



Department of
Environmental
Conservation

Department
of Health

Agriculture
and Markets

HARMFUL ALGAL BLOOM ACTION PLAN CAYUGA LAKE



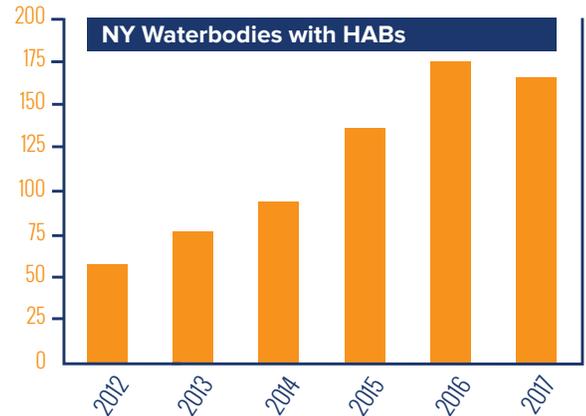
EXECUTIVE SUMMARY

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.

CAYUGA LAKE

Cayuga, Tompkins, and Seneca Counties

Cayuga Lake, a 42,800-acre lake that is the second largest of the Finger Lakes in central New York (with the largest watershed), is one of the 12 priority lakes impacted by HABs. The lake is used for swimming, fishing and boating. In addition, Cayuga Lake is the primary drinking water source and/or backup source for nearly 100,000 watershed residents.

The Southern End of Cayuga Lake was assessed as an “impaired waterbody” due to the lake’s primary and secondary contact recreation uses (swimming and boating) that are known to be impaired by excessive phosphorus and silt/sediment load from various sources throughout the watershed. In the other three portions of Cayuga Lake, primary and secondary contact recreation are stressed due to suspected impacts from algal/plant growth and aquatic invasive species

The significant sources of phosphorus loading in the lake are:

- Non-point source sediment and nutrient inputs from the contributing watershed (e.g., agricultural lands, stormwater runoff from developed lands and road ditches).

There were 12 confirmed HABs occurrences in the lake from 2013 through 2017, including 3 confirmed HABs with high toxins. Large portions of the lake shoreline were in bloom during late summer in 2017, resulting in closures of six beaches for a total of 62 beach days.

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 Cayuga Lake, including the following:

- Build the capacity of Soil and Water Conservation Districts (SWCDs) in the Cayuga Lake watershed to implement Agricultural Environmental Management (AEM); implement livestock exclusion programs and manure management techniques; conduct a pilot program for new and emerging Best Management Practices (BMPs); and implement sediment control measures;
- Implement runoff reduction BMPs, roadside ditch and culvert improvement projects; install stream stabilization on selected tributaries; and plant trees and shrubs on available municipal lands and willing landowner properties;
- Establish a septic system inspection program;
- Implement comprehensive municipal stormwater programs throughout the watershed; and
- Acquire and conserve lands and wetlands within the watershed.



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.

CAYUGA LAKE 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 Cayuga Lake 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 Cayuga Lake 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.

Contents

List of Tables.....	3
List of Figures.....	4
1. Introduction.....	6
1.1 Purpose	6
1.2 Scope, Jurisdiction and Audience	6
1.3 Background.....	7
2. Lake Background	8
2.1 Geographic Location.....	8
2.2 Basin Location	8
2.3 Morphology	8
2.4 Hydrology.....	10
2.5 Lake Origin	11
3. Designated Uses.....	11
3.1 Water Quality Classification – Lake and Major Tributaries.....	11
3.2 Potable Water Uses	13
3.3 Public Bathing Uses.....	15
3.4 Recreation Uses	16
3.5 Fish Consumption/Fishing Uses	16
3.6 Aquatic Life Uses	16
3.7 Other Uses.....	19
4. User and Stakeholder Groups.....	19
5. Monitoring Efforts	21
5.1 Lake Monitoring Activities	21
5.2 Tributary Monitoring Activities.....	24
6. Water Quality Conditions.....	25
6.1 Physical Conditions.....	27
6.2 Chemical Conditions	30
6.3 Biological Conditions.....	35
6.4 Other Conditions	38
6.5 Remote Sensing Estimates of Chlorophyll-a Concentrations.....	39

7.	Summary of HABs.....	42
7.1	Ambient Lake HABs History.....	43
7.2	Drinking Water and Swimming Beach HABs History	44
7.3	Other Bloom Documentation.....	46
7.4	HABs and Remote Sensing	47
8.	Waterbody Assessment.....	52
8.1	WI/PWL Assessment	52
8.2	Source Water Protection Program (SWPP)	53
8.3	CSLAP Scorecard.....	54
9.	Conditions triggering HABs	55
10.	Sources of Pollutants.....	59
10.1	Land Uses.....	60
10.2	External Pollutant Sources.....	62
10.3	Internal Pollutant Sources.....	63
10.4	Summary of Priority Land Uses and Land Areas	64
11.	Lake Management / Water Quality Goals.....	64
12.	Summary of Management Actions to Date	64
12.1	Local Management Actions.....	64
12.2	Agricultural Environmental Management Program.....	65
12.3	Funded Projects.....	65
12.4	NYSDEC Issued Permits	66
12.5	Research Activities	66
12.6	Clean Water Plans (TMDL, 9E, or Other Plans)	67
13.	Proposed Harmful Algal Blooms (HABs) Actions	68
13.1	Overarching Considerations	68
13.1.1	Phosphorus Forms.....	68
13.1.2	Climate Change	69
13.2	Priority Project Development and Funding Opportunities	70
13.3	Cayuga Lake Priority Projects.....	73
13.3.1	Priority 1 Projects.....	73
13.3.2	Priority 2 Projects.....	78
13.4	Additional Watershed Management Actions	78

13.5	In-Lake Management Actions	79
13.6	Monitoring Actions	79
13.7	Research Actions.....	80
13.8	Coordination Actions.....	81
13.9	Long-term Use of Action Plan	82
14.	References	83
	Appendix A. Wind and Wave Patterns	92
	Appendix B. Waterbody Classifications.....	94
	Appendix C. Remote Sensing Methodology.....	96
	Appendix D. NYSDEC Water Quality Monitoring Programs	104
	Appendix E. WI/PWL Summary	110
	Appendix F. Road Ditches.....	110

List of Tables

Table 1.	Cayuga Lake fishing regulations (NYSDEC 2018d).	16
Table 2.	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 concentrations (± standard error) at Cayuga Lake sample locations (CSLAP, DBPs, LSC, CLMP).	26
Table 3.	New York State criteria for trophic classifications (NYSFOLA 2009) and average values (± standard error) for the Cayuga Lake sampling (CSLAP, DBPs, LSC, CLMP) locations.	26
Table 4.	Number of HABs notifications by bloom status.....	44
Table 5.	HABs guidance criteria.	46
Table 6.	Measured toxin and cyanobacteria (BGA) chlorophyll-a concentrations for bloom events (2014-2017, CSLAP).....	47
Table 7.	Percent (%) of water surface area with an estimated chlorophyll-a concentration (µg/L) above and below 10 µg/L and 25 µg/L in Cayuga Lake (2015 to 2017).	51
Table 8.	Cayuga Lake use assessment.	53
Table 9.	Total number of AEM projects conducted in the Cayuga Lake watershed (2011-2017).	65
Table 10.	Landsat 8 overpasses of Cayuga Lake from May through October, 2018.....	80

List of Figures

Figure 1. Location of Cayuga Lake within New York State.....	8
Figure 2. Political boundaries within the Cayuga Lake watershed.	9
Figure 3. Bathymetric map of Cayuga Lake (Source: Upstate Freshwater Institute (UFI)).....	10
Figure 4. Cayuga Lake watershed (Source: Cayuga Lake Watershed Network 2018). 11	
Figure 5. Water quality classification by segments in Cayuga Lake.....	12
Figure 6. Historic and current Cayuga Lake water chemistry sample locations.	22
Figure 7. (a) Secchi depth measured at the Mid-South/South sampling location in Cayuga Lake from 1998 to 2017 (CSLAP, DBPs, LCS, CLMP). (b) Annual average Secchi depth (m) from all sampling locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs, LCS, CLMP).....	28
Figure 8. (a) Surface water temperature (°C) measured at the Mid-South/South sampling location in Cayuga Lake from 2002 to 2017. (b) Annual average surface water temperature (°C) from all sampling locations in Cayuga Lake, 2002-2007, and 2017... 29	
Figure 9. Temperature profiles in Cayuga Lake from May to September 2017 (a) Site 1: 42° 37.92" N, 76° 40.33" W and (b) Site 2 42 33.25" N, 76 35.5" W. Data provided by John Halfman, Hobart and William Smith Colleges.....	30
Figure 10. (a) Total phosphorus (mg/L) measured at the Mid-South/South sampling location in Cayuga Lake from 2002 to 2017 (CSLAP, DBPs, LCS, CLMP). (b) Annual average total phosphorus (mg/L) from all sampling locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs, LCS, CLMP).....	32
Figure 11. Annual average total nitrogen (mg/L) from all sample locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs).	33
Figure 12. Annual average ratios of total nitrogen (TN) to total phosphorus (TP) (by mass) from the Mid-South/South location in Cayuga Lake, 1996 to 2017.....	34
Figure 13. Dissolved oxygen profiles in Cayuga Lake from May-August and October in 2014 (a) Site 1: 42° 37.92" N, 76° 40.33" W and (b) Site 2 42 33.25" N, 76 35.5"W. Data provided by John Halfman, Hobart and William Smith Colleges.	35
Figure 14. (a) Chlorophyll-a (µg/L) measured at the Mid-South/South sampling location in Cayuga Lake from 2002 to 2017 (CSLAP, DBPs, LCS, CLMP). (b) Annual average chlorophyll-a concentrations (µg/L) from all sampling locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs, LCS, CLMP).....	38
Figure 15. Estimated chlorophyll-a concentrations in Cayuga Lake, 2015 to 2017.....	40
Figure 16. Measured (CSLAP, blue circles) and estimates (Landsat 8, orange circles) chlorophyll-a concentrations in Cayuga Lake from 2015 to 2017.....	41

Figure 17. Number of beach days lost due to beach closures associated with HABs in Cayuga Lake from 2015 to 2017.	46
Figure 18. Estimated chlorophyll-a concentrations in Cayuga Lake during September 2015.	48
Figure 19. Estimated chlorophyll-a concentrations in Cayuga Lake during July 2015... ..	49
Figure 20. Remote sensing estimated of chlorophyll-a indicate complex wind-driven circulation patterns in Cayuga Lake.	50
Figure 21. Cayuga Lake 2017 CSLAP scorecard.....	55
Figure 22. Average precipitation (mm,± standard error) in the preceding 5 days of a reported bloom (green bar) and days with no reported HAB (blue bar).....	58
Figure 23. Land uses and percentages in the Cayuga Lake watershed. Natural areas include forests, shrublands, grasslands, and wetlands.	60
Figure 24. (a) Cayuga Lake watershed land use and (b) septic system density.	61
Figure 25. Locations (depicted in red) of either hydric, very poor, or poorly drained soils in the Cayuga Lake watershed, which are not mapped as wetlands per the National Wetland Inventory (NWI).....	77

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 Cayuga Lake 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, duration, and intensity 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 efforts to combat HABs now and in the future, both in Cayuga Lake and in other lakes of similar morphology, hydrology, and background water quality. **It is important to note that several sections of this Action Plan will be further refined by the upcoming Cayuga Lake Total Maximum Daily Load (TMDL) as noted within the document.**

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 highly accessible to the public
- 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. Cayuga Lake, with its public beaches, recreational opportunities, 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

- Members of the public interested in background information about the development and implications of the HABs program
- Local and regional agencies involved in the oversight and management of Cayuga Lake (e.g., County Soil and Water Conservation Districts (SWCDs), Departments of Health (DOHs), County Water Quality Coordinating Committees (WQCC), Tompkins County Water Resources Council, and the Cayuga Lake Monitoring Partnership)
- 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 NYSDEC HABs monitoring and surveillance program
- Cayuga Lake Watershed Network
- The Cayuga Lake Watershed Intermunicipal Organization (IO) and other Cayuga Lake watershed conservation and oversight organizations
- Lake residents, managers, consultants, and others that are directly involved in the management of HABs in Cayuga Lake
- Academic and other researchers interested in the water quality of Cayuga Lake and/or Harmful Algal Blooms
- As well as local governments which play a significant role in water quality restoration and protection efforts. Local governments have land use authority, storm water management responsibility, operate waste water treatment plants, and are responsible for engineering and implementing roadway and public infrastructure projects.

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

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 Cayuga Lake, 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 as well as the effects that HABs have on both lake users and resident biological communities.

2. Lake Background

2.1 Geographic Location

Cayuga Lake is located in the Finger Lakes region of central New York, and covers parts of Seneca, Cayuga, and Tompkins counties, including the towns of Montezuma, Aurelius, Springport, Ledyard, Genoa, Lansing, Ithaca, Ulysses, Covert, Ovid, Romulus, Varick, Fayette, and Seneca Falls (**Figures 1 and 2**) (NYSDEC 2008a).

2.2 Basin Location

Cayuga Lake has the largest watershed of the eleven Finger Lakes, covering approximately 514,000 acres (785 square miles). The watershed includes all or part of 44 municipalities within six counties: Tompkins, Cayuga, Schuyler, Seneca, Cortland, and Tioga (G/FLRPC and EcoLogic 2000; Callinan 2001).



Figure 1. Location of Cayuga Lake within New York State.

2.3 Morphology

Of the eleven Finger Lakes, Cayuga Lake is the second largest and is one of the deepest (only Seneca Lake is deeper). Cayuga Lake has a length of 61.5 km (38.2 miles), a mean width of 2.8 km (1.75 miles), a maximum depth of 132.6 meters (435 feet), a mean depth of 54.5 meters (179 feet) (**Figure 3**), and 153.4 km (95.3 miles) of shoreline (G/FLRPC and EcoLogic 2000, NYSDEC 2008a). It has a volume of 2.5 trillion gallons and surface area of approximately 42,800 acres, with a drainage-to-surface area ratio of 12:1 (G/FLRPC and EcoLogic 2000, NYSDEC 2008a). This ratio (**Figure 4**) is often associated with shorter water retention times, however, as noted in **Section 2.4**,

the retention time in Cayuga Lake is much longer than in most New York State lakes due to its depth.

The wind rose in **Appendix A** indicates that stronger prevailing wind directions influencing Cayuga Lake between 2006 to 2017 during the months of June through November were generally out of the northwest, and south-southeast, as measured from the Ithaca Tompkins Regional Airport. These wind patterns, combined with the orientation of the lake, likely result in a large fetch length over which wind and wave action can mix the water and drive water-borne nutrients and cyanobacteria, towards the northern and southern portions of Cayuga Lake. When HABs occur in the lake, cyanobacteria may concentrate in the northern and/or southern regions due to wind driven accumulation. Thus, bathing beaches and access locations in the north (e.g., Cayuga Lake State Park, Frontenac Park) and south (e.g., Lansing Myers Park) ends of Cayuga Lake (**Figure 5**), and recreational uses in these areas, may be more prone to the negative effects of HABs.

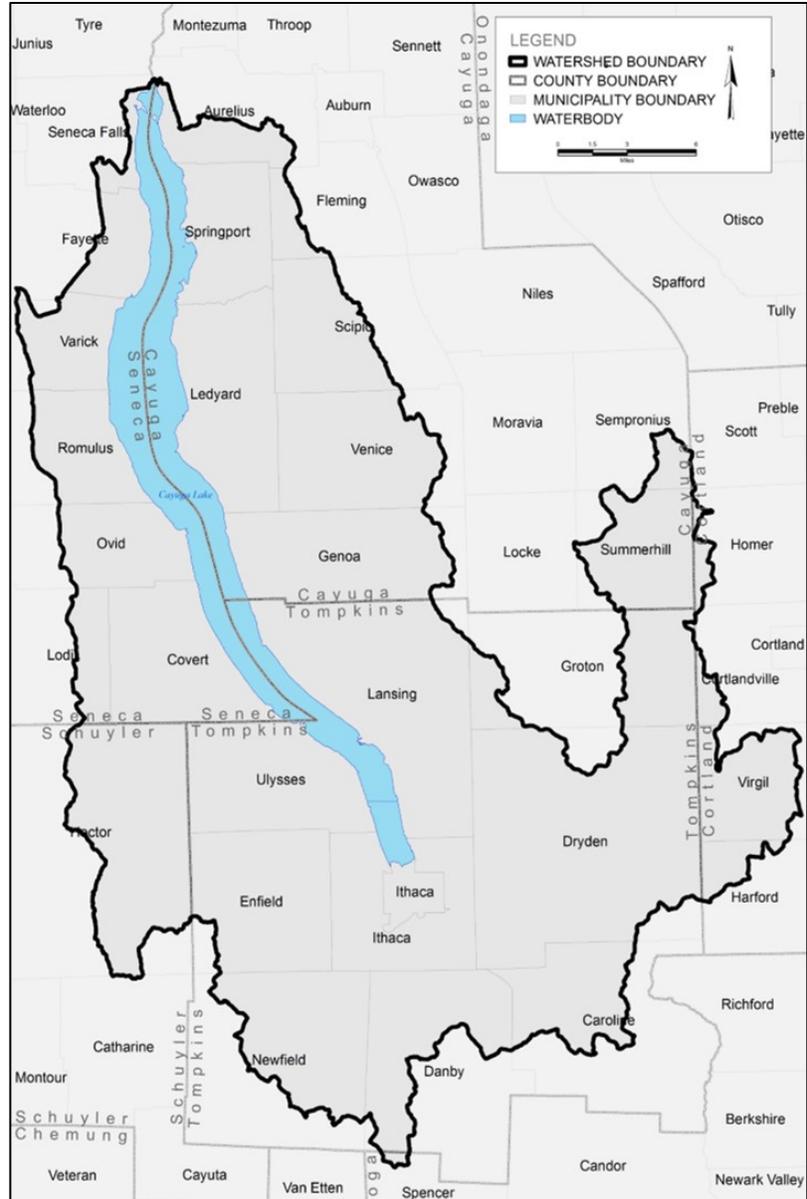


Figure 2. Political boundaries within the Cayuga Lake watershed.

