often exhibit a resistance to change that can delay outcomes associated with HABs management. This system resilience demands that prevention and management of these triggers be viewed long-term through a lens of both watershed and in-lake action. It may take significant time following implementation of recommended actions for the frequency, duration, and intensity of HABs to be reduced.

A dataset spanning 2012 to 2017 of 163 waterbodies in New York State has been compiled to help understand the potential triggers of HABs at the state-scale (CSLAP data). This dataset includes information on several factors that may be related to the occurrence of HABs, e.g., lake size and orientation (related to fetch length, or the horizontal distance influenced by wind); average total phosphorus and total nitrogen concentrations; average surface water temperatures; as well as the presence of invasive zebra and quagga mussels (i.e., dreissenid mussels). This data set has been analyzed systematically, using a statistical approach known as logistic regression, to identify the minimum number of factors that best explain the occurrences of HABs in NYS. A minimum number of factors are evaluated to provide the simplest possible explanation of HABs occurrences (presence or absence) and to provide a basis for potential targets for management. One potential challenge to note with this data set is that lakes may have unequal effort regarding HABs observations which could confound understanding of underlying processes of HABs evaluated by the data analysis. Since waterbodies in the Monhagen-Middletown Reservoirs System were not systematically sampled for HABs, the influence of these factors on bloom formation in these waterbodies cannot be evaluated.

Across New York, four of the factors evaluated were sufficiently correlated with the occurrence of HABs, namely, average total phosphorus levels in a lake, the presence of dreissenid mussels, the maximum lake fetch length and the lake compass orientation of that maximum length. The data analysis shows that for every 0.01 mg/L increase in total phosphorus levels, the probability that a lake in New York will have a HAB in a given year increases by about 10% to 18% (this range represents the 95% confidence interval based on the parameter estimates of the statistical model). The other factors, while statistically significant, entailed a broad range of uncertainty given this initial analysis. The presence of dreissenid mussels is associated with an increase in the annual HAB probability of 18% to 66%. Lakes with long fetch lengths are associated with an increased occurrence of HABs; for every mile of increased fetch length, lakes are associated with up to a 20% increase in the annual probability of HABs. Lastly, lakes with a northwest orientation along their longest fetch length are 10% to 56% more likely to have a HAB in a given year. Each of these relationships are bounded, i.e., the frequency of blooms cannot exceed 100%, meaning that as the likelihood of blooms increases the marginal effect of these variables decreases. While this preliminary evaluation will be expanded as more data are collected on HABs throughout New York, these results are supported by prior literature. For example, phosphorus has long known to be a limiting nutrient in freshwater systems and a key driver of HABs, however the potential role of nitrogen should not be overlooked as HABs mitigation strategies are contemplated (e.g., Conley et al. 2009). Similarly, dreissenid mussels favor HABs by increasing the bioavailability of phosphorus and selectively filtering organisms that may otherwise compete with cyanobacteria (Vanderploeg et al. 2001). The statistically-significant association of fetch length and northwest orientation with HABs may suggest that these conditions are particularly favorable to wind-driven accumulation of cyanobacteria and/or to wind-driven hydrodynamic mixing of lakes leading to periodic pulses of nutrients. While each of these potential drivers of HABs deserve more evaluation, the role of lake fetch length and orientation are of interest and warrant additional study.

There is continuing interest in the possible role of nitrogen in the occurrence and toxicity of HABs (e.g., Conley et al. 2009), and preliminary analysis of this statewide data set suggests that elevated total N and total P concentrations are both statistically significant associates with the occurrence of toxic blooms. When total N and total P concentrations are not included in the statistical model, elevated inorganic nitrogen (NH4 and NOx) concentrations are also positively associated with toxic blooms. The significant association of inorganic N forms with toxic blooms may provide a more compelling association than total N, which may simply be a redundant measure of the biomass associated with toxins. It should be noted that while this analysis may provide some preliminary insight into state-scale patterns, it is simplistic in that is does not account for important local, lake-specific drivers of HABs such as temperature, wind, light intensity, and runoff events.

Documentation of HABs (both presence and absence) with water quality measurements will allow for lake-specific analyses to be conducted for waterbodies in the Monhagen-Middletown Reservoir System.

# 10. Sources of Pollutants

## 10.1 Land Uses

Land use percentages within the six sub-watersheds that make up the Monhagen-Middletown Reservoir System were estimated using the Loading Estimator of Nutrient Sources (LENS) screening tool completed by the NYSDEC using digital aerial photography and geographic information system (GIS) datasets (NYSDEC, undated). However, as shown in **Table 5** and **Figure 12a**, there is significant variation in the land uses that make up the sub-watersheds of the Monhagen-Middletown Reservoir System. Forest land is the dominant land use within each, but the percentage of agricultural and developed land varies significantly (**Table 5**).

It should be noted that NYSDEC's LENS screening tool is intended to be used to assess land use and relative load contributions by source to help determine the most appropriate watershed management approach and support prioritization of projects. The LENS tool is a simple steady state model that uses average, assumed conditions and estimated average annual loads from nonpoint sources and point sources, and employs the most recent data for the National Land Cover Dataset, septic information collected by NYS Office of Real Property and Tax, and State Pollution Discharge Elimination System (SPDES) permit and discharge monitoring report information. The LENS tool does not include all the data requirements for detailed watershed load analysis that would be completed for a TMDL or Nine Element (9E) Plan (see **Section 12.5**), and does not take into consideration existing best management practices (BMPs) and other nutrient reduction measures potentially implemented by the agricultural community and other potential contributors of nutrients to the lake. Consequently, the land use estimates presented in this section and the external loading estimates provided in **Section 10.2** for the Monhagen-Middletown Reservoir System should be interpreted with caution.

**Table 5. Land Use percentages, Monhagen-Middletown Reservoir System. Natural areas include forests, shrublands, grasslands, and wetlands.**

| Waterbody | Monhagen Lake | Highland Lake | Shawangunk Reservoir | Mill Pond | Kinch Pond | Indigot Intake |
|---|---|---|---|---|---|---|
| **Source Type** | **Percentage (%)** | | | | | |
| **Agricultural** | 6 | 4 | 21 | 23 | 25 | 19 |
| **Natural Areas** | 73 | 71 | 54 | 62 | 65 | 73 |
| **Developed Land** | 4 | 1 | 5 | 14 | 10 | 7 |
| **Open Water** | 17 | 24 | 20 | 1 | 0 | 1 |