2.4 Hydrology

Cayuga Lake has a hydraulic retention time, or the amount of time it takes water to pass through the lake, of over 10 years (G/FLRPC and EcoLogic 2000). The lake drains north to the Seneca River which joins the Oneida River downstream of Oneida Lake to form the Oswego River which drains to Lake Ontario. The southern portion of the lake contains a shallow shelf (<10 m maximum depth), lake circulation is complex and dynamic with significant mixing occurring between the shelf and the main lake (Effler et al. 2010; Cornell 2017). These circulation patterns are further complicated by an internal seiche and intermittent upwelling, which increases flushing rates of the southern shelf (Effler et al. 2010). There is also an extensive shallow shelf located at the north end of Cayuga Lake.

A network of more than 140 tributaries provide a conduit for nutrients and sediment to enter the lake. Many of these tributaries are small and intermittent; two of the larger tributaries (Cayuga Inlet [including Six Mile, Cascadilla, Enfield and Buttermilk Creeks] and Fall Creek) at the southern end of the lake drain over half of the direct drainage area and contribute approximately 40% of the flow to the lake (G/FLRPC and EcoLogic 2000). Other principal tributaries include Salmon Creek (east side of lake) and Taughannock Creek (west side of lake) representing approximately 16% and 9%, respectively, of the drainage area (G/FLRPC and EcoLogic 2000). Sediment loading

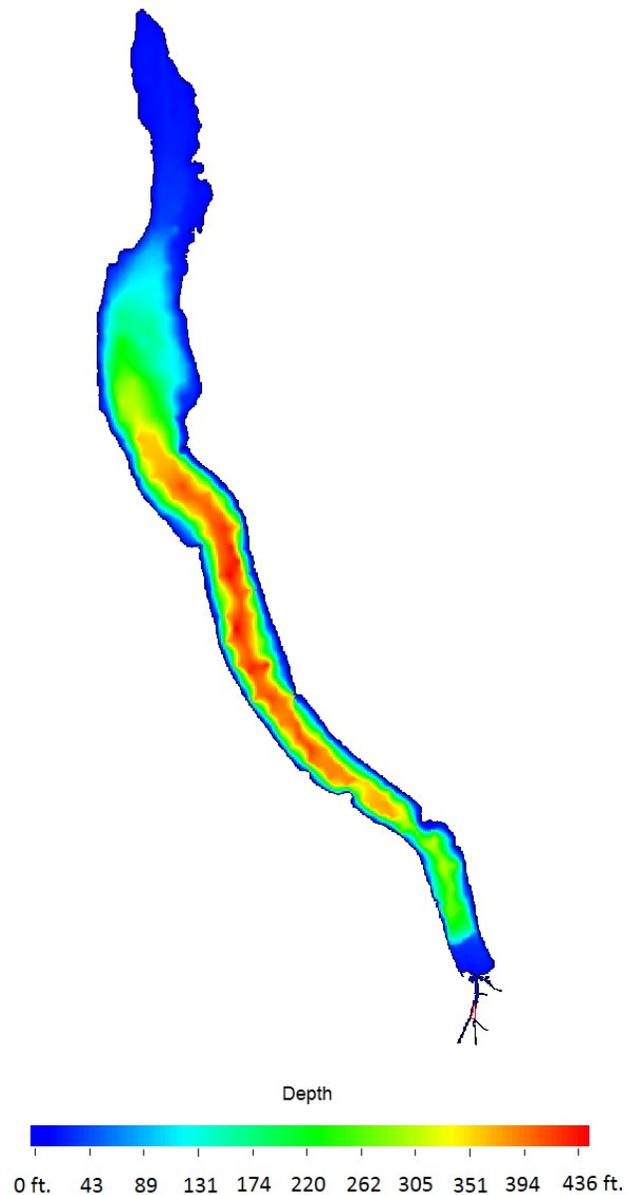


Figure 3. Bathymetric map of Cayuga Lake (Source: Upstate Freshwater Institute (UFI)).

from these tributaries can increase turbidity, adversely affecting the quality of drinking water, making treatment difficult at the water purification facilities located in the watershed (Cayuga County SWCD 2015).

2.5 Lake Origin

The Finger Lakes, including Cayuga Lake, were formed more than 2 million years ago during the Pleistocene Epoch. Glacial scouring carved deep slices into the land through the area, moving land and rocks southward. As the ice gradually melted and the glaciers receded, valleys of water dammed by unconsolidated glacial debris were left, which are now the Finger Lakes (Murdock 2010).

3. Designated Uses

3.1 Water Quality Classification – Lake and Major Tributaries

The Main Lake/Mid-South portion of Cayuga Lake includes the portion of the lake south of an east–west line extended from Coonley Corners Road in Coonley Corners and north of an east–west line through McKinneys Point in McKinneys, and is commonly referred to as the “southern pelagic zone” (**Figure 5**). The portion of the lake is classified as Class AA(T) according to the New York Codes, Rules, and Regulations (6NYCRR Part 898.4), meaning it is suitable for culinary or food processing, primary and secondary contact recreation, fishing, and fish propagation and survival. These waterbodies, if subjected to approved treatments, will be suitable as a water supply for drinking. The (T) standard indicates a waterbody is suitable for trout survival.

The Main Lake/Mid-North portion of Cayuga Lake includes the portion of the lake south of an east–west line extending from Bridgeport–Seneca Falls Road on the west shore to the Village of Cayuga on the east shore and north of an east–west line extended from Coonley Corners Road in Coonley Corners (**Figure 5**).

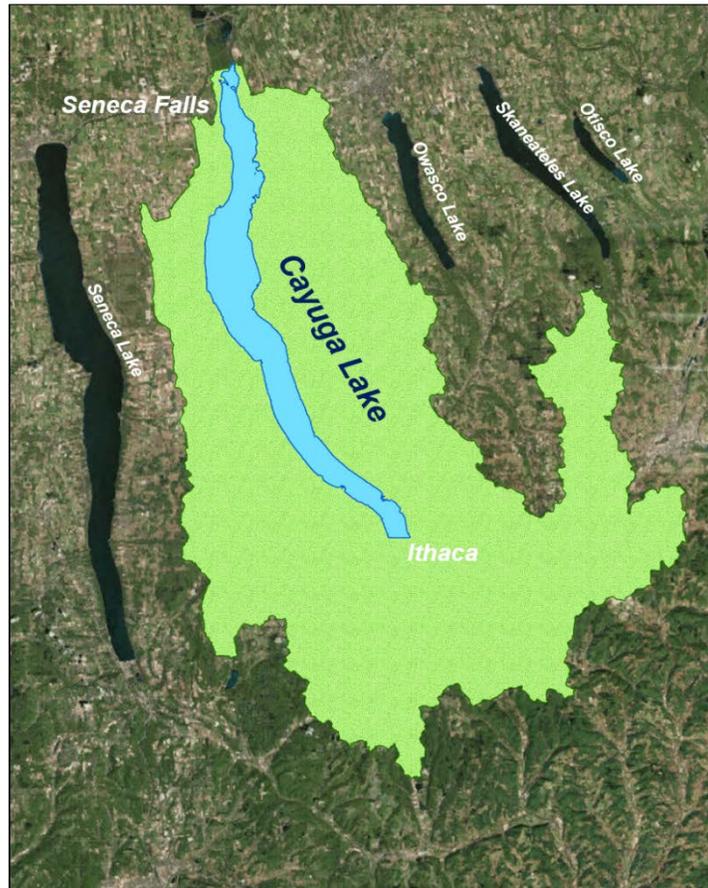


Figure 4. Cayuga Lake watershed (Source: Cayuga Lake Watershed Network 2018).

This portion of the lake is classified as Class A(T). The southern section, commonly referred to as the “south shelf”, includes the portion of the lake south of an east-west line through McKinneys Point in McKinneys, and is classified as Class A. Class A waters are the same as Class AA, but require approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary.

The northern section of the lake includes the portion of the lake south of Lock 1 in Mud Lock and north of an east-west line extending from Bridgeport-Seneca Falls Road on the west shore to the Village of Cayuga on the east shore (**Figure 5**). This portion is classified as B(T), meaning it is best used for primary and secondary contact recreation, fishing, and fish propagation and survival.

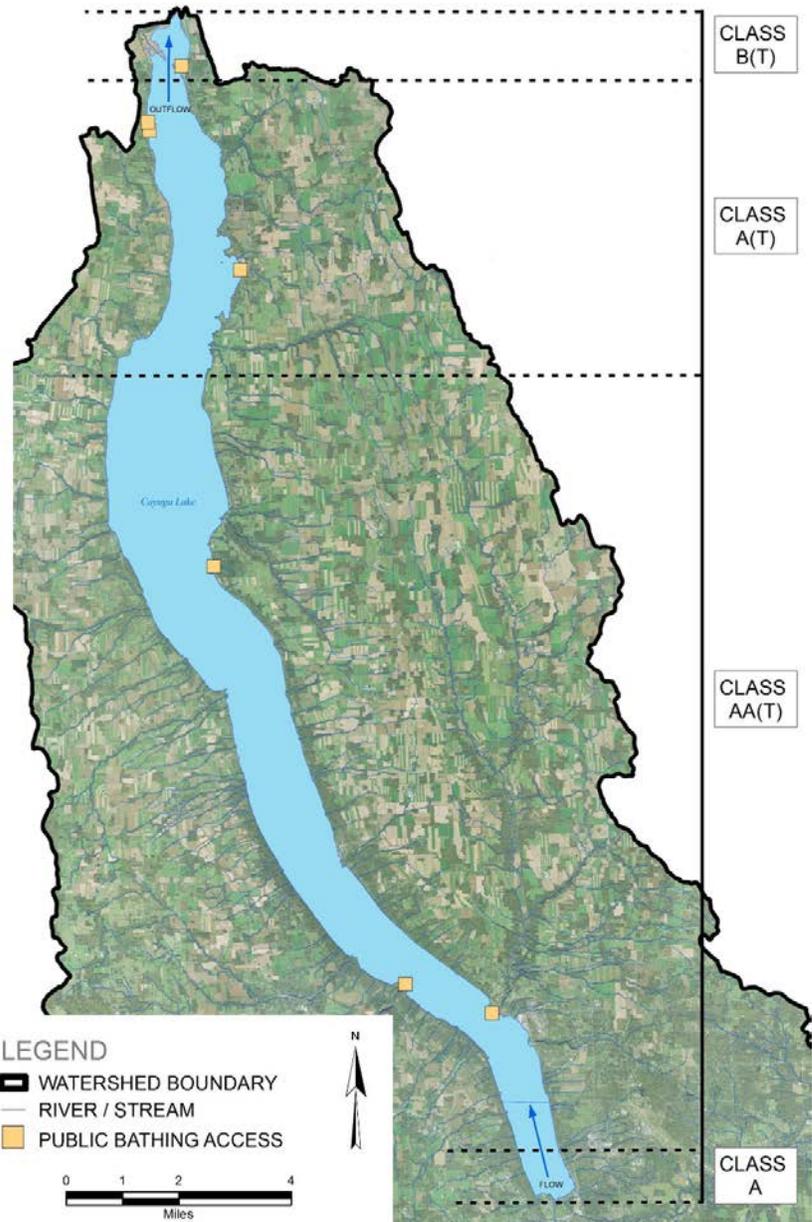


Figure 5. Water quality classification by segments in Cayuga Lake.

Each of these sections represent distinct units assessed by the NYSDEC to evaluate support of designated uses.

Major tributaries to Cayuga Lake and their New York State water quality classifications are described below.

- Salmon Creek is a Class C(TS) waterbody (NYSDEC 2018c), meaning it is best used for fishing, fish propagation and survival, and primary and secondary contact recreation; although other factors may limit the use for these purposes. The (TS) standard indicates it may support trout spawning.

- Cayuga Inlet, Cascadilla Creek, and the lower sections of Six Mile Creek are Class C waterbodies (NYSDEC 2018c).
- Six Mile Creek and its tributaries above the Van Natta Dam are Class A waterbodies (NYSDEC 2018c)
- Fall Creek is designated as Class B waterbody, and Taughannock Creek is a Class B(T) waterbody (NYSDEC 2018c, Cayuga Lake-Yawgers Creek Watershed WI/PWL 2016). The upper reaches of Fall Creek are Class A.
- Trumansburg Creek and its tributaries are Class C waterbodies (Cayuga Lake-Yawgers Creek Watershed WI/PWL 2016)
- Yawgers Creek and its tributaries are Class C waterbodies (Cayuga Lake-Yawgers Creek Watershed WI/PWL 2016)

The New York State classification system is provided in **Appendix B**.

3.2 Potable Water Uses

Cayuga Lake serves as the primary drinking water source and/or backup source for nearly 100,000 watershed residents. Drinking water sources include the following:

- The Mid-South and Mid-North sections of the lake provide drinking water for the Village of Seneca Falls (Cayuga Lake-Yawgers Creek Watershed WI/PWL 2016). The intake for Seneca Falls' treatment plant is located 1,850 feet from the western shoreline of Cayuga Lake at a depth of 20 feet (Town of Seneca Falls Water Department 2016).
- The Mid-South section of the lake also provides drinking water to the Towns of Dryden, Ithaca, and Lansing and the Villages of Cayuga Heights and Lansing through the Southern Cayuga Lake Intermunicipal Water Commission's Bolton Point Water System. The Bolton Point Water System intake is at the southeastern end of the lake, 3 miles north of Stewart Park, 400 feet out from the eastern shore, and 65 feet below the surface of the lake (SCLIWC 2017). The intake extends into the lake just past the southern shelf into the Mid-South portion of the lake.
- The Village of Cayuga once relied on the northern end of Cayuga Lake for drinking water, but water district changes and a decline in water quality has shifted the Village's water supply to nearby Auburn (Village of Cayuga 2013, Town of Aurelius 2016).
- Wells College draws water from Cayuga Lake and treats it with diatomaceous earth filters and injection of sodium hypochlorite solution before entering the distribution system. Water is stored in two storage tanks totaling 300,000 gallons. This water system serves a population of 740 through 220 metered connections, including Wells College and the Village of Aurora.

- Numerous seasonal residences on the shoreline of Cayuga Lake draw untreated water directly from the lake for potable use. As recommended by NYSDOH, it is never advisable to draw drinking 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 one chooses to explore in-home treatment systems, he/she is living with some risk of exposure to BGA and their toxins and other contaminants. Those who desire to reduce HAB toxin levels in home treated water for non-potable household uses 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).

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 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 ($\mu\text{g/L}$) for infants and children under the age of 6, and 1.6 $\mu\text{g/L}$ 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 1000-fold lower than levels that caused health effects in laboratory animals. The USEPA's lower 10-day health advisory of 0.3 $\mu\text{g/L}$ 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 $\mu\text{g/L}$ as the basis for recommendations, and a do not drink recommendation will be issued upon confirmation

that microcystin levels exceed 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 detected HAB toxin.

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 EPA 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

Six parks along Cayuga Lake's shoreline offer public bathing beach access: Taughannock Falls State Park, Cayuga Lake State Park, Cayuga Village, Long Point State Park, Frontenac Park, John Harris Park, and Lansing Myers Park (NY Falls 2018). Additional regulated bathing beaches can be found at the Ithaca Yacht Club; Camp Comstock; Camp Barton; Camp Caspar Gregory Beach; Frontenac Park; Harris Park Beach and the Wells College Boathouse.

As noted in **Section 2.3**, the prevailing wind patterns influencing Cayuga Lake (**Appendix A**) indicate that cyanobacteria may accumulate in the northern and southern ends of the lake during HAB events. Thus, public swimming and access locations such as Cayuga Lake State Park in the north and Myers Park in the south represent potential priority locations to monitor to limit the negative effects of HABs on public health.

3.4 Recreation Uses

Cayuga Lake is a popular summer destination because it offers a wide variety of recreational opportunities to residents and tourists, including boating, swimming, fishing, jet-skiing, kayaking, windsurfing, and paddle boarding. Boats can be launched at Cayuga Lake State Park, Dean’s Cove, Long Point State Park, Mudlock Canal Park, Allen H. Treman State Marine Park/Cass Park, Lansing Myers Park, Frontenac Park, and Taughannock State Park. The Cayuga-Seneca Canal at the northern end of the lake connects Cayuga Lake to the Erie Canal, which provides additional recreational opportunities. Parks along the shoreline offer picnic areas, playgrounds, athletic fields, bird sanctuaries, duck and goose hunting, and other forms of recreation (NY Falls 2018, I Love the Finger Lakes 2018). Cayuga Lake (and the entire Finger Lakes region) is also home to a thriving grape-growing and wine industry. The Cayuga Lake Wine Trail offers almost 20 wineries for residents and tourists to visit while enjoying the scenery of the lake (Lake Wine Trail 2018).

3.5 Fish Consumption/Fishing Uses

Both open water and ice fishing are permitted in Cayuga Lake in accordance with general statewide fishing regulations. Trolling, tributary fishing, vertical jigging, and shore fishing are all effective methods of fishing on Cayuga Lake, dependent on the time of year and type of fish (NYSDEC 2018d). **Table 1** details the special fishing regulations that also apply (NY Freshwater Fishing 2018). The New York State Department of Health (NYSDOH) advises eating no more than four fish meals a month from the Finger Lakes region, including Cayuga Lake (NYSDOH 2018a).

Species	Open Season	Minimum Length	Daily Limit	Method
Northern Pike	1 st Sat. in May – March 15	22"	5	Ice fishing permitted
Walleye	1 st Sat. in May – March 15	18"	3	
Brown Trout Rainbow Trout Lake Trout Atlantic Salmon	All year	15", except 18" for Atlantic salmon	5 in combination. Catch shall include no more than 3 brown trout, 3 rainbow trout, or 3 Atlantic salmon	

3.6 Aquatic Life Uses

Fish

Consistent with its waterbody classifications, Cayuga Lake is suitable for fish propagation and survival. Similar to other large Finger Lakes, Cayuga Lake is considered a two-story fishery that supports an assemblage of both coldwater and warmwater species, several of which are important recreationally and may be taken for consumption. Sought after species include but are not limited to:

Coldwater

- Atlantic salmon (*Salmo salar*)
- Lake trout (*Salvelinus namaycush*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Brown trout (*Salmo trutta*)
- Rainbow smelt (*Osmerus mordax*)

Warmwater

- Largemouth bass (*Micropterus salmoides*)
- Smallmouth bass (*Micropterus dolomieu*)
- Walleye (*Sander vitreus*)
- Chain pickerel (*Esox niger*)
- Yellow perch (*Perca flavescens*)
- Brown bullhead (*Ameiurus nebulosus*)
- White sucker (*Catostomus commersoni*)
- Panfish, including bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), rock bass (*Ambloplites rupestris*), and black crappie (*Pomoxis nigromaculatus*)

The NYSDEC stocks Cayuga Lake annually with approximately 60,000 lake trout, 25,000 brown trout and 40,000 Atlantic salmon (NYSDEC 2018d). NYSDEC also stocks Cayuga Lake's tributaries with 50,000 rainbow trout, which migrate to the lake after spending one to two years imprinting on the stream. These rainbow trout remain in the lake for one to three years before returning to the streams to spawn as adults. Lake trout and the Finger Lakes strain of rainbow trout found in Cayuga Lake serve as broodstock; eggs from adult lake trout are collected in the fall and from rainbow trout in the spring. The eggs are then hatched at the NYSDEC Bath Fish Hatchery (NYSDEC 2018a, NYSDEC 2018d).

Careful management of the sport fishery in Cayuga Lake, coupled with the absence of observable impairment to the aquatic life use in the northern and central portions of the lake, suggests that the fish species assemblage and its potential cascading regulating effects on lower trophic levels (e.g., zooplankton) is not a driver for HABs formations in Cayuga Lake. However, the presence of alewife (*Alosa pseudoharengus*), an invasive fish species in the lake that forages selectively on larger prey organisms (e.g., *Daphnia*), may exert "top-down" effects on the plankton community, leading to smaller individuals of zooplankton that are less efficient feeders of phytoplankton, which can contribute to HABs. This trophic interaction is discussed further in **Section 6.4**.

Aquatic Plants

The relatively shallow depth and rich substrate found in the northern section of Cayuga Lake provides ideal conditions for aquatic plants, which offer a variety of benefits for the lake including oxygen production, energy reduction which leads to sedimentation, nutrient absorption, and wildlife food and shelter. Aquatic vegetation also grows well in

the southern section (referred commonly to the southern shelf) of Cayuga Lake, but to a lesser extent than the northern section. A survey of the plant community in the southern portion of the lake, the Cayuga Inlet and Fall Creek indicated that frequency (number of samples) of non-native and native plants were similar (Racine-Johnson Aquatic Ecologist 2017b). The shoreline along the middle sections of the lake supports a narrow fringe of submerged aquatic vegetation. The aquatic plant community of Cayuga Lake include but are not limited to the following dominant species (NYSDEC 2018d, Racine-Johnson Aquatic Ecologist 2017b); the 2016 survey found at least 24 native plant species and five non-native species in the southern end of the lake.

Native

- Coontail (*Ceratophyllum demersum*)
- Water stargrass (*Heteranthera dubia*)
- Muskgrass (*Chara vulgaris*)
- Slender naiad (*Najas flexilis*)
- Sheathed pondweed (*Stuckenia vaginata*)
- Small Pondweed (*Potamogeton pusillus*)
- Horned pondweed (*Zanichellia palustris*)
- Sago pondweed (*Stuckenia pectinata*)
- Eelgrass (*Vallisneria americana*)
- Common waterweed (*Elodea* spp.)

Non-native

- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Starry stonewort (*Nitellopsis obtusa*), macro algae
- Curly leafed pondweed (*Potamogeton crispus*)
- Brittle Naiad (*Najas minor*)
- Hydrilla (*Hydrilla verticillata*)

Hydrilla verticillata (water thyme) is a non-native, highly-invasive aquatic plant that has been invading aquatic habitats throughout the continental United States since the 1960s (Langeland 1996, Les et al. 1997). *Hydrilla* is an extremely aggressive canopy-forming plant with 50% of its biomass located in the upper 0.5 meter (m) of the water column. It can grow rapidly (up to 2.5 cm per day per stem), and branch profusely leading to significant physical, chemical and biological modification of the areas that it invades (OBG 2013).

Hydrilla was first observed in the Cayuga Lake Inlet in August of 2011; later it was found that approximately 9 miles of Inlet shoreline were colonized, i.e., the Inlet proper from just north of the fish ladder to the northern lighthouse, marina, Old Cayuga Inlet, Cascadilla Creek west of Route 13, Six Mile Creek west from the junction with Old Cayuga Inlet, Fall Creek, and small patches in the southeast corner of the lake. In general, dense growth occurred in areas with up to eight feet of water (OBG 2013).

The *Hydrilla* occurrence in the Cayuga Lake Inlet is notable because it is the first known location of *Hydrilla* that is directly connected to the Great Lakes, which poses a significant threat to this unique resource.

Shortly after *Hydrilla* was found in the Inlet, a state task force, led by NYSDEC Invasive Species Coordination Unit (NYSDEC ISCU), and a local *Hydrilla* Task Force (led by the City of Ithaca, Racine Johnson Aquatic Ecologists) was formed. This local task force includes management, outreach, and local task force groups composed of individuals from Cornell Cooperative Extension, the City of Ithaca, New York State Parks, consulting scientists, Tompkins County Health Department, the Tompkins County Soil and Water Conservation District, and the Tompkins County Sheriff's Department and the Finger Lakes Partnership for Regional Invasive Species Management (PRISM). The Task Force hired a *Hydrilla* Project Manager, and has developed and implemented a holistic rapid response and eradication program that includes herbicide application, monitoring, and public outreach programs (OBG 2013).

In September 2016, an approximately 27-acre area of *Hydrilla* was discovered adjacent to Wells College on the lake's eastern central shoreline, as well as in Paines and Little Creeks. The affected area was delineated and in 2017 an herbicide treatment was applied (Racine-Johnson Aquatic Ecologists 2017a; Finger Lakes PRISM 2018).

The recent introduction of the non-native macroalga starry stonewort (*Nitellopsis obtusa*) represents a growing threat to many lakes in the Finger Lakes region, given its rapid spread dense coverage of lake benthos. Although it was only recently discovered in the south end of Cayuga Lake, by 2016 it was observed in nearly 75% of all surveyed sites and is now the most common plant in the lake (Racine-Johnson Aquatic Ecologist 2017b).

3.7 Other Uses

Many birds and mammals rely on Cayuga Lake and its shoreline for foraging, roosting, and nesting. The lake supports a high number of individual waterfowl and a large variety of waterfowl species year-round and particularly during migration and winter.

Approximately 30 species of ducks and geese can be found on the lake, including American black ducks, mallards, canvasbacks, redheads, scaup, and common goldeneyes. Gulls, terns, and grebes can also be found on the lake (Audubon 2018).

Mammalian species found within the Cayuga Lake watershed include deer, coyote, opossum, rabbit, squirrel, hare, raccoon, and red and gray fox (G/FLRPC and EcoLogic 2000).

4. User and Stakeholder Groups

Cayuga Lake is used by all age groups of residents and tourists who enjoy the myriad of recreational opportunities that are available. Access to Cayuga Lake is available to the public via multiple beaches, parks, and boat launches (see **Section 3.3 and 3.4**).

Several citizen advocacy groups have formed with the shared goal of protecting the water resources of Cayuga Lake, including those focused on the entire Finger Lakes region. These groups, as well as, county and municipal (towns, villages, cities) representatives, and their partnerships will be crucial to successful implementation of projects to help mitigate HABs. These include:

- The Cayuga Lake Watershed Network (The Network) is a non-profit organization founded in 1997 with over 400 members. It identifies key threats to Cayuga Lake and its watershed, advocates for solutions, and provides educational opportunities through conferences, newsletters, a website, listservs, and public events. The Board of Directors is composed of up to 15 members serving three-year terms with a minimum of three members selected from each of the three counties the lake exists within. The remaining members must be residents of the watershed (The Network 2018a).
- The Cayuga Lake Monitoring Partnership was originally formed to develop a plan for tracking water quality in the southern end of Cayuga Lake. Since the creation of that plan (in 2008), the Monitoring Partnership has expanded its mission to become a forum where agencies and organizations that monitor the health of Cayuga Lake meet regularly to share the results of their work and to explore ways to improve and expand monitoring efforts (Tompkins County 2018a). The Community Science Institute (CSI) focuses on fostering and supporting volunteer-based environmental monitoring with the goal of educating the public about the Cayuga Lake watershed's natural resources and protecting such resources using scientifically credible data. CSI's mission is fulfilled through programs such as surface and drinking water quality testing and stream monitoring programs (CSI 2018). The Cayuga Lake Watershed Intermunicipal Organization (IO) was created in 2001 when a state-funded and approved Cayuga Lake Watershed Restoration and Protection Plan was being developed. The organization is comprised of representatives appointed by county, city, town, and village governing boards. IO is a group with a mission to bring the watershed municipalities together to work collectively and collaboratively on monitoring, protecting, and restoring the health of the watershed; and to create and implement a watershed management plan that allows local governments within the watershed to work together to prioritize water quality problems and solutions (IO 2018). The IO will be an important organization to assist with implementation of projects.
- Several groups have formed with the overarching goal of monitoring and protecting the regions natural resources (CSI 2018). These include but are not limited to:
 - Finger Lakes - Lake Ontario Watershed Protection Alliance (FOLLOWPA) stems from conservation efforts dating back to the mid-1980s, and facilitates processes that encourage partnerships and action plans to

protect and enhance water quality through the sharing of information, data, resources, and approaches (FOLLOWPA 2018).

- The Finger Lakes Land Trust was founded in 1989 to conserve land within the region, and has protected over 21,000 acres through the creation of public nature preserves and private property conservation (FL Land Trust 2018).
- The Finger Lakes Regional Watershed Alliance (FLRWA) was formed in 2010 and is a collaboration between nine lake and watershed organizations representing the Finger Lakes whose mission is to preserve and protect the region's watersheds (FLRWA 2018).
- The Genesee Finger Lakes Regional Planning Council (G/FLRPC) works to identify, define, and inform its member counties of issues and opportunities critical to the physical, economic, and social health of the region through forums for discussion, debate, and consensus building. G/FLRPC develops and implements a focused action plan with clearly defined outcomes, which include programs, personnel, and funding (G/FLRPC 2018).
- The Tompkins County Water Resource Council (WRC) coordinates activities associated with the management and protection of the County's water resources by advising the Tompkins County Legislature, identifying problems, and proposing priorities. The WRC also provides a public forum for local organization and stakeholder to address and discuss their water resources concerns (Tompkins County 2018b).
- Cayuga County Water Quality Management Council provided support to management and monitoring efforts of the Cayuga County water resource, including Cayuga Lake.

5. Monitoring Efforts

5.1 Lake Monitoring Activities

Water quality conditions have been evaluated in the Finger Lakes generally, and Cayuga Lake specifically, throughout the last century, beginning with the pioneering studies of the Finger Lakes by Birge and Juday in the 1910s (Birge and Juday 1914), the Conservation Department (predecessor to the NYSDEC) in the 1920s, and multiple academic studies. Many of these are summarized in *The Lakes of New York State, Volume 1* (Bloomfield 1978). Most of these studies, including recent academic studies, have focused on the southern portion of the lake.

Monitoring efforts on Cayuga Lake have been conducted as part of the Citizen's Statewide Lake Assessment Program (CSLAP) from 2002-2007 and then again in

2017. Water quality parameters monitored as part of the 2017 CSLAP summary for Cayuga Lake (CSLAP 2017) included:

- Water temperature
- Water clarity (Secchi depth)
- Total phosphorus (TP)
- Total nitrogen (TN)
- Chlorophyll a
- pH
- Specific conductivity
- Color

Four sites have been identified for sampling during CSLAP: North, Mid-North, Mid-South, and South. However, not all sites have been sampled each year (NYSDEC 2008a). Specifically, CSLAP sample locations covered the geography of Cayuga Lake from north to south (**Figure 6**):

- North: 2002 to 2004; 2017
- Mid-North: 2002 to 2006
- Mid-South/South: 2002 to 2007; 2017
- South: 2002 to 2004

Water quality summary reports are being developed for each Finger Lake and for the entire Finger Lakes region, including comparisons to historical NYSDEC data.

Other data collections conducted in Cayuga Lake include the NYSDEC Finger Lakes Water Quality (FLWQ) study from 1996 to 1999 (Callinan 2001), the NYSDEC Disinfection By-Products study (DBPs) in 2004, the Finger



Figure 6. Historic and current Cayuga Lake water chemistry sample locations.

Lakes Institute's Finger Lakes Survey (FLI/FLS 2005-2017, Halfman 2017), Cornell University studies related to Lake Source Cooling (LSC; 1998-2012; Adams 2010) and the Cayuga Lake Modeling Program (CLMP) (2013; Cornell 2017, 2018); as well as the

Community Science Institute (CSI) data collection efforts from the southern section of the lake and about half of the northern section since 2011 (Peningroth 2017) and monitoring efforts by the Seneca County SWCD from 1991 to 2006 at the north end of the lake (Makarewicz et al. 2007).

The DEC Finger Lakes study in the late 1990s was an attempt to replicate comparative investigations of the Finger Lakes not conducted systematically on all eleven Finger Lakes since at least the 1970s. This study included sediment coring and monthly water quality monitoring from 1996 to 1999 on at least one sample site per lake, as well as comparisons of water quality data to historical NYS sampling results. Four sites were sampled on Cayuga Lake as part of this study.

The NYSDEC collects data as part of the Lake Classification Inventory (LCI) program to support water quality assessments and management activities, including identifying and responding to HABs. The LCI data set for Cayuga Lake includes monthly samples collected in 2005 and 2012 from May to September. These were analyzed for several water quality indicators, including TP, several nitrogen species, chlorophyll a, and calcium. Data collection during the LCI for Cayuga Lake included monthly profiles of water quality parameters from just below the water surface, including:

- Surface water temperature
- Dissolved oxygen
- pH
- Specific conductivity
- Oxidation reduction potential

The DBP study was conducted in 2004 in response to USEPA initiation of a National Nutrient Strategy (USEPA 1998) that called on states to establish a numeric nutrient criteria (NNC). A total of 21 lakes, including Cayuga Lake, were included in the NYSDEC DBP study, which focused on lakes designated as potable water supplies. Nutrient enrichment in lakes used as potable water supplies are associated with increases in human health-risk factors such as increased generation of DBPs and production of cyanotoxins by certain species of cyanobacteria (Callinan et al. 2013). Sampling efforts focused on total phosphorus, chlorophyll-a, dissolved organic carbon (DOC), and the total trihalomethanes formation potential (THMFP - a measure of DBPs). The DBP data set for Cayuga Lake is comprised of monthly samples collected in 2004, from May to September.

Data from the Cornell University LSC study conducted from 1998 to 2012 and the CLMP (2013) were used by the NYSDEC to develop a phosphorus Total Maximum Daily Load (TMDL) for Cayuga Lake (see **Section 10**). These data include Secchi depths (m), TP (mg/L) and chlorophyll-a ($\mu\text{g/L}$) concentrations. These data were collected at the South and Mid-South locations (**Figure 6**) from 1998 to 2013 and throughout the lake in 2013.

The eight easternmost Finger Lakes have been sampled by Hobart William Smith College and the Finger Lakes Institute since 2005. This work involves monthly sampling from May through September sampling at least two sites per lake for several water quality indicators, plankton tows, and depth profiles. This program did not operate under a Quality Assurance Project Plan (QAPP) or laboratory certification under the NYS Department of Health (DOH) Environmental Laboratory Approval Program (ELAP), so these data cannot be used for this DEC water quality assessment.

Many of the other academic studies of the lake are not cited here due to the lack of an approved QAPP or laboratory certification under the NYSDOH ELAP.

It should be noted that the CSLAP data, and the water quality data from other programs meeting NYSDEC data quality objectives from approved QAPPs and ELAP laboratories were collected only from the mid-south and mid-north sections of the lake. Although each section may experience significant hydrologic and nutrient exchange from adjacent sections, water quality findings and assessments from any section may not apply to other sections of the lake.

5.2 Tributary Monitoring Activities

Two tributaries to Cayuga Lake have been monitored through the NYSDEC Rotating Integrated Basin Studies (RIBS) Intensive Network: Salmon Creek in Myers Point (at Lakeshore Road) and Fall Creek in Ithaca (NYSDEC 2008). Monitoring of Salmon Creek and Fall Creek was conducted in 2002 and 1996, respectively (Cayuga Lake-Salmon Creek WI/PWL 2007, G/FLRPC and EcoLogic 2000). Waters within this study area are scheduled to be monitored between 2016-2018 and again from 2021-2023 (NYSDEC 2018f). Stream biomonitoring occurred at the following stream sites (NYSDEC 2008a):

- Cayuga Lake Inlet, Newfield Station (2001)
- Cascadilla Creek, Lake Ave/Madison St (2001)
- Fall Creek, Red Mills to Ithaca (1995, 1996, 2001)
- Taughannock Creek, mouth of Cayuga Lake (2001)
- Salmon Creek, Ludlowville (1996, 1998, 2000, 2001)
- Big Salmon Creek, Genoa (1998, 2000)
- Yawger Creek, Cross Roads (1993-2001, 1997)

Water quality monitoring efforts have taken place through the Cayuga Lake watershed. These monitoring efforts include but are not limited to:

- Monitoring of total phosphorus, total dissolved phosphorus, and soluble reactive phosphorus at the mouths of Cayuga Inlet and Fall Creek by UFI from 2003 to 2006 (Effler et al. 2010)
- Collection of water quality conditions at Fall Creek, Cayuga Inlet, Sixmile Creek Salmon Creek, and Taughannock Creek as part of the 2013 Cayuga Lake Modeling project (Cornell University 2018)

- Water quality data collected by Dr. D.R. Bouldin of Cornell University in Fall Creek from the early 1972 to 1995 (Cornell University 2007)
- Volunteer monitoring coordinated by the Community Science Institute (CSI) from 2002 to the present. Monitoring efforts have been conducted on 12 streams at 187 locations and have included several water quality parameters and total coliform (CSI 2018)

6. Water Quality Conditions

Trends in water quality were assessed using data that were collected under a State-approved QAPP, and analyzed at an Environmental Laboratory Accredited Program (ELAP) certified laboratory. Sources of data include CSLAP, FLWQ, DBPs, LSC, and CLMP (see **Section 5.1** for a description of the monitoring and/or study programs). The 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. 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 2 provides a regional summary of surface water TP concentrations (mg/L) from the four water quality sampling locations in Cayuga 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**).