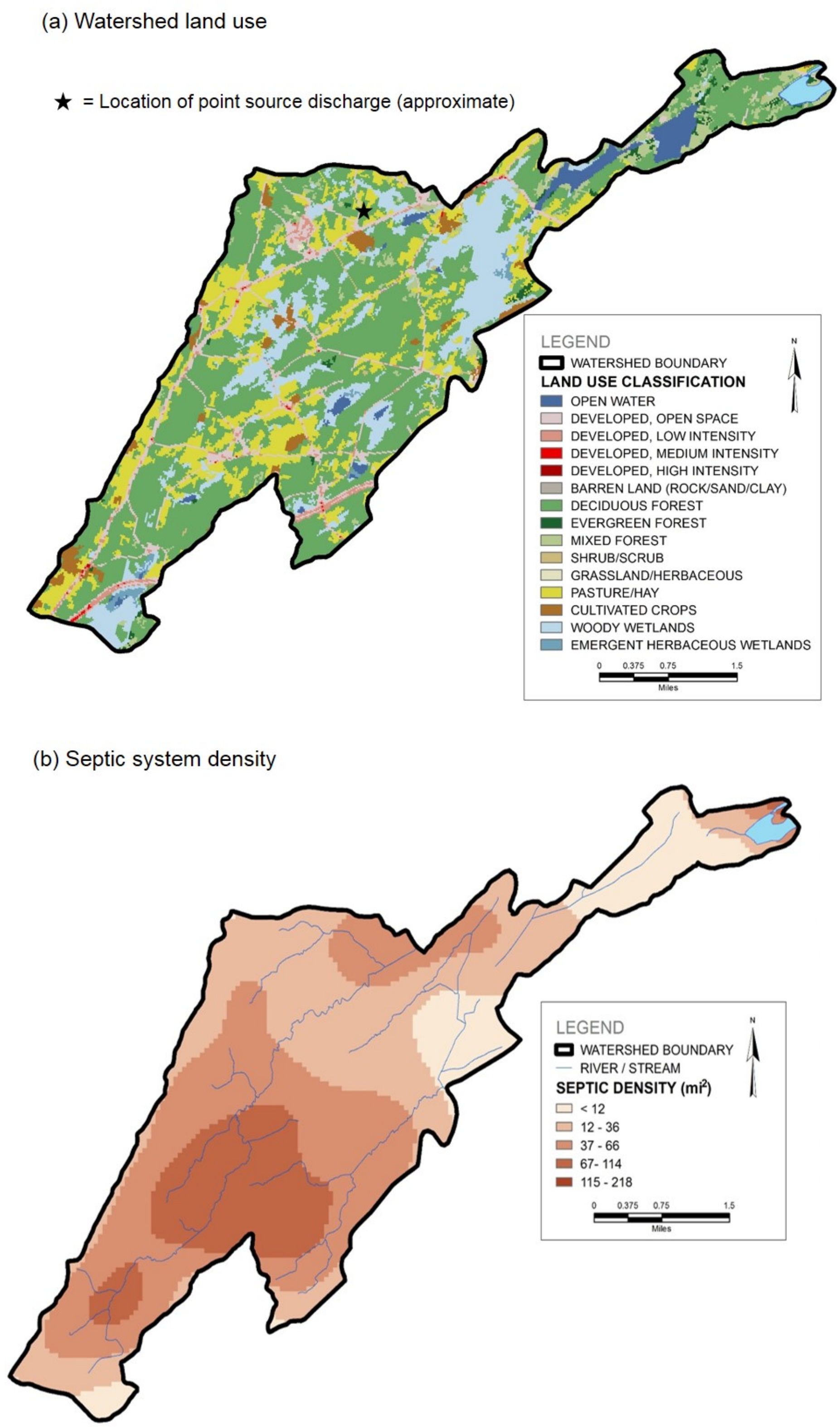


**Figure 12.** (a) Watershed land use and (b) septic system density in the Monhagen-Middletown Reservoir System.

## 10.2 External Pollutant Loadings

NYSDEC's LENS tool is a simple watershed model that uses average, assumed meteorological conditions, estimated average annual loading rates from nonpoint sectors based on accepted literature values, and estimates of point source contribution. It employs the most recent data from the National Land Cover Dataset, septic density information collected by NYS Office of Real Property and Tax, and State Pollution Discharge Elimination System (SPDES) permits. LENS is a screening tool, used by the NYSDEC, intended to assess the relative load contributions by watershed source to help determine the most appropriate watershed management approach (i.e., a TMDL or 9E plan; https://www.dec.ny.gov/docs/water_pdf/dowvision.pdf) and, for purposes of this Action Plan, support prioritization of water quality improvement projects and allocation of associated resources to mitigate HABs (presented in Section 13).

LENS is not designed to be a comprehensive watershed analysis and does not include all data requirements for a Total Maximum Daily Load (TMDL) or Nine Element (9E) Plan. Although LENS output has shown to be consistent with more comprehensive watershed analyses in New York State, there is uncertainty in the watershed loading estimates presented in this Action Plan. For example, LENS does not take into consideration: (1) other potential contributors of nutrients to the lake such as groundwater, consistently underperforming septic systems, and streambank erosion, (2) internal sources of nutrients (e.g., sediments, dreissenid mussels), and (3) existing best management practices (BMPs) and other nutrient reduction measures being implemented by the municipalities, agricultural community, Soil and Water Conservation Districts, and other stakeholders.

Therefore, LENS results discussed here and in subsequent sections should be considered a ***preliminary approximation*** of external nutrient sources to the lake. Precise quantification of nutrient sources from the watershed is needed and should be determined through: (1) a detailed inventory of nutrient sources – ***from all suspected sectors*** within the watershed, (2) complete a detailed analysis of nutrient load and budget that includes critical factors not accounted for in LENS, (3) the development of a robust land-side nutrient loading model, and (4) completion or update of a NYSDEC approved clean water plan.

This Action Plan should be considered the first step of an adaptive management approach to HABs in the Monhagen-Middletown Reservoir System. Any completed TMDL or 9E plan developed for the Monhagen-Middletown Reservoir System will supplement the loading assessment included in this report. At that time, this Action Plan can be updated to reflect current and better understanding of Monhagen-Middletown Reservoir System.

**Table 6** provides the LENS model analysis of phosphorus loading rates from different watershed sources, indicating variation in the loading rates for the six resources that make up the Monhagen-Middletown Reservoir System.

| Table 6. Phosphorus loading percentages, Monhagen-Middletown Reservoir System. Natural areas include forests, shrubland, grasslands, and wetlands. | | | | | | |
|---|---|---|---|---|---|---|
| **Waterbody** | **Monhagen Lake** | **Highland Lake** | **Shawangunk Reservoir** | **Mill Pond** | **Kinch Pond** | **Indigot Intake** |
| **Source Type** | **Percentage (%)** | | | | | |
| **Agricultural** | 29 | 8 | 67 | 18 | 52 | 46 |
| **Natural Areas** | 60 | 88 | 24 | 10 | 25 | 35 |
| **Developed Land** | 11 | 4 | 9 | 8 | 16 | 14 |
| **Septic Load** | 0 | 0 | 0 | 1 | 6 | 5 |
| **Point Source** | 0 | 0 | 0 | 63 | 0 | 0 |

Based on the LENS analysis, forest land contributes most of phosphorus to Monhagen Lake. However, Monhagen Lake phosphorus concentrations are also influenced by the receiving water from the upstream reservoirs. Loading from the other reservoir watersheds (connected by pipes) was not assessed with the LENS tool. Among the upstream tributary sources, agricultural use (Shawangunk Reservoir, Kinch Pond, Indigot Intake) and point source discharge (Mill Pond) may be leading contributors. The density of septic systems increases from south to north (see **Figure 12b**), but septic system discharge contributes a minor percentage of the phosphorus loading due in large part to the public sanitary sewer network that exists in much of the watershed.

Note that the land uses calculated in LENS were obtained from National Land Cover Data at a coarse resolution that may not capture variations in land use in smaller watershed areas such as the Monhagen-Middletown Reservoir System. The NYSDEC is working with the local watershed community to obtain better land use data for use in future nutrient loading analyses, to better describe the sources of pollution to the reservoirs.

The point source within the Mill Pond sub-watershed is the Hidden Valley Estates Sewage Treatment Plant (STP) which is permitted to discharge 60,000 gpd of treated effluent to Mill Pond (NYSDEC undated).

## 10.3 Internal Pollutant Sources

A possible data gap in our understanding of nutrient dynamics in Monhagen Lake and the other resources within the Monhagen-Middletown Reservoir System is the quantity of phosphorus found within the sediments that could mobilize seasonally and become available to algae (i.e., internal loading of legacy phosphorus). Current estimates of annual phosphorus loads do not account for internal loading. Spatially, certain areas of the lakes may be more prone to internal loading due to localized anoxia in deep regions and/or lack of exposure to wind and wave action that can promote the release of legacy phosphorus.

## 10.4 Summary of Priority Land Uses and Land Areas

As discussed in **Sections 10.2** and **10.3**, loading occurs predominately via runoff from forest land, followed by agricultural runoff. Dominant loading sources for the other resources within the Monhagen-Middletown Reservoir System include agricultural runoff and point source discharge associated with the Hidden Valley Estates STP. Management strategies aimed at reducing these dominant loads should be considered and implemented as practicable to reduce TP loads within the watershed. These include:

- Evaluation of WWTP permit monitoring and treatment processes.
- Installation of vegetated riparian buffers to reduce TP concentrations in runoff from agricultural and forested lands.
- Installation of stormwater BMPs to reduce TP concentrations in runoff from developed and agricultural lands.

Additional discussion of recommended management strategies is included in **Section 13**.

# 11. Lake Management / Water Quality Goals

The primary lake management/water quality goal for the Monhagen-Middletown Reservoir System is to understand the likely causes of previous HAB events and develop management actions to prevent and limit the frequency and duration of HABs into the future.

A Monhagen Brook Watershed Management Plan is being developed through a joint effort that includes the Orange County SWCD, Cornell Cooperative Extension (CCE), State University of New York (SUNY) Orange, and the OCWA. Funding for the effort is being provided by a grant from the NYSDEC's Hudson River Estuary Program. While the focus of the Monhagen Brook Watershed Management Plan is on Monhagen Brook downstream of Monhagen Lake, its results may help inform future management of the Monhagen-Middletown Reservoir System, and so was included herein. Goals of the effort include:

- Collect additional water quality data from the brook to better understand system dynamics
- Improve water quality and resiliency within the brook
- Enhance fish and wildlife habitat in both aquatic and upland resources
- Increase and improve educational, access, and recreational opportunities within the watershed.

The project commenced in 2016 and is ongoing.

# 12. Summary of Management Actions to Date

## 12.1 Local Management Actions

As discussed in **Section 5.1**, the water quality of Monhagen Lake has been sampled as part of CSLAP, and is assessed by the City of Middletown and described in annual water quality reports. Additional management actions that have been completed to improve water quality within the Monhagen-Middletown Reservoir System include:

- Logging has been conducted periodically around Monhagen and Highland lakes to thin the canopy to allow air movement and sun penetration and to promote plant growth that minimizes erosion. Logging is done in the winter to minimize disturbance to other plants. A forester, approved by the NYSDEC, identifies the areas to be logged and oversees the operation.
- Documentation dating back to the early 1900s indicate Monhagen Lake has been, and continues to be, treated with copper sulfate due to the lake being a water supply. The application was effective at treating a heavy growth of *Potamogeton* (pond weed) and algae that had settled in the lake and seemed to reduce the number of cyanobacteria based upon pre- and post-treatment examinations (Moore and Kellerman 1905).

## 12.2 Agricultural Environmental Management Program

The New York State Agricultural Environmental Management (AEM) Program that was created by the New York State Department of Agriculture and Markets as a voluntary, incentive-based program that helps farmers make common-sense, cost-effective, and science-based decisions to meet business objectives while protecting and conserving New York State's natural resources. Soil and Water Conservation Districts in agricultural counties lead the local AEM effort, including Orange County.