Sampling locations in Cayuga Lake had similar TP concentrations relative to other Finger Lakes (**Table 2**), and lower concentrations relative to other regional lakes (e.g., Central New York). Additionally, the average TP concentration for Cayuga Lake is less than New York State water quality guidance value of 0.02 mg/L of TP, although seasonal total phosphorus concentrations exceeded this guidance value in certain years on the southern region (Callinan 2001).

Water clarity (based on Secchi depth, m), TP (mg/L), and chlorophyll-a ($\mu\text{g/L}$) concentrations are used to assess trophic state using New York State criteria (**Table 3**) – during CSLAP water quality sampling, these indicators reflected mesotrophic (moderate productivity) conditions.

Table 2. 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 concentrations (± standard error) at Cayuga Lake sample locations (CSLAP, DBPs, LSC, CLMP).

Region	Number of Lakes	Average TP (mg/L)	Average TP North (mg/L)* 2002-2004, 2013, 2017	Average TP Mid-North (mg/L)* 2002-2006, 2013	Average TP Mid-South (mg/L)* 1998-2013, 2017	Average TP South (mg/L)* 1998-2013
NYS	521	0.034 (± 0.003)	-	-	-	-
NYC-LI	27	0.123 (± 0.033)	-	-	-	-
Lower Hudson	49	0.040 (± 0.005)	-	-	-	-
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)	0.013 (± 0.001)	0.011 (± 0.0004)	0.012 (± 0.0002)	0.018 (± 0.0008)
Western NY	47	0.045 (± 0.008)	-	-	-	-

*See Figure 6 for locations.

Table 3. New York State criteria for trophic classifications (NYSFOLA 2009) and average values (± standard error) for the Cayuga Lake sampling (CSLAP, DBPs, LSC, CLMP) locations.

Parameter	Oligotrophic	Mesotrophic	Eutrophic	North 2002-2004, 2013, 2017	Mid-North 2002-2006, 2013	Mid-South 1998-2013, 2017	South 1998-2013
Transparency (m)	>5	2-5	<2	3.2 (± 0.16)	5.0 (± 0.38)	4.5 (± 0.1)	2.8 (± 0.1)
TP (mg/L)	<0.010	0.010-0.020	>0.020	0.013 (± 0.001)	0.011 (± 0.0004)	0.012 (± 0.0002)	0.018 (± 0.0008)
Chlorophyll a (µg/L)	<2	2-8	>8	4.1 (± 0.4)	4.0 (± 0.3)	4.7 (± 0.15)	4.3 (± 0.12)

6.1 Physical Conditions

Water clarity can be related to the amount of suspended material in the water column including sediment, algae, and cyanobacteria. Water clarity measurements, as represented by Secchi depth, in Cayuga Lake between 2002 and 2017 typically ranged between 2 and 5 meters, indicating mesotrophic (moderate productivity) conditions (**Figure 7a**). Long-term trends in water clarity from 1996 to 2017 at all sample locations showed a non-significant increasing trend ($p = 0.115$, $\tau = 0.263$, **Figure 7b**) and no significant trend ($p = 0.599$, $\tau = -0.088$) in annual minimum Secchi depth (e.g., the shallowest recorded value for a given year). Data collected during the NYSDEC's 1996-1999 Finger Lake's water quality study indicated increased water clarity compared to the 1970s. In the southern section of the lake, this increase in water clarity was speculated to be a result of increased zebra mussels (Callinan 2001; Cayuga Lake Yawgers Creek Watershed WI/PWL 2016). Additionally, a decrease in water clarity was noted in 2014 and 2015 attributed to more turbid water potentially caused by an increase in early spring precipitation in those years (Halfman 2017). Similarly, water clarity in 2017 was likely reduced due to large spring storm events.

In evaluating specific sampling locations, there was no statistical trend in water clarity observed at:

- North sampling location between 2002-2004, 2013 and in 2017 ($p = 0.327$, $\tau = -0.400$).
- Mid-North sampling location between 2002-2006 and 2013 ($p = 0.279$, $\tau = -0.527$).
- Mid-South/South sampling location since 1996-2013 and 2017 ($p = 0.172$, $\tau = 0.228$).
- South sampling was conducted 1998 – 2013 annually ($p = 1.000$, $\tau = 0.000$). Secchi depths at this site were typically were close to or deeper than the maximum water depth.

At the Mid-South/South sampling location shown in **Figure 6**, Secchi disk transparency readings have always exceeded the New York State Sanitary Code requirements for siting new bathing beaches (1.2-meter [4 ft] minimum, NYSDOH 2018b) (**Figure 7**). However, water clarity should continue to be monitored to document potential changes. Although water clarity has increased in recent years, water clarity remains reduced compared to historical measurement conducted by Birge and Juday (1914) and Burkholder (1931) who reported Secchi depths of 6.1 and 5.6 m, respectively.

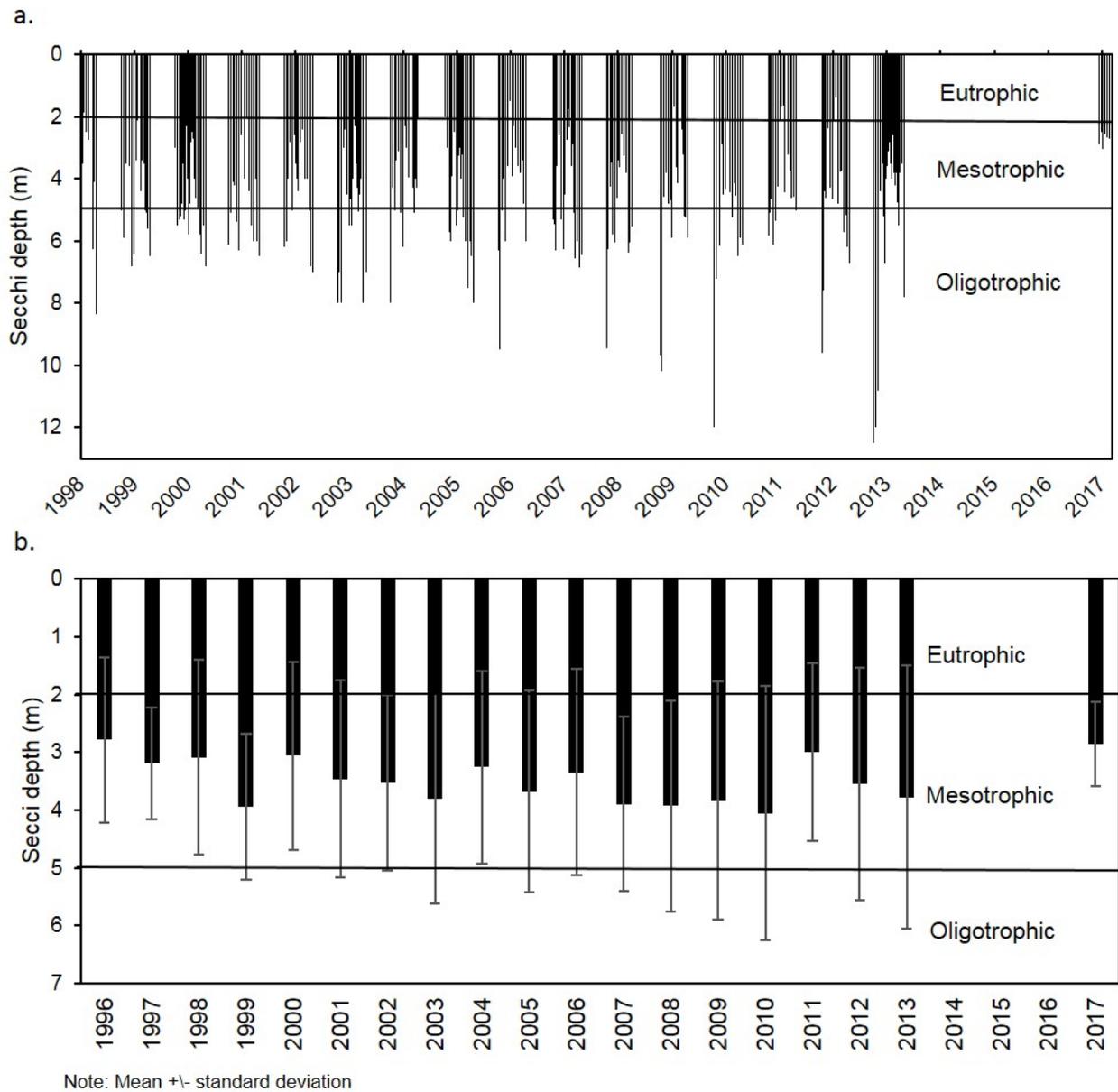


Figure 7. (a) Secchi depth measured at the Mid-South/South sampling location in Cayuga Lake from 1998 to 2017 (CSLAP, DBPs, LCS, CLMP). (b) Annual average Secchi depth (m) from all sampling locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs, LCS, CLMP).

Understanding temperature changes within a waterbody (both seasonally and annually), is important in understanding HABs. Most cyanobacteria taxa grow better at higher temperatures which may increase competitive advantages at higher temperatures (typically above 25°C) (Paerl and Huisman 2008). Seasonal trends in surface water temperature (°C) in Cayuga Lake generally indicate a mid-season peak in temperature (see **Figure 8a** for the Mid-South sampling location, typical of the Cayuga Lake sampling locations). Long-term trends in surface water temperature based on annual

average values across all sample locations were not apparent ($p = 0.293$, $\tau = 0.333$, **Figure 8b**).

Temperature depth profiles for 2017 indicate that thermal stratification was strong in Cayuga Lake throughout the growing season (June-September) (**Figure 9**). These profiles do not indicate any mixing events during this period. However, as noted previously, temperature and flow dynamics in Cayuga Lake are complicated by internal seiches and other factors, and a detailed discussion of these dynamics are beyond the scope of this Action Plan.

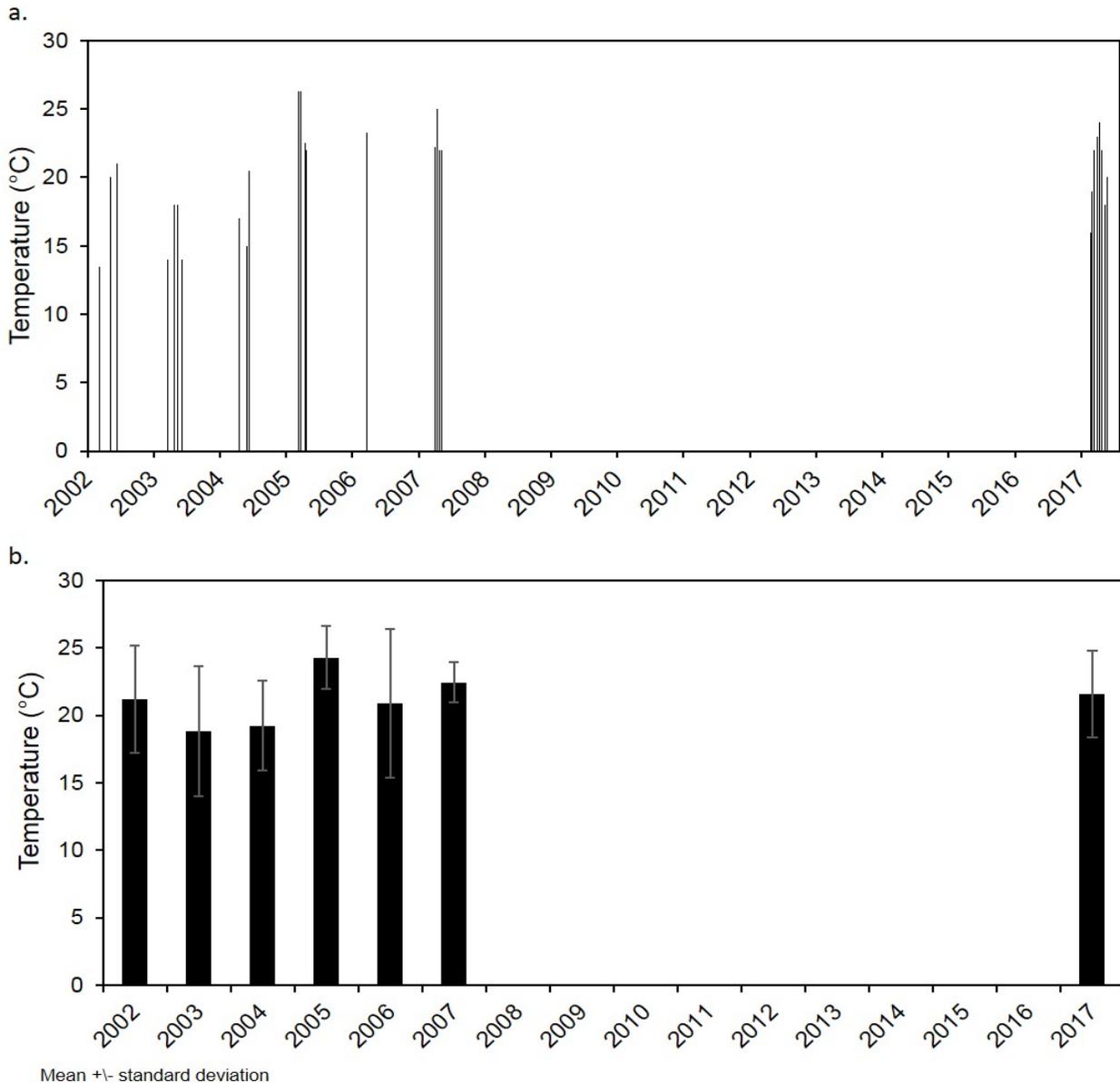


Figure 8. (a) Surface water temperature (°C) measured at the Mid-South/South sampling location in Cayuga Lake from 2002 to 2017. (b) Annual average surface water temperature (°C) from all sampling locations in Cayuga Lake, 2002-2007, and 2017.

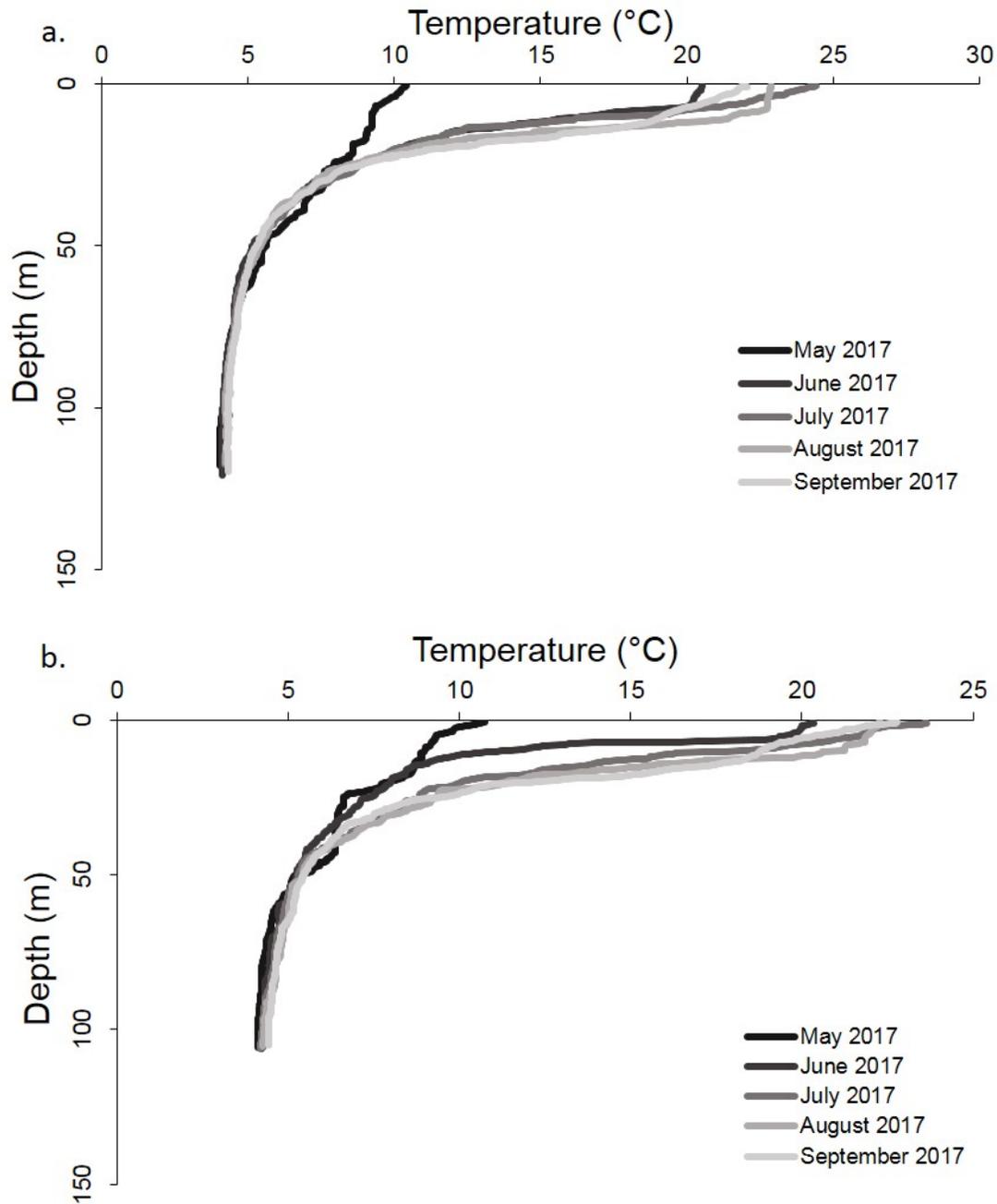


Figure 9. Temperature profiles in Cayuga Lake from May to September 2017 (a) Site 1: 42° 37.92" N, 76° 40.33" W and (b) Site 2 42° 33.25" N, 76° 35.5" W. Data provided by John Halfman, Hobart and William Smith Colleges.

6.2 Chemical Conditions

Based on average annual TP concentrations, Cayuga Lake can be characterized as mesotrophic (see **Figure 10a**), although TP levels periodically exceed 0.02 mg/l. Seasonal trends in TP concentrations generally indicate an early to mid-season peak (**Figure 10a**). Long-term trends in TP concentrations from 1996 to 2017 based on

annual average summer values at all sampling locations combined did not indicate a significant trend ($p = 0.861$, $\tau = -0.029$) (**Figure 10b**).