AEM uses a five-tiered framework to categorize on-farm activities that have been prioritized by a committee of resource professionals and stakeholders. The following includes important elements associated with each tier (NYSSWCC 2018):

- **Tier 1** – Inventory current activities, future plans, and potential environmental concerns
- **Tier 2** – Document current land stewardship, assess and prioritize areas of concern
- **Tier 3** – Develop conservation plans addressing concerns and opportunities tailored to farm goals
    - **Tier 3A**: Component Conservation Plan
    - **Tier 3B**: Comprehensive Nutrient Management Plan (CNMP)
- **Tier 4** – Implement plans utilizing available financial, educational, and technical assistance
- **Tier 5** – Evaluate to ensure the protection of the environment and farm viability
    - **Tier 5A**: Update Tier 1 and 2

- o **Tier 5B**: Plan evaluation/update, BMP system evaluation

The Orange County SWCD developed an *AEM Strategic Plan* 2015-2020 (Orange County SWCD 2015a) to promote land stewardship and increase the quality of natural resources and production on agricultural lands within the County. The goal of this Plan is to identify environmental issues on farms and work with the farmer to solve these issues using technical resources from the SWCD, the Natural Resources Conservation Service (NRCS), the Cornell Cooperative Extension (CCE), and financial resources from the NYS Agricultural Nonpoint Source Abatement and Control Program (ANSACP), and other available funding sources. It aims to support traditional agriculture where it continues to work, and to assist the 'new face' of agriculture to address environmental concerns as it diversifies and changes in response to new market opportunities.

The Monhagen-Middletown Reservoir System is located within the Wallkill River Planning Unit of the Orange County AEM Plan. Agricultural sources are identified as a significant source of nutrients and sediments to the Wallkill main stem and some its major tributaries. The AEM Plan encourages pro-active attention to agricultural environmental concerns, and provides a framework for planners to follow to promote a comprehensive treatment and prioritization of identified farm issues that include:

- Manure from dairy and horse farms
- Control of nutrients from "black dirt" or muckland farms that grow sod and vegetables
- Barnyard water management
- Use of cover crops on fields and on ditch banks.

Many AEM-sponsored activities have been undertaken within the Monhagen-Middletown Reservoir System to address important environmental challenges including improving water quality (**Table 7**).

**Table 7. Total number of AEM projects conducted in the Monhagen-Middletown Reservoir System (2011-2017).**

| | Tier 1 | Tier 2 | Tier 3A | Tier 3B | Tier 4 | Tier 5A | Tier 5B |
|---|---|---|---|---|---|---|---|
| **Total Number of AEM Projects** | 3 | 2 | 2 | 0 | 2 | 5 | 0 |

## 12.3 Funded Projects

Limited information exists on projects funded to improve water quality in the Monhagen-Middletown Reservoir System (see **Section 5** for an overview of previous monitoring actions). However, the following are currently funded:

- The City of Middletown received state grant funding for land acquisition and conservation easements including riparian buffer enhancement near Kinch Pond, which will help control the potential negative impacts to water associated with development/redevelopment.

- The City of Middletown has received state grant funding to create a source water protection plan for the reservoir supply system watersheds. The plan will include recommendations for proactive source water protection actions and an initial evaluation of local land use regulations related to source watershed protection.

Additional funding is provided through programs that target water quality improvement and the agricultural community in New York State, such as the Water Quality Improvement Program (WQIP) and the ANSACP program. These programs have supported the implementation of BMPs within the Monhagen-Middletown Reservoir System. Examples of BMP systems implemented that contribute to an improvement in water quality include pesticide management, barnyard runoff management, protection of critical areas, nutrient management, silage leachate control and treatment, and pasture management.

## 12.4 NYSDEC Issued Permits

Article 17 of New York's Environmental Conservation Law (ECL) entitled "Water Pollution Control" was enacted to protect and maintain the state's surface water and groundwater resources. Under Article 17, the State Pollutant Discharge Elimination System (SPDES) program was authorized to maintain reasonable standards of purity for state waters.

The Monhagen-Middletown Reservoir System is located in NYSDEC Region 3. Permits issued through the SPDES program include general permits and individual permits (including wastewater treatment facilities) that discharge to surface and groundwater within the Monhagen-Middletown Reservoir System. One wastewater treatment plant discharges directly into Monhagen-Middletown Reservoir System (NYSDEC 2018h).

For more information about NYSDEC's SPDES program and to view Individual SPDES permits issued in the Monhagen-Middletown Reservoir System visit http://www.dec.ny.gov/permits/6054.html.

## 12.5 Research Activities

Limited information exists on current research activities that focus on water quality within the Monhagen-Middletown Reservoir System. **Section 5** provides an overview of the previous monitoring and research activities for Monhagen Lake and the other resources within the Monhagen-Middletown Reservoir System.

## 12.6 Clean Water Plans (TMDL, 9E, or Other Plans)

As discussed in **Section 10.1**, the LENS model is a screening tool used to prioritize various watershed projects and is not a comprehensive assessment of watershed loads and does not fully account for BMPs or other potential nutrient reduction measures implemented in the Monhagen-Middletown Reservoir System. Consequently, the screening level land use and nutrient loading results generated from the LENS analysis should be interpreted cautiously.

Clean water plans are a watershed-based approach to outline a strategy to improve or protect water quality. Total maximum daily load (TMDL) and 9E Plans are examples of clean water plans; these plans document the pollution sources, pollutant reduction goals and recommend strategies/actions to improve water quality:

- A TMDL calculates the maximum amount of a single pollutant that a waterbody can receive and still meet water quality standards. TMDLs are developed by determining the amount that each source of a pollutant can discharge into the waterbody and the reductions from those sources needed to meet water quality standards. A TMDL is initiated by NYSDEC for waterbodies that are on the 303d impaired waters list with a known pollutant.
- 9E Watershed Plans are consistent with the USEPA's framework to develop watershed-based plans. USEPA's framework consists of nine key elements that are intended to identify the contributing causes and sources of nonpoint source pollution, involve key stakeholders in the planning process, and identify restoration and protection strategies that will address the water quality concerns. The nine minimum elements to be included in these plans include:

  A. Identify and quantify sources of pollution in watershed.
  B. Identify water quality target or goal and pollutant reductions needed to achieve goal.
  C. Identify the best management practices (BMPs) that will help to achieve reductions needed to meet water quality goal/target.
  D. Describe the financial and technical assistance needed to implement BMPs identified in Element C.
  E. Describe the outreach to stakeholders and how their input was incorporated and the role of stakeholders to implement the plan.
  F. Estimate a schedule to implement BMPs identified in plan.
  G. Describe the milestones and estimated time frames for the implementation of BMPs.
  H. Identify the criteria that will be used to assess water quality improvement as the plan is implemented.
  I. Describe the monitoring plan that will collect water quality data need to measure water quality improvement (criteria identified in Element H).

Nine Element Plans are best suited for waterbodies where the pollutant of concern is well understood and nonpoint sources are likely a significant part of the pollutant load; the waterbody does not need to be on the 303d impaired waters list to initiate a 9E Plan.

# 13. Proposed Harmful Algal Blooms (HABs) Actions

## 13.1 Overarching Considerations

When selecting projects intended to reduce the frequency and severity of HABs, lake and watershed managers may need to balance many factors. These include budget, available land area, landowner willingness, planning needs, community priorities or local initiatives, complementary projects or programs, water quality impact or other environmental benefit (e.g., fish/habitat restoration, flooding issues, open space).

Additional important considerations include (1) the types of nutrients, particularly phosphorus, involved in triggering HABs, (2) confounding factors including climate change, and (3) available funding sources (discussed in section 13.2).

### 13.1.1 Phosphorus Forms

As described throughout this Action Plan, a primary factor contributing to HABs in the waterbody is excess nutrients, in particular, phosphorus. Total phosphorus (TP) is a common metric of water quality and is often the nutrient monitored for and targeted in watershed and lake management strategies to prevent or mitigate eutrophication (Cooke et al. 2005).

However, TP consists of different forms (Dodds 2003) that differ in their ability to support algal growth. There are two major categories of phosphorus: particulate and dissolved (or soluble). The dissolved forms of P are more readily bioavailable to phytoplankton than particulate forms (Auer et al. 1998, Effler et al. 2012, Auer et al. 2015, Prestigiacomo et al. 2016). Phosphorus bioavailability is a term that refers to the usability of specific forms of phosphorus by phytoplankton and algae for assimilation and growth (DePinto et al. 1981, Young et al. 1982).

Because of the importance of dissolved P forms affecting receiving waterbody quality, readers of the Action Plan should consider the source and form of P, in addition to project-specific stakeholder interest(s), when planning to select and implement the recommended actions, best management practices or management strategies in the Action Plan. Management of soluble P is an emerging research area; practices designed for conservation of soluble phosphorus are recommended in Sonzogni et al. 1982, Ritter and Shiromohammadi 2000, and Sharpley et al. 2006.

### 13.1.2 Climate Change

Climate change is also an important consideration when selecting implementation projects. There is still uncertainty in the understanding of BMP responses to climate change conditions that may influence best management practice efficiencies and effectiveness. More research is needed to understand which BMPs will retain their effectiveness at removing nutrient and sediment pollution under changing climate conditions, as well as which BMPs will be able to physically withstand changing conditions expected to occur because of climate change.

Where possible, selection of BMPs should be aligned with existing climate resiliency plans and strategies (e.g., floodplain management programs, fisheries/habitat restoration programs, or hazard mitigation programs). When selecting BMPs, it is also important to consider seasonal, inter-annual climate or weather conditions and how they may affect the performance of the BMPs. For example, restoration of wetlands and riparian forest buffers not only filter nutrient and sediment from overland surface flows, but also slow runoff and absorb excessive water during flood events, which are expected to increase in frequency due to climate change. These practices not only reduce disturbance of the riverine environment but also protect valuable agricultural lands from erosion and increase resiliency to droughts.

In New York State, ditches parallel nearly every mile of our roadways and in some watersheds, the length of these conduits is greater than the natural watercourses themselves. Although roadside ditches have long been used to enhance road drainage and safety, traditional management practices have been a significant, but unrecognized contributor to flooding and water pollution, with ditch management practices that often enhance rather than mitigate these problems. The primary objective has been to move water away from local road surfaces as quickly as possible, without evaluating local and downstream impacts. As a result, elevated discharges increase peak stream flows and exacerbate downstream flooding. The rapid, high volumes of flow also carry nutrient-laden sediment, salt and other road contaminants, and even elevated bacteria counts, thus contributing significantly to regional water quantity and quality concerns that can impact biological communities. All of these impacts will be exacerbated by the increased frequency of high intensity storms associated with climate change. For more information about road ditches, see **Appendix E**.

For more information about climate change visit NYSDEC's website (https://www.dec.ny.gov/energy/44992.html) and the Chesapeake Bay Climate Resiliency Workgroup Planning Tools and Resources website (https://www.chesapeakebay.net/documents/Resilient_BMP_Tools_and_Resources_November_20172.pdf).

## 13.2 Priority Project Development and Funding Opportunities

The priority projects listed below have been developed by an interagency team and local steering committee that has worked cooperatively to identify, assess feasibility and costs, and prioritize both in-lake and watershed management strategies aimed at reducing HABs in the Monhagen-Middletown Reservoir System.

*Steering committee members:*

- David Smith, CDM Smith
- Jacob Tawil, City of Middletown, Department of Public Works
- Lucy Joyce, Cornell University Cooperative Extension
- George Schuler, The Nature Conservancy
- Jennifer Clifford, NYSDAM

- Karen Stainbrook, NYSDEC
- Ken Kosinski, NYSDEC
- Scott Cuppett, NYSDEC
- Shohreh Karimipour, NYSDEC
- Keith Miller, Orange County Department of Health
- Jim Deluane, Orange County Land Trust
- Kelly Morris, Orange County Planning Department
- Kevin Summer, Orange County Soil and Water Conservation District (SWCD)
- Dave Church, Orange County Water Authority
- Jen Epstein, Riverkeeper
- Mike Sturm, Shawangunk Kill Watershed Alliance
- David Richardson, SUNY New Paltz
- Jillian Decker, SUNY Rockland Community College

These projects have been assigned priority rankings based on the potential for each individual action to achieve one of two primary objectives of this HABs Action Plan:

1. *In-lake management actions:* Minimize the internal stressors (e.g., nutrient concentrations, dissolved oxygen levels, temperature) that contribute to HABs within the Monhagen-Middletown Reservoir System.
2. *Watershed management actions:* Address watershed inputs that influence in-lake conditions that support HABs.

As described throughout this HABs Action Plan, the primary factors that contribute to HABs in the Monhagen-Middletown Reservoir System include:

- Phosphorus inputs associated with wastewater treatment plant discharges
- Reduction of nonpoint source nutrient inputs from forested and agricultural runoff

The management actions identified below have been prioritized to address these sources. Projects were prioritized based on the following cost-benefit and project readiness criteria:  local support or specific recommendation by steering committee members, eligibility under existing funding mechanisms, and expected water quality impacts as determined by the interagency team. Additionally, nutrient forms and the impacts of climate change were considered in this prioritization as described above.

The implementation of the actions outlined in this Plan is contingent on the submittal of applications (which may require, for example, landowner agreements, feasibility studies, match (financial or in-kind), or engineering plans), award of funding, and timeframe to complete implementation. Due to these contingencies, recommended projects are organized into broad implementation schedules: short-term (3 years), mid-term (3-5 years), and long-term (5-10 years).

*Funding Programs*

The recommended actions outlined in this Section may be eligible for funding from the many state, federal and local/regional programs that help finance implementation of projects in New York State (see https://on.ny.gov/HABsAction). The New York State Water Quality Rapid Response Team stands ready to assist all partners in securing funding. Some of the funding opportunities available include:

**The New York State Environmental Protection Fund (EPF)** was created by the state legislation in 1993 and is financed primarily through a dedicated portion of real estate transfer taxes. The EPF is a source of funding for capital projects that protect the environment and enhance communities. Several NYS agencies administer the funds and award grants, including NYSDAM, NYSDEC, and Department of State. The following two grant programs are supported by the EPF to award funding to implement projects to address nonpoint source pollution:

**The Agricultural Nonpoint Source Abatement and Control Program (ANSACP)**, administered by the NYSDAM and the Soil and Water Conservation Committee, is a competitive financial assistance program for projects led by the Soil and Water Conservation Districts that involves planning, designing, and implementing priority BMPs. It also provides cost-share funding to farmers to implement BMPs. For more information visit https://www.nys-soilandwater.org/aem/nonpoint.html.

**The Water Quality Improvement Program (WQIP)**, administered by the NYSDEC Division of Water, is a competitive reimbursement program for projects that reduce impacted runoff, improve water quality, and restore habitat. Eligible applicants include municipalities, municipal corporations, and Soil and Water Conservation Districts.

**The Environmental Facilities Corporation (EFC)** is a public benefit corporation which provides financial and technical assistance, primarily to municipalities through low-cost financing for water quality infrastructure projects. EFC's core funding programs are the Clean Water State Revolving Fund and the Drinking Water State Revolving Fund. EFC administers both loan and grant programs, including the Green Innovation Grant Program (GIGP), Engineering Planning Grant Program (EPG), Water Infrastructure Improvement Act (WIIA), and the Septic System Replacement Program. For more information about the programs and application process visit https://www.efc.ny.gov/.

**Wastewater Infrastructure Engineering Planning Grant** is available to municipalities with median household income equal to or less than $65,000 according to the United States Census 2015 American Community Survey or equal to or less than $85,000 for Long Island, NYC and Mid-Hudson Regional Economic Development Council (REDC) regions. Priority is usually given to smaller grants to support initial engineering reports and plans for wastewater treatment repairs and upgrades that are necessary for municipalities to successfully submit a complete application for grants and low interest financing.

**Clean Water Infrastructure Act (CWIA) Septic Program** funds county-sponsored and administered household septic repair grants. This program entails repair and/or replacement of failing household septic systems in hot-spot areas of priority watersheds. Grants are channeled through participating counties.

**CWIA Inter-Municipal Grant Program** funds municipalities, municipal corporations, as well as soil and water conservation districts for wastewater treatment plant construction, retrofit of outdated stormwater management facilities, as well as installation of municipal sanitary sewer infrastructure.

**CWIA Source Water Protection Land Acquisition Grant Program** funds municipalities, municipal corporations, soil and water conservation districts, as well as not-for-profits (e.g., land trusts) for land acquisition projects providing source water protection. This program is administered as an important new part of the Water Quality Improvement Project program.

**Consolidated Animal Feeding Operation Waste Storage and Transfer Program Grants** fund soil and water conservation districts to implement comprehensive nutrient management plans through the completion of agricultural waste storage and transfer systems on larger livestock farms.

**Water Infrastructure Improvement Act Grants** funds municipalities to perform capital projects to upgrade or repair wastewater treatments plants and to abate combined sewer overflows, including projects to install heightened nutrient treatment systems.

**Green Innovation Grant Program** provides municipalities, state agencies, private entities, as well as soil and water conservation districts with funds to install transformative green stormwater infrastructure.

Readers of this Action Plan that are interested in submitting funding applications are encouraged to reference this Action Plan and complementary planning documents (i.e., TMDLs or Nine Element (9E) Plans) as supporting evidence of the potential for their proposed projects to improve water quality. However, applicants must thoroughly review each funding program’s eligibility, match, and documentation requirements before submitting applications to maximize their potential for securing funding.

There may be recommended actions that are not eligible for funding through existing programs, however, there may be opportunities to implement actions through watershed programs (https://www.dec.ny.gov/chemical/110140.html) or other mechanisms.

Projects below are focused on Mill, Kinch, Shawangunk, Highland, and Monhagen Lake watersheds. Given that the Indigot Intake is a certified intermittent supply, and appears to be used as a last resort, projects in the Indigot watershed were not included. If this supply is further developed in the future, Indigot watershed projects can be added to the list of priorities.

## 13.3 Monhagen-Middletown Reservoir System Priority Projects

### 13.3.1 Priority 1 Projects

Priority 1 projects are considered necessary to manage water quality and reduce HABs in the Monhagen-Middletown Reservoir System, and implementation should be evaluated to begin as soon as possible.

*Short-term (3 years)*

1. Update land classification for the reservoir system watershed area using most current imagery for Orange County as well as local knowledge.
2. Complete a Feasibility Study (which may include associated monitoring) and cost estimate to upgrade the Hidden Valley Estates wastewater treatment plant (WWTP) to reduce TP loading within the Mill Pond sub-watershed.
3. Collect additional thermal and dissolved oxygen profiles to evaluate stratification in different parts of Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System to characterize the potential for internal nutrient loading and the role of thermal stratification.
4. Predicated on the results of the stratification assessment described above, complete a Feasibility Study, cost estimate, and design to install aeration facilities within Monhagen Lake, Highland Lake, and Shawangunk Reservoir to increase dissolved oxygen levels and reduce the likelihood and frequency of HABs.