In evaluating specific sampling locations, a significant increasing trend was observed at the mid-South location while no statistical trends in TP was observed at the other locations:

- North sampling location between 2002-2004, 2013 and in 2017 ($p = 0.801$, $\tau = -0.105$).
- Mid-North sampling location between 2002-2006 and 2013 ($p = 0.702$, $\tau = -0.138$).
- Mid-South/South sampling location since 1996, a significant increasing trend was observed for average ($p = 0.017$, $\tau = 0.399$) and maximum ($p = 0.023$, $\tau = 0.380$) TP.
- South sampling was conducted 1998-2013 annually ($p = 0.857$, $\tau = -0.033$).

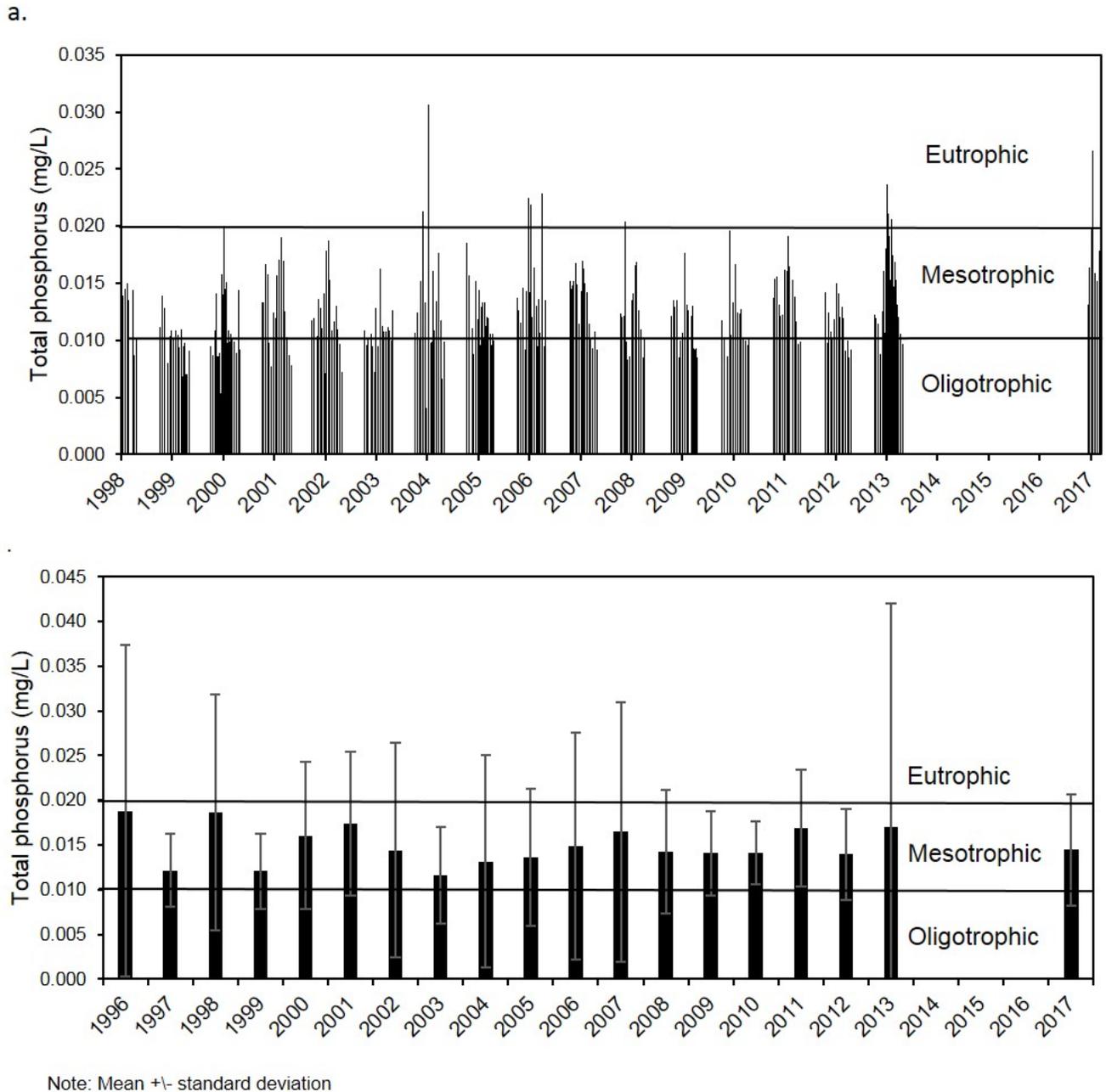


Figure 10. (a) Total phosphorus (mg/L) measured at the Mid-South/South sampling location in Cayuga Lake from 2002 to 2017 (CSLAP, DBPs, LCS, CLMP). (b) Annual average total phosphorus (mg/L) from all sampling locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs, LCS, CLMP).

The LSC monitoring (1998-2012) revealed annual average hypolimnetic (lower water layer) soluble reactive phosphorus (SRP) concentrations in Cayuga Lake ranged from 0.0035 to 0.098 mg/L. A general increase in SRP concentrations were observed from 1998 to 2012, particularly in the early 2000s (see Figure 10 in DeFrees 2013). The effect of increasing hypolimnetic SRP levels in the mid-South segment (from which the LSC intake is drawn) on SRP and algae levels in the mid-South and south segments

continues to be evaluated. Concentrations of soluble reactive phosphorus (SRP) should continue to be measured as part of ongoing monitoring to better inform management actions related to available phosphorus for cyanobacteria. However, a detailed evaluation of phosphorus speciation within the complicated hydrodynamics in Cayuga Lake is better addressed in detailed modeling and data analysis being undertaken in the TMDL.

Average total nitrogen (TN) concentrations from all sample locations in Cayuga Lake combined have generally declined between 1996 and 2017 ($p = 0.051$, $\tau = -0.619$, **Figure 11**). However, total dissolved nitrogen (TDN) concentrations, or the portion of TN present that is soluble in water, did not show a significant trend over time from 1996 to 2017 across all sampling locations ($p = 0.652$, $\tau = -0.048$).

A long-term trend in annual average ammonia concentrations (0.046 – 0.010 mg/L) in Cayuga Lake from 1996 to 2017 at all sample locations combined was not observed ($p = 0.677$, $\tau = 0.111$), and were not significant spatially:

- North sampling location between 2002-2004 and 2017 ($p = 0.279$, $\tau = 0.548$).
- Mid-North sampling location between 2002-2006 ($p = 1.0$, $\tau = 0.0$).
- Mid-South/South sampling location since 1996-1997, 2002-2007 and 2017 ($p = 0.677$, $\tau = 0.111$).

However, inorganic nitrogen concentrations (NO_x), which is a measure of the sum of nitrate (NO_3^-) and nitrite (NO_2^-), decreased significantly between 1996 and 2017 in Cayuga Lake ($p = 0.033$, $\tau = -0.683$), based on annual averages from all sample locations. Note that nitrate concentrations in Cayuga Lake remain high, suggesting that algal growth is not limited by nitrogen.

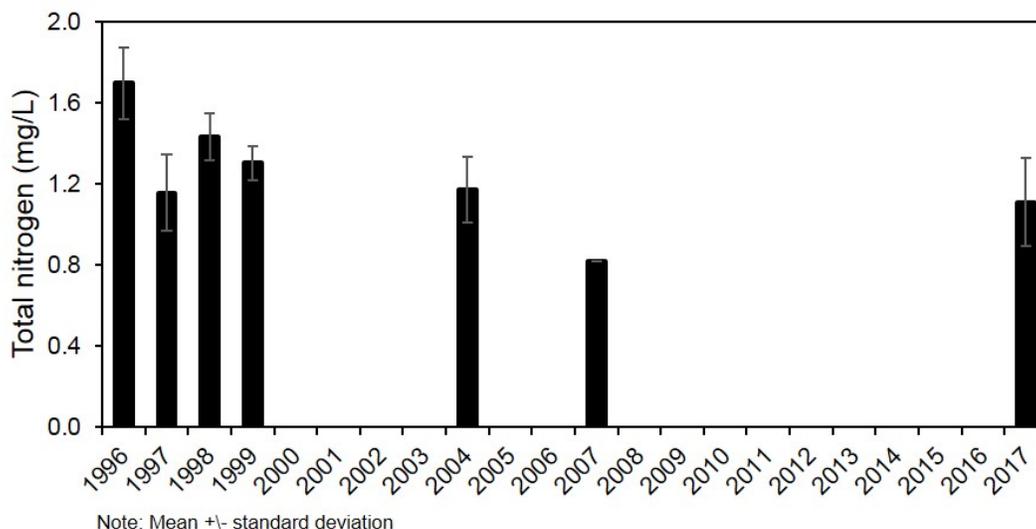


Figure 11. Annual average total nitrogen (mg/L) from all sample locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs).

The relative concentrations of nitrogen and phosphorus may influence algal community composition and abundance of cyanobacteria. Ratios of total nitrogen (TN) to total phosphorus (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 nitrogen to phosphorus (TN:TP, by mass) may determine whether or not HABs occur, with cyanobacteria blooms rare in lakes where mass based TN:TP ratios are greater than 29:1 (Filstrup et al. 2016, Smith 1983). Certain cyanobacteria taxa can utilize atmospheric dinitrogen (N₂), which is unavailable to other phytoplankton, providing a competitive advantage to N-fixing cyanobacteria when nitrogen becomes limiting. Observed TN:TP (42 to 108) in Cayuga Lake based on annual average concentrations from the Mid-South/South sampling location showed no long-term trend between 1996 and 2017 ($p = 0.348$, $\tau = -0.333$, **Figure 12**). Note that trends in TN:TP could not be evaluated at the other sampling locations due to limited measurements of TN concentrations. Ratios of TN:TP in Cayuga Lake suggest that algae are generally limited by the availability of phosphorus (TN:TP > 40).

Dissolved oxygen depth profiles for 2014 (the latest year for which there was validated data, FLI) indicate that oxygen concentrations were high throughout the water column in Cayuga Lake during the growing season (May-October) (**Figure 13**). The depth profile indicates lower DO in the metalimnion, characteristic of mesotrophic lakes, reflects accumulation of organic matter in this area and the consumption of oxygen associated with the decay of this material (Callinan 2001). Increased DO concentrations in deeper water likely reflect higher saturation of oxygen associated with colder water.

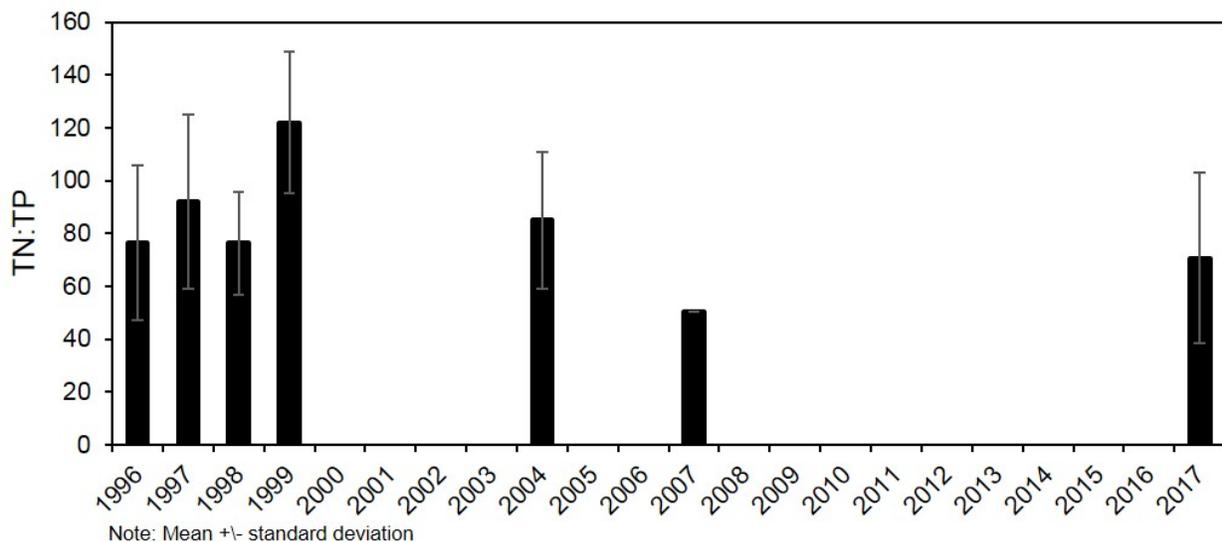


Figure 12. Annual average ratios of total nitrogen (TN) to total phosphorus (TP) (by mass) from the Mid-South/South location in Cayuga Lake, 1996 to 2017.

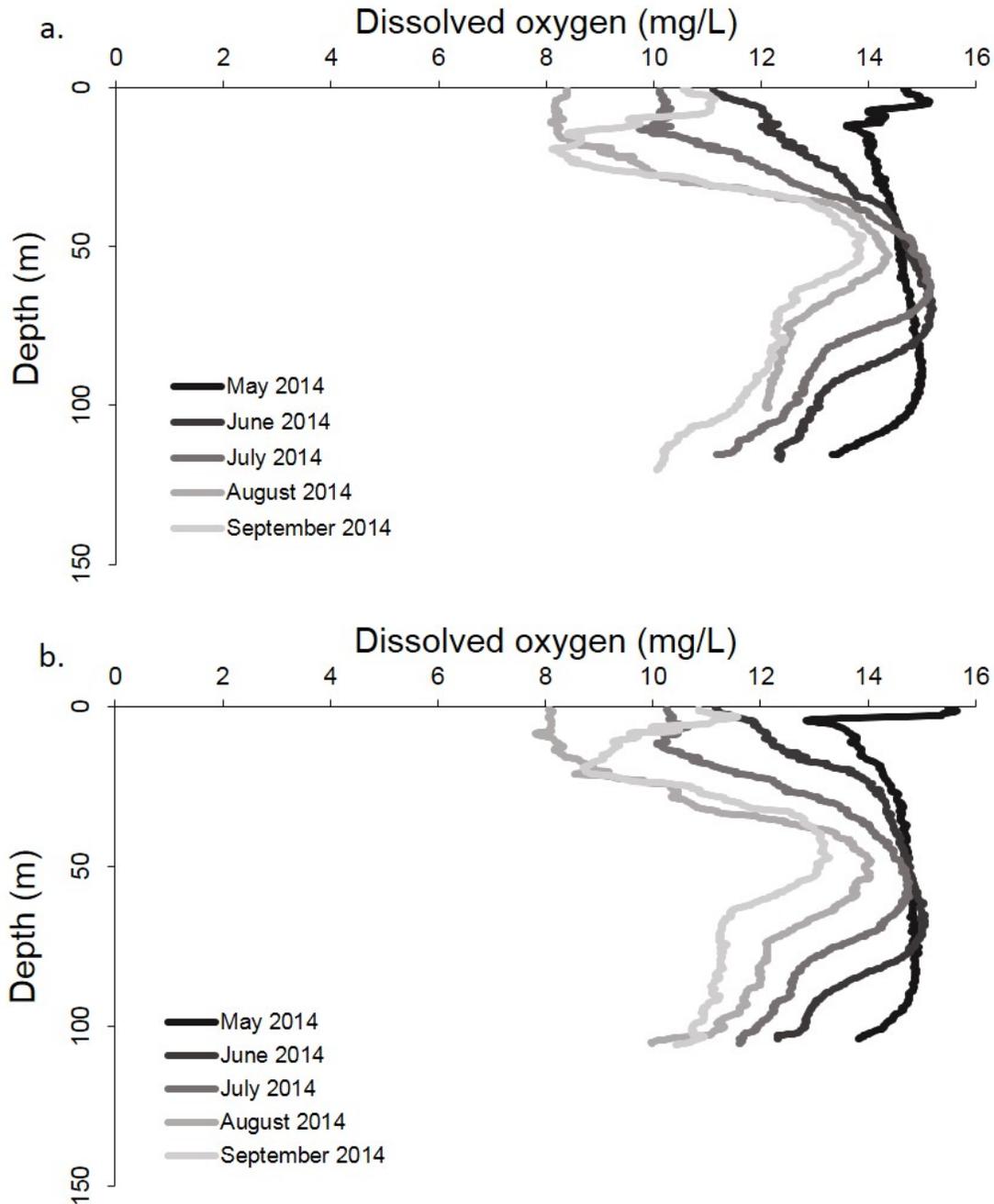


Figure 13. Dissolved oxygen profiles in Cayuga Lake from May-August and October in 2014 (a) Site 1: 42° 37.92" N, 76° 40.33" W and (b) Site 2 42° 33.25" N, 76° 35.5"W. Data provided by John Halfman, Hobart and William Smith Colleges.

Current trend analyses are based off the limited data available for these parameters. More data are necessary to develop accurate conclusions on general temporal trends.

6.3 Biological Conditions

Aquatic plants are visually assessed as part of CSLAP based on the perceived extent of aquatic vegetation abundance in the lake. These assessments have indicated that

aquatic plant coverage can be highly variable in Cayuga Lake (NYSDEC 2008a). In general, most of the lake, with the exception of the shallower north and south segments, has minimal habitat to support aquatic vegetation due to steep littoral zone slopes (see **Figure 3**). CSLAP plant evaluations are incomplete for very large lakes where visual assessments are limited to small parts of the lake.

While invasive species remain a concern in the lake, there are currently no significant impacts on recreational or other uses (Cayuga Lake-Yawgers Creek Watershed WI/PWL 2016). Currently, Cayuga Lake contains eleven aquatic invasive species (NYSFOLA 2018), five invasive plants cited in Section 3.6, and the following invasive animals:

- Zebra mussels (*Dreissena polymorpha*)
- Quagga mussels (*Dreissena bugensis*)
- Common carp (*Cyprinus carpio*)
- European stream valvata (*Valvata piscinalis*)
- Scud (*Echinogammarus ischnus*)
- Alewife (*Alosa pseudoharengus*)

Certain invasive species may influence the frequency and duration of HABs. For instance, common carp can increase sediment suspension and associated nutrients in the water column based on their feeding behavior. This species feeds on benthic macroinvertebrates found within the sediment, with that sediment suspended during active feeding. The increased sediment being suspended in the water will include nutrients that may be utilized by cyanobacteria.