*Mid-term (3 to 5 years)*

1. Based on the results of the Feasibility study (**Section 13.2.1** #4), install aeration facilities within Monhagen Lake, Highland Lake, and Shawangunk Reservoir. Alternative power sources such as solar should be incorporated where practicable to minimize their carbon footprint. Facilities that could be deployed include:
   a. Circulation pumps to expose the water column to the atmosphere.
   b. Air diffusers that release oxygen into the lower portion of the water column.
   c. Fountains or surface spray systems that increase aeration and improve aesthetics.
2. Purchase land and conservation easements surrounding Mill and Kinch Ponds and enhance riparian buffers on those properties to stabilize the contributing watershed.

3. Continue research into the sources and implications of phosphorus, nitrogen, and other causes and solutions to algal blooms and cyanotoxins in Monhagen Lake, Shawangunk Reservoir, and Highland Lake watersheds. Surface-water quality monitoring will be conducted for water chemistry (primarily nutrients and chlorophyll-a) and algal toxins in 2018, including two locations on Monhagen Brook and three on tributaries to the Monhagen-Middletown Reservoir System.

*Long-term (5 to 10 years)*

1. The public water systems, with support from the DEC and DOH, should pursue engineering studies to evaluate the potential efficacy of adding additional treatment. If these studies show that adding treatment is appropriate and feasible, then the water systems should then work with DOH and EFC to pursue funding opportunities through programs such as the Drinking Water State Revolving Fund (DWSRF) and Water Infrastructure Improvement Act (WIIA), as well as engage their local elected officials for support.

### 13.3.2 Priority 2 Projects

Priority 2 projects are considered necessary, but may not have a similar immediate need as Priority 1 projects.

*Short-term (3 years)*

1. Complete an assessment of riparian corridors using the riparian opportunity assessment tool in the target watershed areas and develop a prioritized list of buffer enhancement and streambank stabilization projects. This assessment could be conducted by, but not limited to, local SWCDs, municipalities, and non-profits organizations. Depending on funding availability, landowner interest and other factors, implementation projects would be pursued.

2. Replace septic systems along Guymard Road to reduce nutrient loading to the Mill Pond-Shawangunk Reservoir sub-watershed.

*Mid-term (3 to 5 years)*

1. Implement buffer enhancement and streambank stabilization projects in those locations identified through the completed assessment (*Short-term* #1, this Section). BMPs would be those covered by the Stream Corridor and Shoreline Management System (Ag BMP Catalogue), including Riparian Forest Buffer (NRCS 391), Riparian Herbaceous Cover (NRCS 390) and Streambank and Shoreline Protection (NRCS 580) and could include:

    a. Install vegetated riparian buffers to inhibit or restrict nutrient-rich stormwater runoff and eroded soil from reaching tributary streams and/or reservoirs.

   b. Rehabilitate degraded vegetated buffers to improve riparian habitat function.

   c. Preserve hillside integrity with vegetation or other stabilizing material to minimize runoff. Utilize natural depressions and sediment catches in roadside ditches, particularly along steep slopes to limit nonpoint source nutrient loads from within the watershed.

   d. Install stream stabilization structures such as rock or log vanes and streambank armoring with wood and stone in tributaries deemed to be sediment and nutrient sources.

   e. Restore or enhance degraded or impacted wetlands and floodplains with a focus on minimizing downstream sediment flux.

2. Develop Agricultural Environmental Management (AEM) Plans through the local SWCDs. These could include:

   a. Implement an outreach program to work with small farms and horse farms to develop AEM Tier 1 Plans for their operations.

   b. Develop AEM Tier 3 Plans for larger crop farms and targeted small farms.

   c. Develop AEM Nutrient Management Plans (NMPs) for beef/dairy operations and targeted small farms.

3. Establish a program to monitor, inspect, sample, and maintain existing septic systems within the Kinch Pond watershed to maximize the functional capacity of these systems and minimize nutrient contribution.

*Long-term (5 to 10 years)*

1. Depending on AEM assessments and manure management recommendations, construct waste/manure storage and transfer system and/or composting facility areas.

### 13.3.3 Priority 3 Projects

Priority 3 projects are considered important, but may not have a similar immediate need as Priority 1 and 2 projects.

*Mid-term (3 to 5 years)*

1. Implement roadside ditch improvement projects that are likely to contribute the greatest reduction in erosion:

   a. Timing of cleanout to minimize soil erosion.

   b. Properly sizing culverts and channels to avoid headcuts and other erosion.

   c. Use of vegetation to assist in ditch bank stabilization.

    d. Installation of check dams or other facilities to reduce flow velocities, minimize erosion, and promote sedimentation.

*Long-term (5 to 10 years)*

1. Identify preferred locations and implement multiple stormwater BMPs to reduce runoff and nutrient and sediment loading:

    a. Install infrastructure retrofits to replace existing stormwater management facilities that were installed prior to the promulgation of Article 17, Titles 7, 8, and Article 70 of the New York State Environmental Conservation Law. Approaches may include green roofs, permeable pavement, rain gardens, bioretention areas, and vegetated, urban treescapes in developed areas.

    b. If streams within the watershed are contributing to high nutrient loads, install stormwater management basins or wetlands or enhance existing wetlands at Lake inlets or along the tributaries.

## 13.4 Additional Watershed Management Actions

In addition to the priority actions identified above by the steering committee, the following watershed management actions could be considered:

1. Emphasize phosphorus source control in stormwater planning, targeting areas with high levels of phosphorus runoff. Emphasis should be placed on locations within the Monhagen-Middletown Reservoir System that have a combination of relatively high percentages of impervious cover, small lot sizes, and/or compacted soils.

2. Portions of the Monhagen-Middletown Reservoir System that are dominated by tree species such as eastern hemlock (*Tsuga spp.*) and ash (*Fraxinus spp.*) could be significantly impacted by nuisance pest species such as the hemlock wooly adelgid (HWA) (*Adelges tsugae*) and emerald ash borer (*Agrilus planipennis*). The resultant disruption could exacerbate erosion and sediment loading within the watershed. Forest research and management should be implemented to identify and control these and other pests as a proactive means to minimize impacts. Strategic planting of species less susceptible to impacts of infestation should be implemented in areas where canopy loss will result in significant system destabilization.

3. Evaluate locations where animal wastes are concentrated (e.g., pet stores and animal care/boarding facilities) for illicit connections and exposure to stormwater, and provide them with tailored education and outreach materials.

4. Evaluate locations where yard or food wastes are stored (e.g., “dumpsters” serving restaurants and grocery stores, yard waste composting and disposal areas) for illicit connections and exposure to stormwater and provide them with tailored education and outreach materials.

5. Construct wetlands or enhance/restore existing wetlands within the watershed to reduce nutrient loads. **Figure 13** shows the locations within the Monhagen-Middletown Reservoir System that have either hydric, very poorly drained, or poorly drained soils, but are not currently mapped wetland habitats per the National Wetland Inventory (NWI) database. These locations should be targeted for proposed new wetlands as they are more likely to support wetland hydrology and vegetation.