Eurasian watermilfoil and *Hydrilla* are of major concern in Cayuga Lake because the species often grows in large dense beds, outcompeting and crowding out native aquatic vegetation (Boylen et al. 1999). The dense beds of these aquatic invasive species provide less suitable habitat for fish and other aquatic life and can impede recreational activities such as boating, fishing, and swimming. Eurasian watermilfoil and *Hydrilla* also act as a nutrient pump, by bringing nutrients up from the sediment and back into the water column as plant biomass during the growing season. Some of these nutrients are then released into the water column during respiration and decay of plant material (e.g., Smith and Adams 1986). While several studies from the scientific literature discuss the role of milfoil as a potential nutrient pump, lake specific conditions can alter these dynamics including, local anoxic patches, trophic state, plant density, and plant decomposition rates (Carpenter 1983, Carpenter and Lodge 1986); further research is warranted to assess these variables in Cayuga Lake. Note that Eurasian watermilfoil abundance has largely declined in Cayuga Lake, attributed to herbivory from *Acentria ephemerella* (a moth) and *Euhrychiopsis lecontei* (a weevil) (Johnson et al. 1997, Johnson et al. 2000), although *Hydrilla* was recently discovered in a large bed near Aurora.

Dreissenid mussels (i.e., zebra mussels and quagga mussels) can influence phytoplankton composition by selectively feeding on phytoplankton which can result in increased prevalence of cyanobacteria (Vanderploeg et al. 2001). Dreissenid mussels are often found in nearshore zones and coupled with their high filtration rates of algae and subsequent elimination of wastes, can concentrate nutrients in nearshore zones (Hecky et al. 2004). Shifts in nutrient concentrations to nearshore areas may result in greater incidence of shoreline HABs. In recent years, quagga mussels have colonized a wide range of depths, including nearshore and deep water locations (up to approximately 120 m) of Cayuga Lake (Watkins et al. 2013) and have largely replaced zebra mussels. This extensive colonization has likely expanded the potential effects of selective feeding and nutrient recycling influencing the phytoplankton assemblage.

Chlorophyll-a is a main photosynthetic pigment of all algae, including cyanobacteria, and is often used as a proxy variable to estimate the amount of algae present. Seasonal trends in chlorophyll-a concentrations at all sampling locations in Cayuga Lake from 2002 to 2017 generally show a peak early in the growing season (see **Figure 14a** for the Mid-South/South sampling location which was used as representative of the other locations). Trends from 1996 to 2017 of chlorophyll-a in Cayuga Lake suggest a non-significant increasing trend ($p = 0.115$, $t = 0.263$) based on annual average values at all sampling locations combined (**Figure 14b**).

Trends in chlorophyll-a concentrations were observed when analyzing data from specific sampling locations:

- North sampling location between 2002-2004, 2013 and in 2017 ($p = 0.625$, $\tau = -0.200$).
- Mid-North sampling location between 2002 to 2006 and 2013 ($p = 0.091$, $\tau = -0.600$).
- Mid-South/South sampling location since 1996, no significant increasing trend was observed for average chlorophyll-a ($p = 0.086$, $\tau = 0.287$) and a significant increasing trend was observed for maximum ($p = 0.016$, $\tau = 0.404$) chlorophyll-a.
- South sampling was conducted 1998 – 2013 annually ($p = 0.418$, $\tau = 0.150$).

Summer averages of chlorophyll-a concentrations (**Figure 14b**) in Cayuga Lake often exceeded the Class AA threshold of 4.0 $\mu\text{g/L}$ and occasionally exceeded the Class A threshold of 6.0 $\mu\text{g/L}$ for lakes proposed by Callinan et al. (2013). Callinan et al. (2013) indicated that chlorophyll-a concentrations above 4 to 6 $\mu\text{g/L}$ could be sufficient to reach or exceed the existing USEPA maximum contamination level of 80 $\mu\text{g/L}$ total trihalomethanes concentration for drinking water (USEPA 2006). Total trihalomethanes concentrations are used as a measure of DBPs in drinking water systems. During water treatment, DBPs form when an oxidizing agent (e.g., chlorine) reacts with natural organic matter (NOM). Sources of NOM in lakes includes external (e.g., leaves) and internal sources (e.g. algae). Note that due to the depth and location of water system

intake(s) it is likely that chlorophyll-a concentrations are reduced compared to concentrations measured at the water surface.

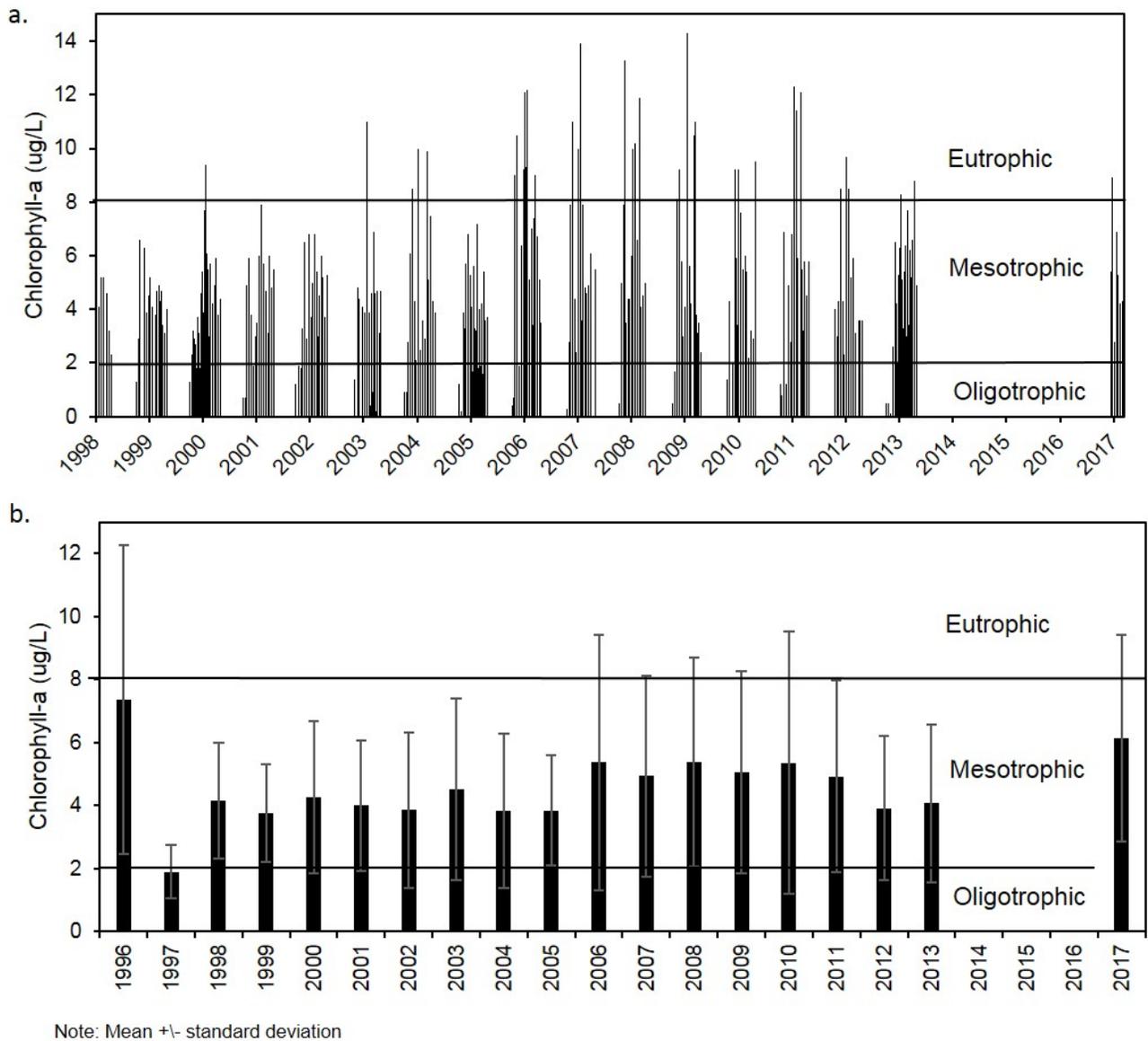


Figure 14. (a) Chlorophyll-a ($\mu\text{g/L}$) measured at the Mid-South/South sampling location in Cayuga Lake from 2002 to 2017 (CSLAP, DBPs, LCS, CLMP). (b) Annual average chlorophyll-a concentrations ($\mu\text{g/L}$) from all sampling locations in Cayuga Lake, 1996 to 2017 (CSLAP, FLWQ, DBPs, LCS, CLMP).

6.4 Other Conditions

The zooplankton grazing alewife (*Alosa pseudoharengus*) has also been documented in Cayuga Lake. Alewife grazing has been shown to reduce zooplankton abundance and shift zooplankton composition to smaller taxa (Makarewicz 2000) which can, in turn, result in an increase in phytoplankton abundance, including those that contribute to HABs.

6.5 Remote Sensing Estimates of Chlorophyll-a Concentrations

Chlorophyll-a concentrations were estimated for the entire lake using a remote sensing chlorophyll-a model developed by the University of Massachusetts (Trescott 2012) for Lake Champlain. The analysis provides an estimate of the spatial distribution of chlorophyll-a on a particular day and is intended to supplement the field measurement programs. The model estimates of chlorophyll-a are based on the spectral properties of chlorophyll-a, and are thus a measure of green particles near the water surface. At this time, the estimated chlorophyll-a concentrations are reported as a concentration index due to the limited number of field measurements to calibrate the model to the other NYS lakes; for more information, including limitations of the model, refer to **Appendix C**.

The remote sensing analysis was conducted using satellite imagery from NASA's Landsat 8 satellite. Seasonal imagery from May to October was acquired and processed for the past three years (2015-2017). Based on the available remote sensing images shown in **Figure 15**, chlorophyll-a concentrations tend to be higher in the north portion of the lake and near Ithaca in the south. Chlorophyll-a tends to increase through the summer season; however, localized chlorophyll-a "hot spots" may be observed at any time in the summer.

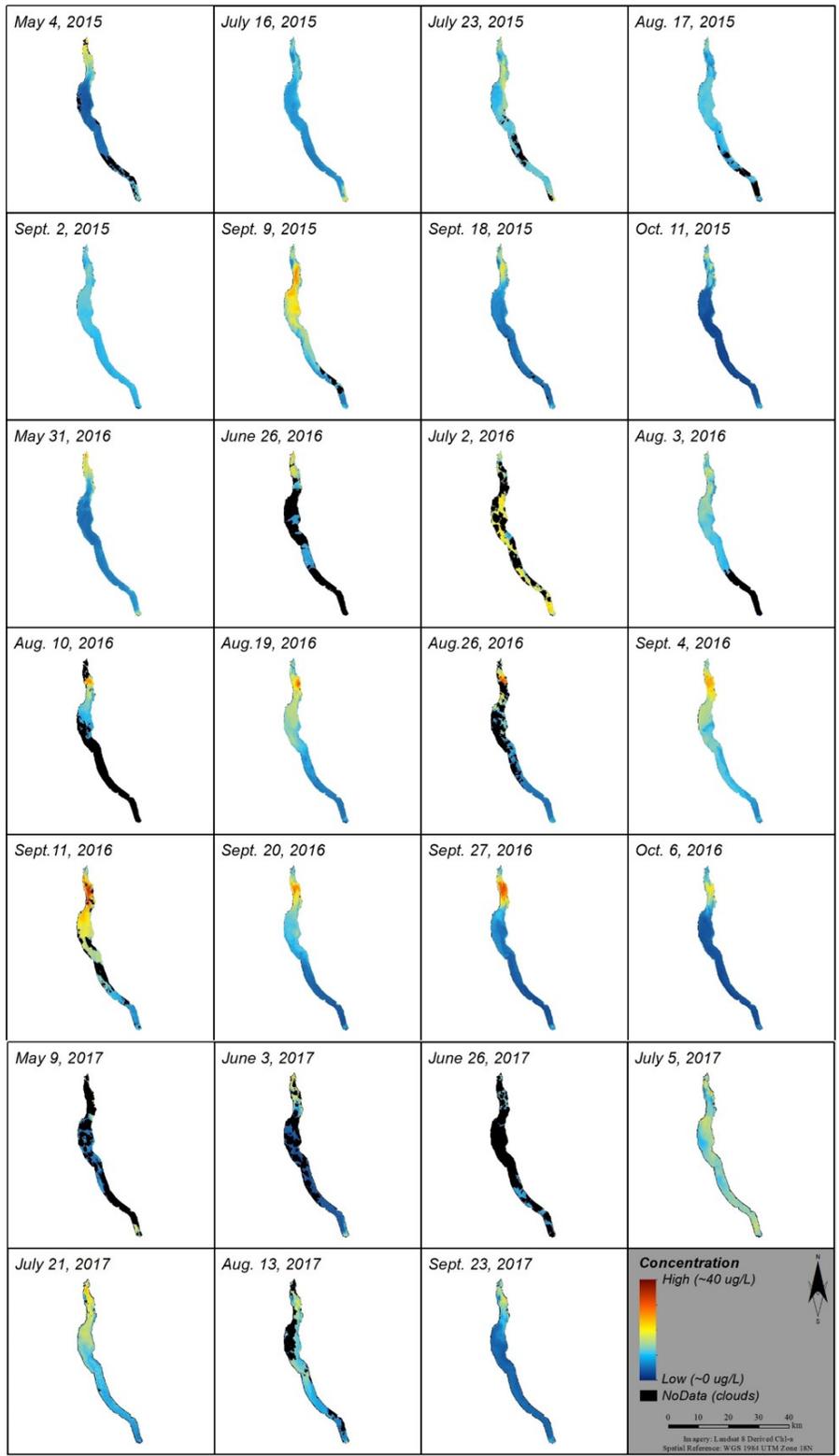


Figure 15. Estimated chlorophyll-a concentrations in Cayuga Lake, 2015 to 2017.

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 the 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. The NYSDEC HABs Program 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 $\mu\text{g/L}$ 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 $\mu\text{g/L}$ (shoreline samples) or microcystin ≥ 10 $\mu\text{g/L}$ (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 Ambient Lake HABs History

Cayuga Lake, along with some of the other Finger Lakes, has received considerable attention by state agencies, non-governmental organizations, community interest groups, lake users, water suppliers, and other stakeholders because of the documented presence of HABs in the lake in recent years. HABs have been reported to the NYSDEC by many data providers including Tompkins and Cayuga County DOH, NYSDOH, trained CSLAP volunteers, and members of the public. HABs in Cayuga Lake occur predominantly along the shoreline in the lake's north and south ends. Cayuga Lake is sampled bi-weekly by trained citizen volunteers (through CSLAP) with shoreline areas visually assessed for cyanobacteria and samples collected if a bloom is noted. The frequency of bloom reports and bloom status are summarized in **Table 4**. However, it should be noted that in a lake with a 95-mile shoreline, even trained volunteers are unlikely to completely evaluate HABs occurrences at all times throughout the lake. Shoreline surveillance networks, involving trained shoreline surveyors inspecting pre-defined zones every week during the summer, have not yet been established on Cayuga Lake. These surveillance networks, combined with satellite imagery, would be more effective in documenting blooms in Cayuga Lake.

Very limited shoreline reporting and sampling indicated toxin detections have at times been reported in early fall (starting in September), with concentrations that exceeded the NYSDEC Confirmed with High Toxins Bloom threshold first reported in 2017. It is not known if elevated toxins were present in other locations prior to 2017.

The 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. Visual evidence of blooms in multiple locations in recent years indicated an elevated risk for swimmers and other recreational users, even if high toxin levels were not measured.

Based on public bloom reporting in 2017, cyanobacteria HABs were most commonly associated with the eastern shoreline of Cayuga Lake (along Frontenac Point, Wells College Beach, Long Point State Park). Because sampling is often limited to the shoreline, particularly as part of incidental reporting through the open water volunteer monitoring program, the sampling effort does not necessarily reflect the true extent of

the blooms. Northeastern shoreline blooms have resulted in beach closures at multiple locations (see **Section 7.2**).

Year	Suspicious	Confirmed	Confirmed w/High Toxins
2014	2	1	0
2015	0	0	0
2016	1	3	0
2017	24	5	3
Total	27	9	3

7.2 Drinking Water and Swimming Beach HABs History

Drinking Water

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 USEPA 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 noted in **Section 3.2** it is never advisable to draw drinking water from a surface source unless it has been treated by a public drinking water system regardless of the presence of HABs (NSF P477; NYSDOH 2017).

Swimming

Beaches closures have occurred in Cayuga Lake in 2015-2017 (**Figure 17**, data provided by NYSDOH).

In 2017, six locations were closed due to HABs, with varying numbers of beach days lost due to associated closures (NYSDOH):

- Wells College bathing beach – 16 days lost
- Frontenac Park – 13 days lost
- Camp Caspar Gregory bathing beach – 14 days lost
- Ithaca Yacht Club – 7 days lost
- Long Point State Park – 6 days lost
- Taughannock Falls State Park – 6 days lost

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

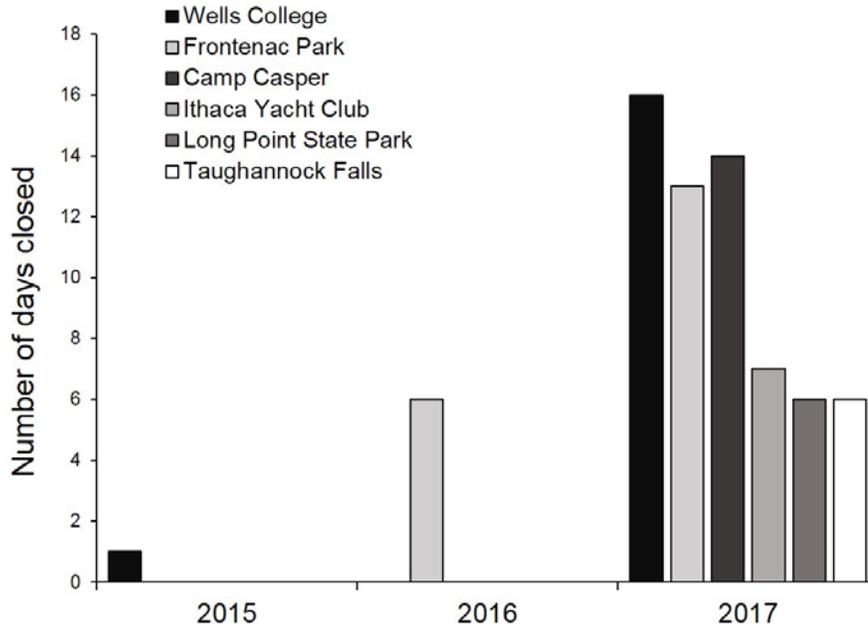


Figure 17. Number of beach days lost due to beach closures associated with HABs in Cayuga Lake from 2015 to 2017.