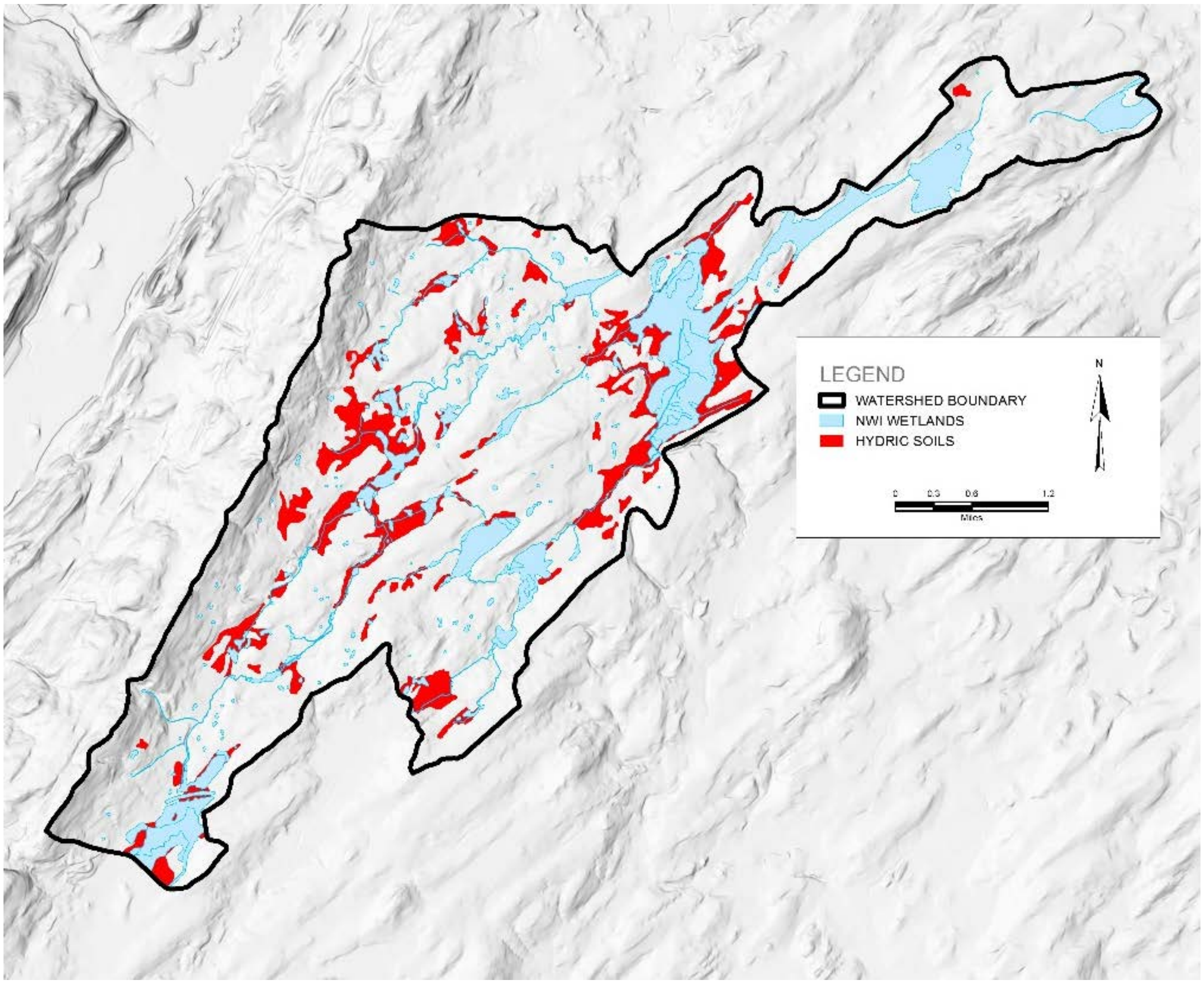


**Figure 13.** Locations (depicted in red) of either hydric, very poor, or poorly drained soils in the Monhagen-Middletown Reservoir System, which are not mapped as wetlands per the National Wetland Inventory (NWI).

## 13.5 Monitoring Actions

To help determine the stresses that lead to HABs in Monhagen-Middletown Reservoir System and to assess improvements associated with management actions, the following monitoring actions are recommended:

*Short-term*

1. Continue to collect toxin concentration data during HAB events, particularly when large or lakewide blooms occur. This information can be used to protect public health, issue advisories, and in conjunction with water quality measurements, provide insight into conditions that lead to blooms with undesirable toxin concentrations.
2. Collect data on lake bed sediment characteristics (phosphorus concentrations and grain size) to evaluate "hot spots" of elevated phosphorus in the sediment of Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System. This information will be important to evaluate in-lake management options.
3. Analyze water quality samples for soluble reactive phosphorus (SRP) to better understand how much is available to algae for growth relative to total phosphorus concentrations.
4. Collect water quality data at nearshore sampling location(s) to determine spatial variability in water quality within Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System (relative to the open water sampling location). This could be through a return to CSLAP or some other systematic monitoring program.
5. Develop a HAB monitoring network, focused on areas of the lakes where prevailing wind and wave action contributes to the accumulation of cyanobacteria.
6. Supplement the understanding of the cyanobacteria species that are prevalent in Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System. Additionally, a greater temporal resolution of algal density in Monhagen Lake and the other resources in the Monhagen-Middletown Reservoir System could help to identify seasonal trends and inform management strategies.
7. Maintain and enhance community and/or volunteer monitoring efforts of water quality conditions in the watershed, particularly during the growing season.
8. Collectively, these data can be used to enhance capabilities for predicting future HABs occurrences.

## 13.6 Research Actions

The following research actions are recommended for evaluation to help identify the stresses that lead to potential HABs in the Monhagen-Middletown Reservoir System and to assess improvements associated with management actions.

*Short-term (3 years)*

1. Evaluate the feasibility of deploying buoyed sampling system(s) in strategic location(s) that could provide remote, high temporal resolution data and alert

stakeholders when HABs are occurring or likely to occur (proactive versus reactive).

2. Evaluate the use of alternatives to copper sulfate, including other chelated copper formulations and hydrogen peroxide, to reduce vegetative and algal growth.

The NYSDEC should continue to coordinate with local organizations and research groups to maximize the efficacy of research efforts with the shared goal of maintaining and/or improving the water quality within the Monhagen-Middletown Reservoir System. Specifically, the role of nitrogen concentrations in the production of toxins by cyanobacteria should be studied and management actions targeted at optimizing the nutrient levels to minimize the production of toxins associated with HABs.

The NYSDEC should support research to better understand how to target dissolved phosphorus with traditional and innovative nonpoint source best management practices. This applied research would guide selection of appropriate BMPs to target dissolved phosphorus in the future.

The NYSDEC should support research to understand and identify which best management practices will retain their effectiveness at removing nutrient and sediment pollution under changing climate conditions, as well as which BMPs will be able to physically withstand changing conditions expected to occur as a result of climate change. This applied research would guide selection of appropriate BMPs in the future and determination of the likely future effectiveness of existing BMPs.

The NYSDEC should support research to investigate the role of climate change on lake metabolism, primary production, nutrient cycling, and carbon chemistry.

## 13.7 Coordination Actions

The following actions are opportunities for stakeholders, general public, steering committee members, federal state, and local partners to collaborate, improve project or program integration, enhance communication and increase implementation. The actions are intended to increase collaboration and cooperation in the overall advancement of this HABs Action Plan. These actions will likely change or expand as the Action Plan is implemented and/or research is completed, or when opportunities for coordination are identified.

*Short-term (3 years)*

1. Promote the implementation of the watershed-scale BMPs for curtailing runoff from farm fields and other agricultural areas (detailed in the Orange County SWCD 2015a), developed land, and forested land.
2. Improve coordination between NYSDEC and owners of highway infrastructure (state, county, municipal) to address road ditch management; including, identify

practices, areas of collaboration with other stakeholder groups, and evaluation of current maintenance practices.

3. Continue to support and provide targeted training (e.g., ditch management, emergency stream intervention, sediment and erosion controls, prescribed grazing, conservation skills, etc.) to municipal decision makers, SWCDs, and personnel in order to underscore the importance of water quality protection as well as associated tools and strategies.
4. Evaluate the potential to reclassify waterbodies within the Monhagen-Middletown Reservoir System that are used as drinking water supplies from Class B to Class A or AA. The NYSDOH and NYSDEC should coordinate efforts needed to complete the evaluation.
5. Consider promulgating Source Water Protection Rules Under NY Public Health Law § 11-1100

*Long-term (5 to 10 years)*

1. Pursue and identify cooperative landowners to facilitate acquisitions of conservation easements to implement watershed protection strategies, harnessing available funding opportunities related to land acquisition for water quality protection.
2. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.
3. Coordinate with Department of Health to support the local health departments to implement onsite septic replacement and inspection activities.
4. Identify areas to improve efficiency of existing funding programs that will benefit the application and contracting process. For example, develop technical resources to assist with application process and BMP selection, identify financial resources needed by applicants for engineering and feasibility studies.
5. Support evaluation of watershed rules and regulations.

## 13.8 Long-term Use of Action Plan

This Action Plan is intended to be an adaptive document that may require updates and amendments, or evaluation as projects are implemented, research is completed, new conservation practices are developed, implementation projects are updated, or priority areas within the watershed are better understood.

Local support and implementation of each plan’s recommended actions are crucial to successfully preventing and combatting HABs. The New York State Water Quality Rapid Response Team has established a one-stop shop funding portal and stands ready to assist all localities in securing funding and expeditiously implementing priority projects.

Communities and watershed organizations are encouraged to review the plan for their lake, particularly the proposed actions, and work with state and local partners to implement those recommendations. Individuals can get involved with local groups and encourage their communities or organizations to take action.

Steering committee members are encouraged to coordinate with their partners to submit funding applications to complete implementation projects. For more information on these funding opportunities, please visit https://on.ny.gov/HABsAction.