Table 5. 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) starting in 2017.	

7.3 Other Bloom Documentation

Cyanobacteria Chlorophyll-a

BGA chlorophyll-a concentrations from samples determined to be Confirmed or Confirmed with High Toxins ranged from 55.3 µg/L (September 2017) to 8,756 µg/L (July 2017) (Table 6).

Cyanotoxins

Some cyanobacteria taxa also produce toxins (cyanotoxins) that can be harmful to people and pets. As a result, several different toxins are monitored by the NYSDEC. Microcystin is the most commonly detected cyanotoxin in New York State (NYSDEC

2017). The 20 µg/L microcystin “high toxin” threshold for shoreline blooms was, like the BGA chlorophyll-a threshold, established based on WHO criteria.

Microcystin concentrations were quantified from shoreline bloom samples, generally collected as a result of visual observation of scum accumulations. Microcystin was detected above the 20 µg/L threshold by laboratory analysis in 3 of 15 samples. Microcystin levels also exceeded the draft USEPA human health recreational swimming advisory threshold of 4 µg/L (USEPA 2016) in 6 of 7 laboratory samples in which microcystin was detected. Sample results below this threshold value are consistent with what is currently prescribed by NYSDOH guidance to allow a regulated bathing beach to reopen.

Table 6. Measured toxin and cyanobacteria (BGA) chlorophyll-a concentrations for bloom events (2014-2017, CSLAP).						
Status	Microcystin (µg/L)			Cyanobacteria (BGA) chl-a (µg/L)		
	Min	Max	# of samples	Min	Max	# of samples
Confirmed	ND	4.2	6	55.3	8756	6
Confirmed, High Toxins	35.5	782.8	3	329.5	3977	3

Cyanobacteria Taxa

Qualitative microscopy was used to document the dominant cyanobacteria taxa present in the Confirmed or Confirmed with High Toxins shoreline HABs samples (a total of 12). *Microcystis* was found to be present in 67%, or 8 out of 12, confirmed reports of HABs in Cayuga Lake. In addition, *Dolichospermum* (formerly *Anabaena*) was present in 50% (6 out of 12) microscopy samples.

Both of these cyanobacteria taxa have the ability to regulate their buoyancy (Mantzouki et al. 2016), which allows for movement up into the photic zone to photosynthesize, while also moving down into the water column to access available nutrients found near the metalimnion. *Dolichospermum* is also capable of fixing dinitrogen (N₂) (Mantzouki et al. 2016). Note that these observations of the dominant cyanobacteria taxa in Cayuga Lake are relatively limited based on the relatively low number of reported HABs.

7.4 HABs and Remote Sensing

Remote sensing images were plotted together with hourly rainfall, wind speed and direction, locations of recreational beaches, locations of wastewater treatment plants, and locations of the detected HABs recorded within three days of the remote sensing images. Hourly rainfall is plotted with hourly air temperature. The weekly average and long-term average (36 years) air temperature are shown to provide context. Hourly wind is presented using stick plots that provide direction and magnitude. Each arrow is pointing in the compass direction the wind is blowing towards; up is north. The magnitude is indicated by the length of the line; a scale line is provided for reference. A full set of these figures is provided in **Appendix C**. Select examples from the past three years are discussed below.

Figure 18 depicts the rapid increase in chlorophyll-a concentrations between September 2 and 9, 2015. Winds were low to moderate and daily temperatures were near 30°C (86°F) over this period. Relative chlorophyll-a concentrations fell by September 18, possibly due to mixing caused by stronger winds (dispersing the chlorophyll-a through the water column), light rain, and perhaps colder temperatures (**Figure 18**).

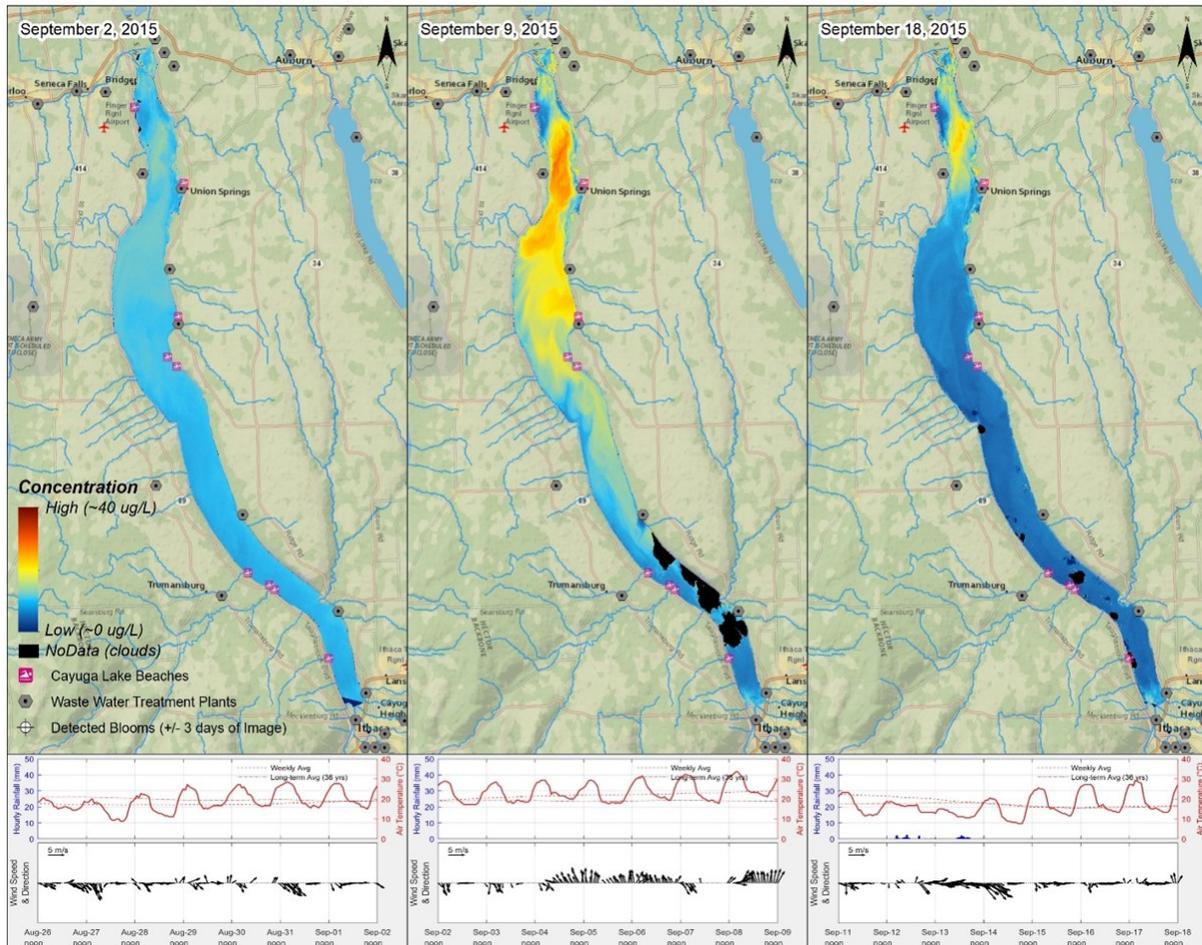


Figure 18. Estimated chlorophyll-a concentrations in Cayuga Lake during September 2015.

Remote sensing estimates also show high chlorophyll-a concentrations at the south end of the lake in July 2015, following precipitation events (**Figure 19**).

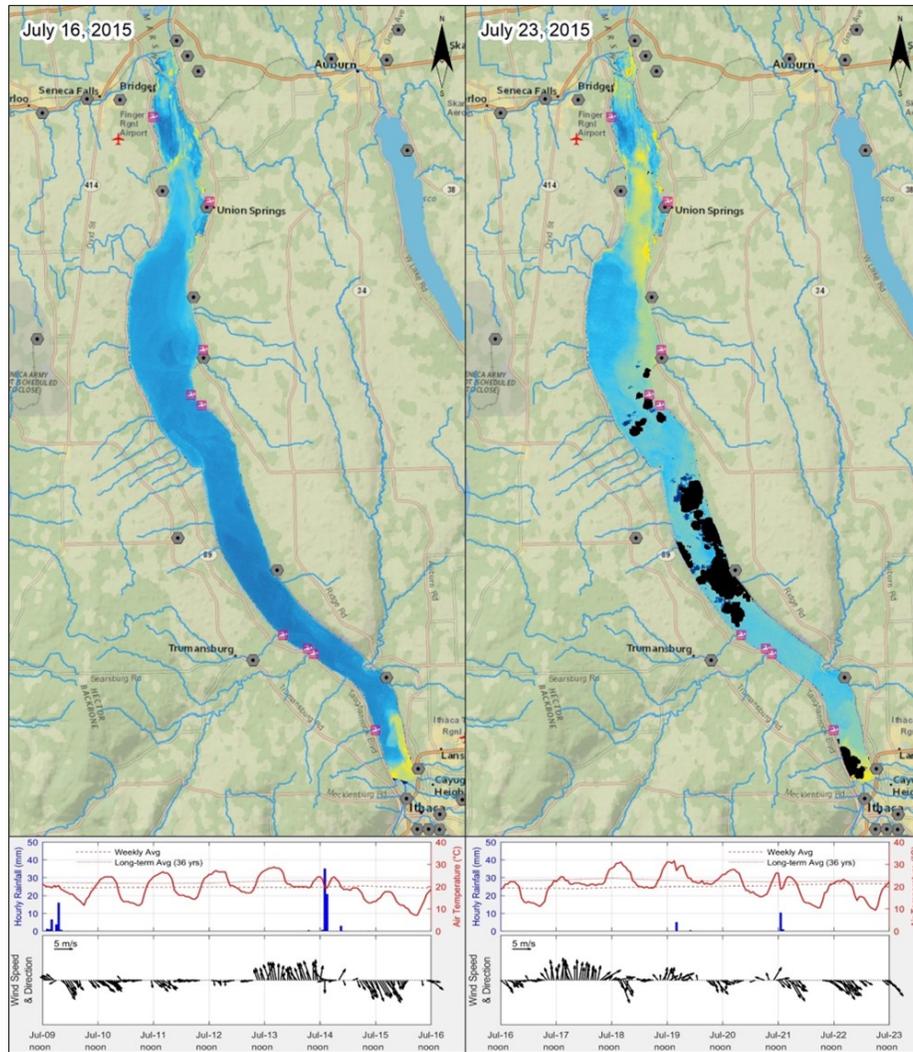


Figure 19. Estimated chlorophyll-a concentrations in Cayuga Lake during July 2015.

HABs were suspected or confirmed in Cayuga Lake in August and September 2016. Remote sensing images show high chlorophyll-a concentrations at the north end of the lake throughout August and September in 2016. In 2017, HABs were suspected or confirmed July 16th and continued through to October 10th. The remote sensing images show high chlorophyll-a concentrations starting in early July and persisting mainly in the north end of the lake by the last available image in September 2017.

The north end of Cayuga Lake is relatively shallow (less than 30 m) compared to the middle of the lake, which is greater than 100 m deep (see **Figure 3**). Winds during June through November from 2006 to 2017 showed south winds (**Appendix A**). Southerly winds coincide with the direction of the main flow, as Cayuga Lake drains towards the north. A combination of southerly winds and flow towards the north is expected to result in the net transport of chlorophyll-a to the north end of the lake. The long-term accumulation of chlorophyll-a in the north end of Cayuga Lake may make this region more susceptible to HABs.

It is worth noting that estimated chlorophyll-a concentrations in Cayuga Lake occasionally reveal the presence of complex circulation patterns (**Figure 20**). This figure illustrates the relative influence of wind and tributary flows on lake mixing processes. The percentage of the Cayuga Lake surface area with an estimated chlorophyll-a concentration greater than 10 $\mu\text{g/L}$ and 25 $\mu\text{g/L}$ is summarized in **Table 7**. Cyanobacteria cell counts and/or chlorophyll-a concentrations (e.g., BGA chlorophyll-a) less than 25 $\mu\text{g/L}$ is NYSDEC’s criteria for “no-bloom”, refer to **Section 7.2** for more information. However, the relationship between measured chlorophyll and satellite-estimated chlorophyll shown in **Appendix C (Figure C2)** suggests that some waterbodies may exhibit bloom conditions at satellite-estimated chlorophyll levels as low as 10 $\mu\text{g/L}$.

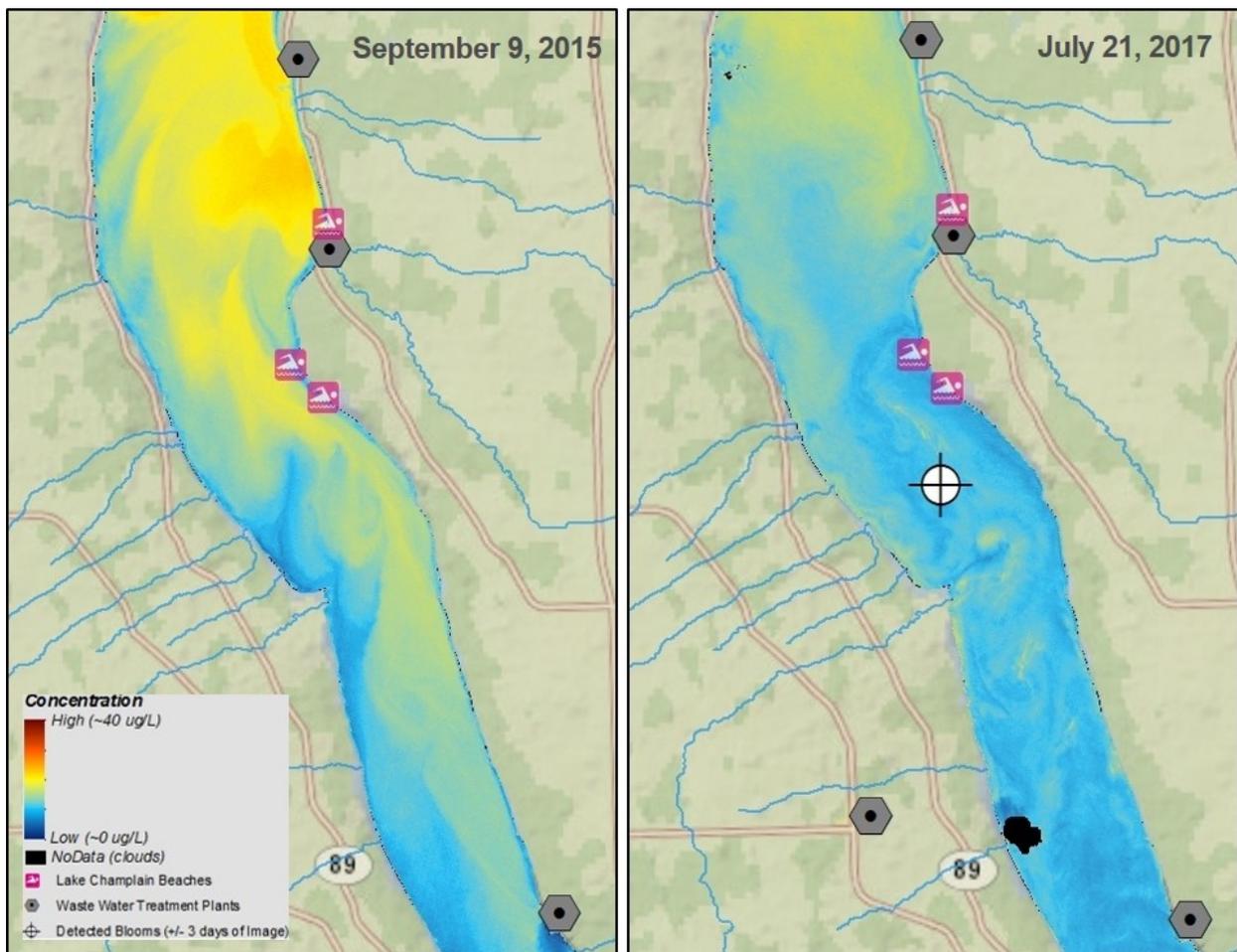


Figure 20. Remote sensing estimated of chlorophyll-a indicate complex wind-driven circulation patterns in Cayuga Lake.

Table 7. Percent (%) of water surface area with an estimated chlorophyll-a concentration ($\mu\text{g/L}$) above and below 10 $\mu\text{g/L}$ and 25 $\mu\text{g/L}$ in Cayuga Lake (2015 to 2017).

Date	% of surface area less than		% of surface area greater than or equal		% No data
	10 $\mu\text{g/L}$	25 $\mu\text{g/L}$	10 $\mu\text{g/L}$	25 $\mu\text{g/L}$	
2015-05-04	56	81	24	0	19
2015-05-29	6	10	4	0	90
2015-06-05	7	19	13	0	81
2015-07-16	75	100	24	0	0
2015-07-23	9	88	78	0	12
2015-08-17	24	86	62	0	14
2015-09-02	22	99	78	0	1
2015-09-09	17	90	76	3	7
2015-09-18	81	98	17	0	2
2015-09-25	12	23	11	0	77
2015-10-11	86	100	14	0	0
2016-05-31	78	99	22	0	0
2016-06-07	14	21	8	0	79
2016-06-16	16	23	7	0	77
2016-06-23	17	31	14	0	69
2016-07-02	4	49	45	0	51
2016-08-03	8	77	69	0	23
2016-08-10	8	32	25	1	67
2016-08-19	40	98	59	2	1
2016-08-26	35	51	18	2	47
2016-09-04	19	98	81	2	0
2016-09-11	15	69	62	8	23
2016-09-20	49	97	51	3	0
2016-09-27	76	93	23	7	0
2016-10-06	82	100	18	0	0
2017-05-09	22	28	6	0	72
2017-06-03	42	55	13	0	45
2017-06-10	3	11	8	0	89
2017-06-26	12	17	6	0	83
2017-07-05	3	99	96	0	1
2017-07-21	27	98	72	0	1
2017-08-06	3	12	9	0	88
2017-08-13	23	69	46	0	31
2017-08-29	8	9	1	0	91
2017-09-23	82	100	17	0	0
2017-10-25	56	64	8	0	36

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 WI/PWL 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). For Cayuga Lake in particular, this includes information about advanced water treatment at some of the treatment plants drawing from the lake, the aquatic plant management actions in the lake and surrounding waterways, and other impacts to designated uses unrelated to HABs.