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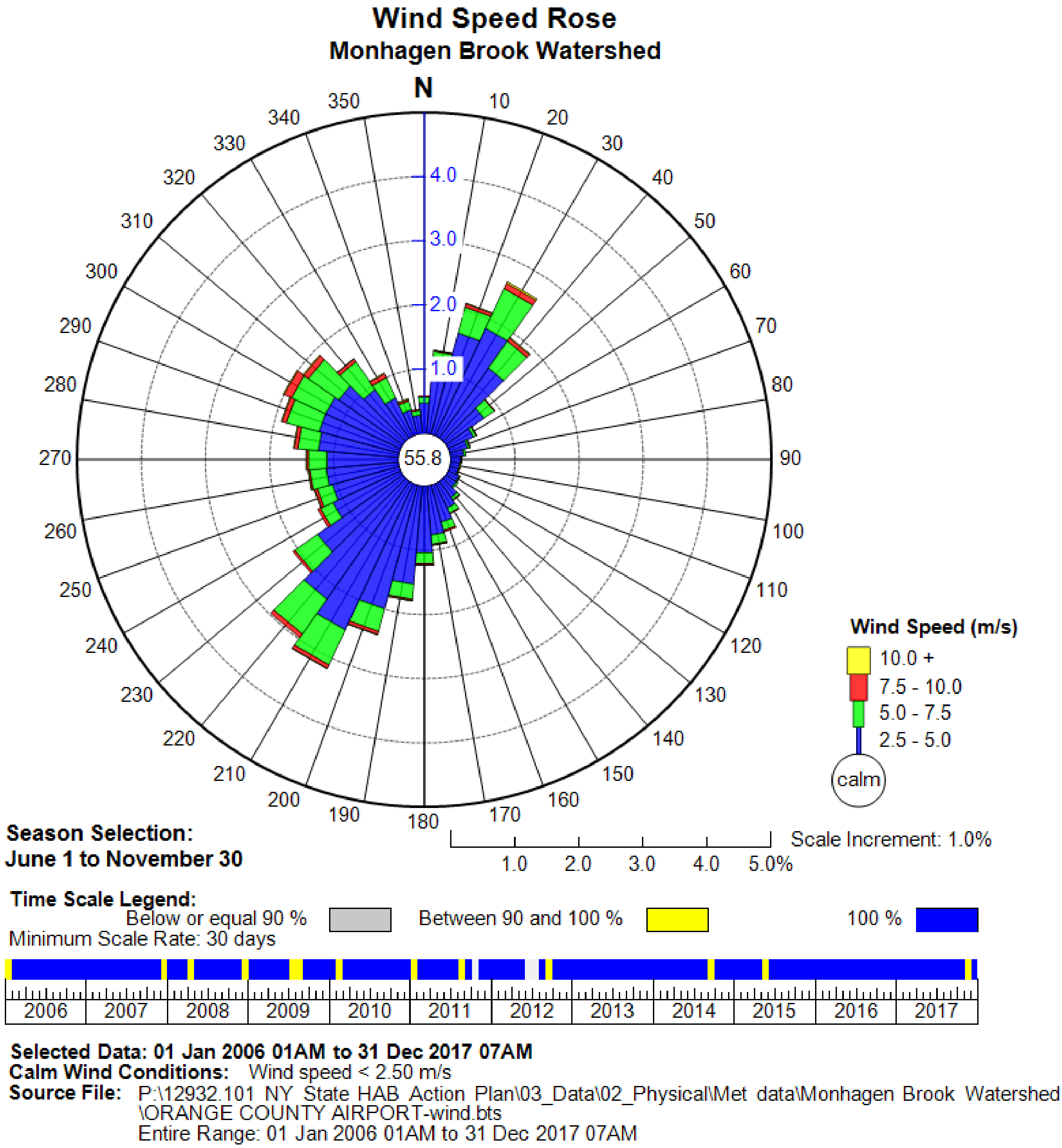
# Appendix A. Wind Patterns

**Wind speed**




The wind speed patterns for Monhagen Lake from 2006 to 2017, during the months of June through November, indicate stronger winds were generally out of the southwest and northeast.

# Appendix B. Waterbody Classifications

Class N: Enjoyment of water in its natural condition and where compatible, as source of water for drinking or culinary purposes, bathing, fishing and fish propagation, recreation and any other usages except for the discharge of sewage, industrial wastes or other wastes or any sewage or waste effluent not having filtration resulting from at least 200 feet of lateral travel through unconsolidated earth. These waters should contain no deleterious substances, hydrocarbons or substances that would contribute to eutrophication, nor shall they receive surface runoff containing any such substance.

Class $AA_{special}$: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival, and shall contain no floating solids, settleable solids, oils, sludge deposits, toxic wastes, deleterious substances, colored or other wastes or heated liquids attributable to sewage, industrial wastes or other wastes. There shall be no discharge or disposal of sewage, industrial wastes or other wastes into these waters. These waters shall contain no phosphorus and nitrogen in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.

Class $A_{special}$: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These international boundary waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class AA: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These waters, if subjected to approved disinfection treatment, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class A: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival.

These waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class B: The best usage is for primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival

Class C: The best usage is for fishing, and fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

Class D: The best usage is for fishing. Due to such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or stream bed conditions, the waters will not support fish propagation. These waters shall be suitable for fish survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

Class (T): Designated for trout survival, defined by the Environmental Conservation Law Article 11 (NYS, 1984b) as brook trout, brown trout, red throat trout, rainbow trout, and splake.

Class (TS): Designated for trout spawning waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout, trout spawning, trout waters, or trout spawning waters applies.

# Appendix C. NYSDEC Water Quality Monitoring Programs

Information about NYSDEC's water quality monitoring program, CSLAP, can be found at: http://www.dec.ny.gov/chemical/81576.html.

# Appendix D. WI/PWL Summary

## Monhagen Lake (1306-0075) Threatened

**Waterbody Location Information** Revised: 05/01/2018 **Water Index No:** H-139-13-52-P598

**Water Class:** AA

| | | | |
|---|---|---|---|
| **Hydro Unit Code:** | Lower Wallkill River (0202000704) | **Drainage Basin:** | Lower Hudson River |
| **Water Type/Size:** | Lake/Reservoir 63.5 Acres | **Reg/County:** | 3/Orange (36) |
| **Description:** | entire lake | | |

### Water Quality Problem/Issue Information

| **Uses Evaluated** | **Severity** | **Confidence** |
|---|---|---|
| Water Supply | Threatened | Known |
| Public Bathing | Stressed | Unconfirmed |
| Recreation | Stressed | Unconfirmed |
| Aquatic Life | Stressed | Unconfirmed |
| Fish Consumption | Unassessed | - |
| **Conditions Evaluated** | | |
| Habitat/Hydrology | Unknown | |
| Aesthetics | Poor | |

**Type of Pollutant(s)** (CAPS indicate Major Pollutants/Sources that contribute to an Impaired/Precluded Uses)

Known: ---
Suspected: Nutrients (Phosphorus), Algal/Weed Growth
Unconfirmed: ---

**Source(s) of Pollutant(s)**

Known: ---
Suspected: ---
Unconfirmed: Other Source

### Management Information

**Management Status:** Verification of Problem Severity Needed
**Lead Agency/Office:** DEC/Reg3
**IR/305(b) Code:** Water with Insufficient Data (IR Category 3)

### Further Details

Overview
Monhagen Lake is assessed as a threatened waterbody segment due to drinking water uses that are threatened.

Use Assessment
Monhagen Lake is a Class AA waterbody, required to support and protect the best uses of: a water supply source for drinking, culinary or foood processing purposes; primary and secondary contact recreation; and fishing.

Evaluation of the use of this lake for public water supply includes conditions of the lake water prior to treatment, not the quality of water distributed for use after treatment. Monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. Water supply use in the waterbody is considered to be threatened by elevated nutrient and chlorophyll levels in the lake that result in increased risk of disinfection by-products (DBPs) formation in finished potable water and make treatment to meet drinking water standards more difficult. DBPs are formed when disinfectants such as chlorine used in water treatment plants react with natural organic matter (i.e., decaying vegetation) present in the source water. Prolonged exposure to DBPs may increase the risk of certain health effects. The lake also requires routine use of algacides to reduce filtration and other water treatement costs. However, water quality data sources are old and it is not known if conditions measured in the early 2000s are still present today (DEC/DOW, BWAM, April 2018)

Primary and secondary contact reacreational uses may be stressed by elevated nutrients (phosphorus), excessive algae and poor water clarity, but these uses are not presently allowed in Monhagen Lake. (DEC/DOW, BWAM/CSLAP, April 2018)

There are no know impacts to fishing use, but due to periodically elevated pH, aquatic life may be stressed. (DEC/DOW, BWAM, April 2018)

Fish consumption use is considered to be unassessed. There are no health advisories limiting the consumption of fish from this waterbody (beyond the general advice for all waters). However due to the uncertainty as to whether the lack of a waterbody-specific health advisory is based on actual sampling, fish consumption use is noted as unassessed. (NYSDOH Health Advisories and NYSDEC/DOW, BWAM, April 2018)

Water Quality Information

Water quality sampling of Monhagen Lake was conducted through the Citizens Statewide Lake Assessment Program (CSLAP) from 2003 through 2009. Results of this sampling indicate the lake is best characterized as mesoeutrophic, or moderately to highly productive. Chlorophyll-a levels in this study exceeded the NYSDEC criteria indicating impaired conditions for potable water supplies, due to a high likelihood of producing potential carcinogens (based on chlorophyll a levels greatly exceeding 4 µg/l) during chlorination of raw water. However, it is not known if this older data is representative of present conditions in the lake. (DEC/DOW, BWAM/LMAS, April 2018)

Chlorophyll/algal levels often exceed criteria corresponding to stressed recreational uses, while phosphorus concentrations are typically moderately high. Lake clarity measurements indicate water transparency typically meet the recommended minimum criteria for swimming beaches, although swimming is not allowed in this drinking water reservoir. Readings of pH occasionally exceed the range established in state water quality standards for protection of aquatic life. The elevated pH is most likely a response to algae levels. (DEC/DOW, BWAM/LMAS, April 2018)

Source Assessment

Specific sources of pollutants to the waterbody have not been identified.

Management Actions

This waterbody is considered a highly-valued water resource due to its drinking water supply classification. On December 21, 2017, New York State Governor Andrew Cuomo announced a $65 million initiative to combat harmful algal blooms in Upstate New York. Monhagen Lake was identified for inclusion in this initiative as it is vulnerable to HABs and is a drinking water source.

Section 303(d) Listing

Monhagen Lake is not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. There appear to be no impacts/impairments that would justify the listing of this waterbody. (DEC/DOW, BWAM/WQAS, April 2018)

Segment Description

This segment includes the entire area of Monhagen Lake (P598)

# Shawangunk Lake/Highland Lake (1306-0060) Threatened

## Waterbody Location Information

Revised: 05/01/2018

**Water Index No:** H-139-13-19-28-P491,P492

**Water Class:** AA

**Hydro Unit Code:** Shawangunk Kill (0202000703)

**Drainage Basin:** Lower Hudson River

**Water Type/Size:** Lake/Reservoir 218.1 Acres

**Reg/County:** 3/Orange (36)

**Description:** total area of both lakes

## Water Quality Problem/Issue Information

| Uses Evaluated | Severity | Confidence |
|---|---|---|
| Water Supply | Threatened | Known |
| Public Bathing | Stressed | Unconfirmed |
| Recreation | Stressed | Unconfirmed |
| Aquatic Life | Fully Supported | Unconfirmed |
| Fish Consumption | Unassessed | - |
| **Conditions Evaluated** | | |
| Habitat/Hydrology | Unknown | |
| Aesthetics | Unknown | |

**Type of Pollutant(s)** (CAPS indicate Major Pollutants/Sources that contribute to an Impaired/Precluded Uses)

Known: ---
Suspected: Nutrients (Phosphorus), Algal/Weed Growth
Unconfirmed: ---

**Source(s) of Pollutant(s)**

Known: ---
Suspected: ---
Unconfirmed: Other Source

## Management Information

**Management Status:** Verification of Problem Severity Needed
**Lead Agency/Office:** DEC/Reg3
**IR/305(b) Code:** Water with Insufficient Data (IR Category 3)

## Further Details

Overview
Shawangunk and Highland Lakes are assessed as needing verification of threatened drinking water uses

Use Assessment
Shawangunk and Highland Lakes are Class AA waterbodies, required to support and protect the best uses as a water supply source for drinking, culinary or food processing purposes, primary and secondary contact recreation, and fishing.

Evaluation of the use of these lakes for public water supply includes conditions of the lake water prior to treatment, not the quality of water distributed for use after treatment. Monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. Water supply use in Shawaununk and Highland Lakes are considered to be threatened by elevated nutrients and chlorophyll levels in the lakes that result in increased risk of disinfection by-products (DBPs) formation in finished potable water and make treatment to meet drinking water standards more difficult. DBPs are formed when disinfectants such as chlorine used in water treatment plants react with natural organic matter (i.e., decaying vegetation) present in the source water. Prolonged exposure to DBPs may increase the risk of certain health effects. The lake also requires routine use of algacides to reduce filtration and other water treatement costs. However, water quality data sources are old and it is not known if conditions measured in the early 2000s are still present today (DEC/DOW, BWAM, April 2018)

Primary and secondary contact recreational uses may be stressed by elevated nutrients (phosphorus), excessive algae, and poor water clarity however, recreational uses are not presently allowed in Shawangunk Lake or Highland Lake due to the lack of public access. (DEC/DOW, BWAM/CSLAP, April 2018)

Fishing use is suspected to be fully supported in Shawaungunk Lake and Highland Lake but additional sampling is needed to confirm conditions. (DEC/DOW, BWAM, April 2018)

Fish Consumption use is considered to be unassessed. There are no health advisories limiting the consumption of fish from this waterbody (beyond the general advice for all waters). However due to the uncertainty as to whether the lack of a waterbody-specific health advisory is based on actual sampling, fish consumption use is noted as unassessed. (NYSDOH Health Advisories and NYSDEC/DOW, BWAM, April 2018)

Water Quality Information
Water quality sampling of Shawangunk and Highland Lakes was conducted through the NYSDEC Citizens Statewide Lake Assessment Program (CSLAP) from 2003 through 2009. Results of this sampling indicate the lake is best characterized as mesoeutrophic, or moderately to highly productive. Chlorophyll a levels in this study exceeded the NYSDEC criteria indicating impacted conditions for potable water supplies in Shawangunk Lake and Highland Lake, due to a high likelihood of producing potential carcinogens (based on chlorophyll a levels greatly exceeding 4 µg/l) during chlorination of raw water. However, it is not known if this older data is representative of present conditions in these lakes. (DEC/DOW, BWAM/LMAS, April 2018)

Shawangunk Lake was assessed through the NYSDOH Source Waters Assessment Program (SWAP) which compiles, organizes, and evaluates information regarding possible and actual threats to the quality of public water supply (PWS) sources. The information contained in SWAP assessment reports assists in the oversight and protection of public water systems. It is important to note that SWAP reports estimate the potential for untreated drinking water sources to be impacted by contamination and do not address the quality of treated finished potable tap water. This assessment found no noteworthy risks to source water quality. Although there are no specific water quality impacts, the segment is considered a highly valued water resource due to its drinking water supply classification as a AA(T) water. This water supply reservoir provides water to the City of Middletown. (NYSDOH, Source Water Assessment Program, 2005).

Source Assessment
Specific sources of pollutants to the waterbody have not been identified.

Management Actions
These waterbodies are considered highly-valued water resources due to their drinking water supply classification. On December 21, 2017, New York State Governor Andrew Cuomo announced a $65 million initiative to combat harmful algal blooms in Upstate New York. Shawangunk and Highland Lakes were identified for inclusion in this initiative as they are vulnerable to HABs and critical drinking water sources.

Section 303(d) Listing
Shawangunk and Highland Lakes are not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. (DEC/DOW, BWAM/WQAS, April 2018)

Segment Description
This segment includes the entire area of Shawangunk Lake (P491) and Highland Lake (P492).

# Appendix E. Road Ditches

In New York State, ditches parallel nearly every mile of our roadways and in some watersheds, the length of these conduits is greater than the natural watercourses themselves. Although roadside ditches have long been used to enhance road drainage and safety, traditional management practices have been a significant, but unrecognized contributor to flooding and water pollution, with ditch management practices that often enhance rather than mitigate these problems. The primary objective has been to move water away from local road surfaces as quickly as possible, without evaluating local and downstream impacts. As a result, elevated discharges increase peak stream flows and exacerbate downstream flooding. The rapid, high volumes of flow also carry nutrient-laden sediment, salt and other road contaminants, and even elevated bacteria counts, thus contributing significantly to regional water quantity and quality concerns that can impact biological communities.  All of these impacts will be exacerbated by the increased frequency of high intensity storms associated with climate change. Continued widespread use of outdated road maintenance practices reflects a break-down in communications among scientists, highway managers, and other relevant stakeholders, as well as tightening budgets and local pressures to maintain traditional road management services. Although road ditches can have a significant impact on water quality, discharges of nutrients and sediment from roadways can be mitigated with sound management practices.

### *Road Ditch Impacts*

Roadside ditch management represents a critical, but overlooked opportunity to help meet watershed and clean water goals in the Monhagen Middletown Lake Reservoir System watershed by properly addressing the nonpoint sources of nutrients and sediment entering the New York waters from roadside ditches. The three main impacts of roadside ditch networks are: (1) hydrological modification, (2) water quality degradation, and (3) biological impairment.

### *Mitigation Strategies to Reduce Impacts*

Traditional stormwater management focused on scraping or armoring ditches to collect and rapidly transport water downstream. The recommended mitigation strategies described below focus on diffusing runoff to enhance sheet flow, slowing velocities, and increasing infiltration and groundwater recharge. This approach reduces the rapid transfer of rainwater out of catchments and helps to restore natural hydrologic conditions and to reduce pollution while accommodating road safety concerns.

These strategies can be divided into three broad, but overlapping categories:

1. **Practices designed to hold or redirect stormwater runoff to minimize downstream flooding.**
    - Redirect the discharges to infiltration or detention ponds.

- Restore or establish an intervening wetland between the ditch and the stream.
- Divert concentrated flow into manmade depressions oriented perpendicular to flow using level lip spreader systems.
- Modify the road design to distribute runoff along a ditch, rather than a concentrated direct outflow.

2. **Practices designed to slow down outflow and filter out contaminants.**
    - Reshape ditches to shallow, trapezoidal, or rounded profiles to reduce concentrated, incisive flow and the potential for erosion.
    - Optimize vegetative cover, including hydroseeding and a regular mowing program, instead of mechanical scraping. Where scraping is necessary, managers should schedule roadside ditch maintenance during late spring or early summer when hydroseeding will be more successful.
    - Build check dams, or a series of riprap bars oriented across the channel perpendicular to flow, to reduce channel flow rates and induce sediment deposition while enhancing ground water recharge.
    - Reestablish natural filters, such as bio-swales, compound or “two-stage” channels, and level lip spreaders.
3. **Practices to improve habitat.**
    - Construct wetlands for the greatest potential to expand habitat.
    - Reduce runoff volumes to promote stable aquatic habitat.

The Upper Susquehanna Coalition (USC) is developing a technical guidance document in the form of a Ditch Maintenance Program Guide that can be used by any local highway department. The guide will include an assessment program to determine if the ditch needs maintenance and what is necessary to stabilize the ditch. It will also contain a group of acceptable and proven management guidelines and practices for ditch stabilization. In addition, the USC is developing a broad-based education and outreach program to increase awareness and provide guidance to stakeholder groups. This program will take advantage of existing education programs, such as the NY’s Emergency Stream Intervention (ESI) Training program, USC, Cornell University and the Cornell Local Roads program. This new program will be adaptable in all watersheds.