8.1 WI/PWL Assessment

The current WI/PWL assessment (**Appendix E**) for Cayuga Lake is captured in four segments of the Lake: Cayuga Lake - Northern End, Cayuga Lake - Mid-North, Cayuga Lake - South, and Cayuga Lake - Southern End. The assessment reflects monitoring data collected through 2017. Lake uses are evaluated by section in **Table 8**.

Cayuga Lake, Southern End is assessed as an impaired waterbody due to primary (swimming) and secondary (boating) contact recreation uses that are known to be impaired by excessive nutrients (phosphorus) and silt/sediment loads from various sources throughout the watershed. In the other three portions of Cayuga Lake, primary and secondary contact recreation are stressed due to suspected impacts from algal/plant growth and aquatic invasive species.

The Southern End of Cayuga Lake is included on the current (2016) NYS Section 303(d) List of Impaired Waters Requiring a TMDL for phosphorus.

Table 8. Cayuga Lake use assessment.				
	North	Mid-North	Mid-South	South
Water Supply Source	N/A	Threatened, need to protect ¹	Stressed excessive algae, advanced treatment, need to protect ¹	Threatened, proximity to mid-south intakes, need to protect ¹
Primary Contact Recreation	Stressed, HABs	Stressed, HABs	Stressed, excessive algae, HABs	Impaired, aquatic plants, excessive algae, HABs
Secondary Contact Recreation	Stressed, HABs	Stressed, HABs	Stressed, excessive algae, HABs	Impaired, aquatic plants, algal blooms
Fishing Use	Fully supported	Fully supported	Fully supported	Fully supported
Fish Consumption	Unassessed	Unassessed	Unassessed	Unassessed
1. Cayuga Lake as a water supply is identified as threatened to note the importance of protecting the resource rather than to identify a particular threat.				

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 Cayuga Lake public drinking supply sources was completed. Although the information provides a historical perspective, the drinking water systems and/or land uses may have changed. Cayuga Lake 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 SWAP identified an elevated susceptibility to contamination for the Village of Seneca Falls, Cayuga Village, Wells College, and Southern Cayuga Lake Intermunicipal Water Commission Cayuga Lake drinking water sources. Potential contamination is due primarily to the amount of agricultural lands in the assessment area that results in elevated potential for phosphorus, DBP precursors, and pesticides contamination. In addition, the moderate density of CAFOs in the assessment area may add to the potential for contamination. While there are some facilities present, permitted discharges do not likely represent an important threat to source water quality based on their volume of discharge in the assessment area. However, it appears that the total amount of wastewater discharged to surface water in this assessment area is high

enough to raise the potential for contamination. Some susceptibility associated with other sources, such as landfills, was also noted (NYSDOH, Source Water Assessment Program 2004)

Although there are no significant known water quality impacts to Cayuga Lake, it is considered a highly valued water resource due to its drinking water supply classification. The inclusion of this waterbody on the NYSDEC/DOW Priority Waterbodies List as a Threatened water reflects its value and the need to provide additional protection, rather than any specifically identified threats.

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 evaluation of one source of data, in this case CSLAP. The scorecard for Cayuga Lake suggests that algae blooms threaten potable water use in the north end of the lake and stress aesthetic conditions in the north and south ends of the lake (**Figure 21**).

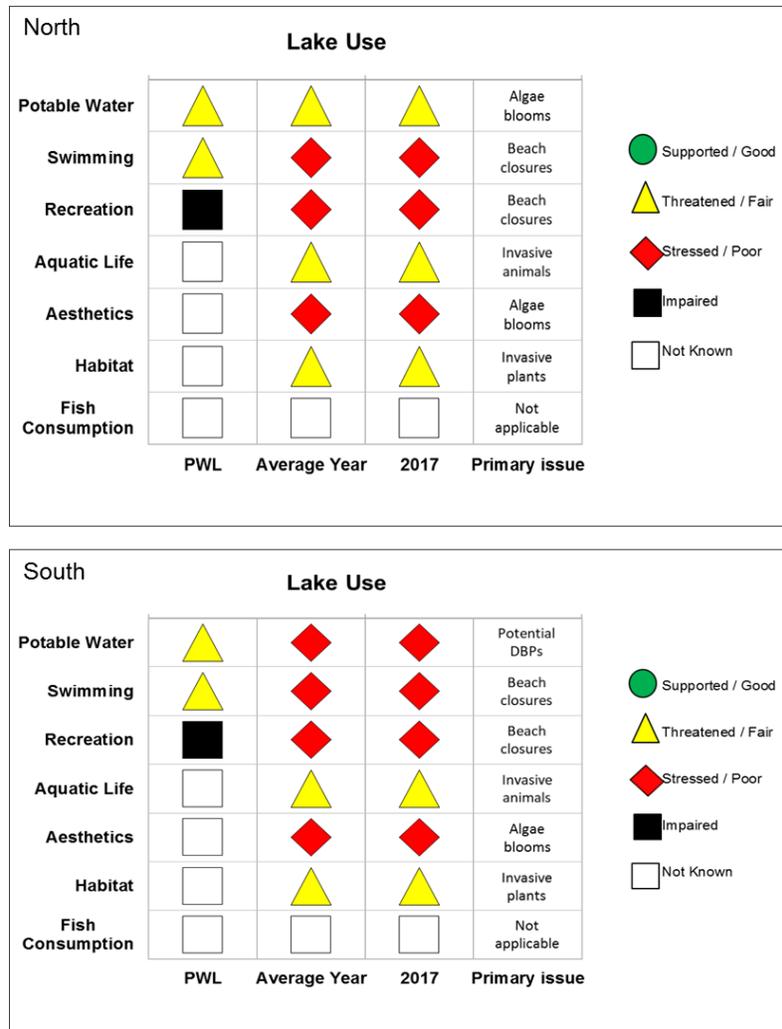


Figure 21. Cayuga Lake 2017 CSLAP scorecard.

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, phytoplankton dynamics may cause the presence of HABs to lag behind associated triggers (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, for example, 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 New York State. 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.

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, that is, 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 suggests 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 NO_x) 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 it does not account for important local, lake-specific drivers of HABs such as temperature, wind, light intensity, and runoff events.

Cayuga Lake exhibits some factors—periodically elevated phosphorus concentration, presence of dreissenid mussels, long fetch length—that render the lake susceptible to HABs. To evaluate if lake-specific HABs triggers, in addition to those observed at the state scale, were important at Cayuga Lake, additional statistical analyses were performed with data spanning from 2014 to 2017. All available HABs observations (bloom/no bloom) were aligned by date with meteorological information (e.g., temperature, precipitation, and wind speed) from the Ithaca Tompkins Regional Airport station. Estimated maximum wave heights were calculated from wind speed and direction data, fetch distances across the lake, and water depths along the fetch length. The fetches were measured in 10 degree increments along the compass rose, taking the longest distance across the lake. Using these data, an hourly wave hindcast covering the duration of the wind field measurements was generated (Donelan 1980). Note that water quality variables were not assessed in this analysis because water quality measurements only aligned with HABs observations in 2017.

As with the statewide data analysis, logistic regression was used to test whether meteorological variables could explain the occurrences of HABs. Because weather variables hypothesized to influence HABs can be correlated (e.g., maximum wind speed and wave height), the logistic regression was performed in two ways: (1) using the original meteorological data as explanatory variables and (2) by first performing a Principal Components Analysis (PCA) on the explanatory variables and using the PCA axes as explanatory variables in the logistic regression. Principal components analysis is helpful when evaluating data sets with correlated variables because it can recast the

original data as an uncorrelated set of “axes” (i.e., linear equations) that are representative of the original input data.

Both approaches to the logistic regression indicated that air temperature and precipitation were correlated with recorded HABs in Cayuga Lake. Specifically:

- Warmer air temperatures the day of a bloom ($p = 0.029$)
- Increased rainfall in the preceding days leading up to a recorded event ($p = 0.001$) (**Figure 22**)

Increasing precipitation can cause an influx of nutrients (Richwaldt and Ghadouani 2012), and when such rainfall does not disrupt stratification, these nutrients can be available for algal growth. Additionally, warmer water temperatures are favorable to algal production, including cyanobacteria – increased air temperatures correlated with HAB events in Cayuga Lake likely caused increased surface water temperatures.

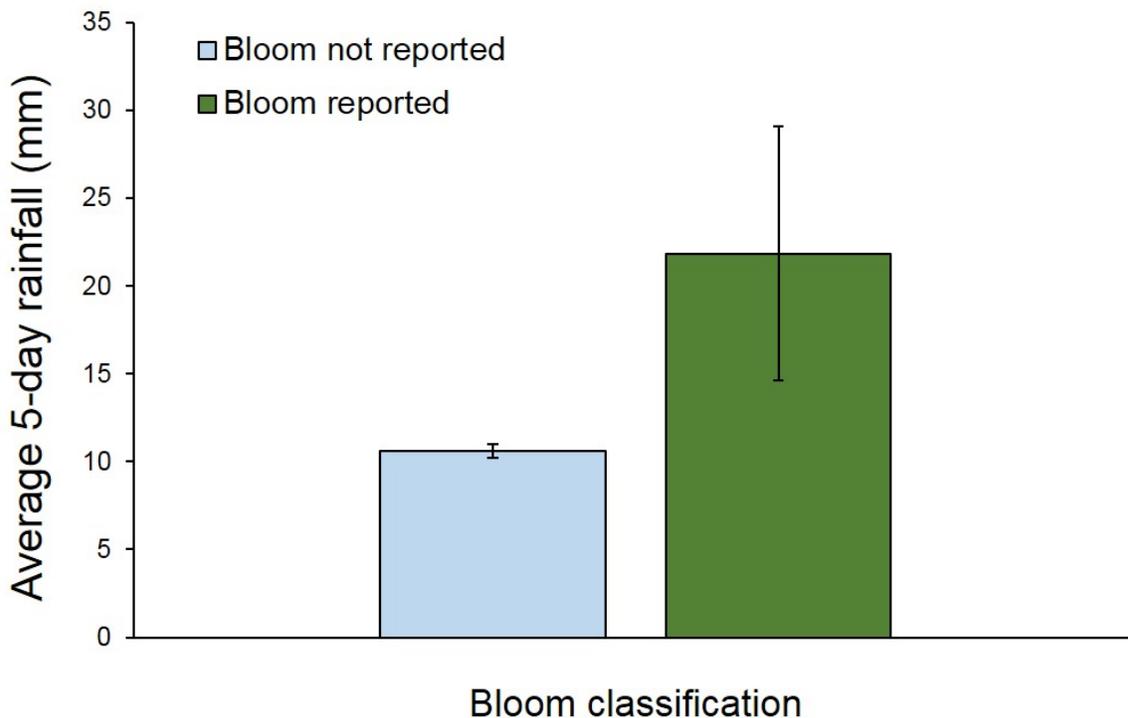


Figure 22. Average precipitation (mm, \pm standard error) in the preceding 5 days of a reported bloom (green bar) and days with no reported HAB (blue bar).

An evaluation of meteorological conditions (daily precipitation and maximum air temperatures) incorporating data spanning the last 50 years was conducted to further evaluate potential climatic driver(s) of HABs in 2017. Weather data was collected from

stations in Aurora and Ithaca, NY from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information¹.

The first reported HAB in 2017 occurred on July 16, and was assigned a “suspicious” status (see **Section 7.2** for status description). At the Ithaca weather station, a rain event that exceeded the 95th percentile of the 50-year daily average occurred two days prior on July 14, totaling of 2.1 inches of rain. The last reported HAB in 2017 was documented on October 10; from July through October (the period for which HABs were reported), there were multiple days with daily maximum air temperatures exceeding the 95th percentile of those 50-year daily averages, particularly in the late-growing season (above 80°F). Thus, the increased precipitation event may have contributed to the onset of HABs in 2017, and historically elevated air temperatures between the first and last reported HAB may have acted to sustain the bloom(s) that were reported. However, the patterns observed in 2017 may have been atypical, and these meteorological drivers of HABs in Cayuga Lake warrant additional investigation and study.

To fully understand the likely triggers of HABs in Cayuga Lake, additional water quality monitoring and associated HABs observations should be collected. Nutrient and water chemistry information aligned with HABs observations (both presence and absence) in subsequent years will complement the meteorological analyses.

10. Sources of Pollutants

Land use and potential pollutant loading data provided in this section were estimated using NYSDEC’s Loading Estimator of Nutrient Sources (LENS) screening tool (NYSDEC, undated). The LENS tool was used to identify potential nutrient pollutant sources in the Cayuga Lake Action Plan to help support prioritization of projects. Existing data indicate that much of the nutrient loading (e.g., TP) to Cayuga Lake is from nonpoint sources. Nutrients enter the lake via overland flow, tributaries, and other nonpoint sources, as well as point sources, where they become available for use by cyanobacteria and aquatic plants, or are deposited and stored in lakebed sediments.

¹ Daily meteorological data obtained from station USC00300331 located in Aurora, NY and station USC00304174 located in Ithaca, NY (<https://www.ncdc.noaa.gov/cdo-web/>).

10.1 Land Uses

Cayuga Lake has a watershed area of approximately 500,000 acres, with a watershed to lake ratio of approximately 12. The watershed is made up of the following land use types (**Figure 23**):

- Natural areas = 35%
- Developed land = 6%
- Agriculture = 50%
- Open water = 9%

If open water is excluded from the Cayuga Lake land use breakdown, approximately 38% of the watershed is comprised of natural areas, while approximately 55% of the watershed is agricultural. As depicted in **Figure 24a**, much of the forested land use in the Cayuga Lake watershed is located in the southern portion.

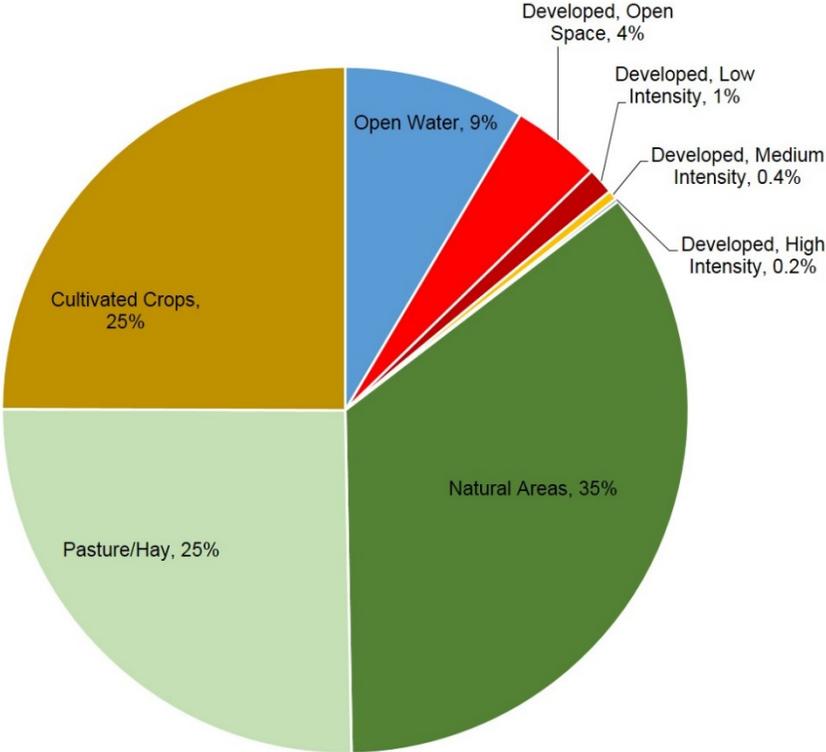
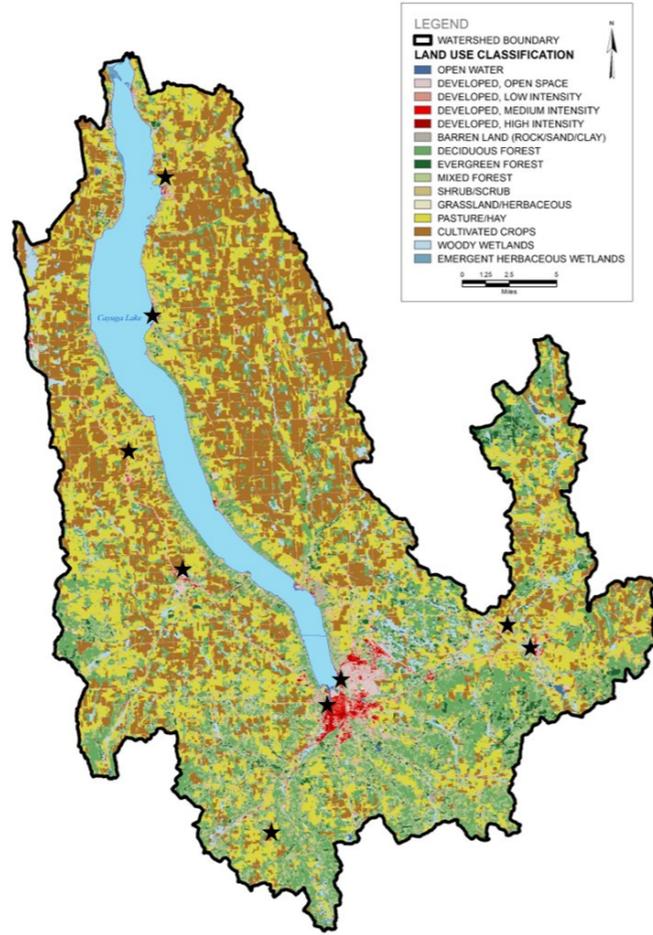
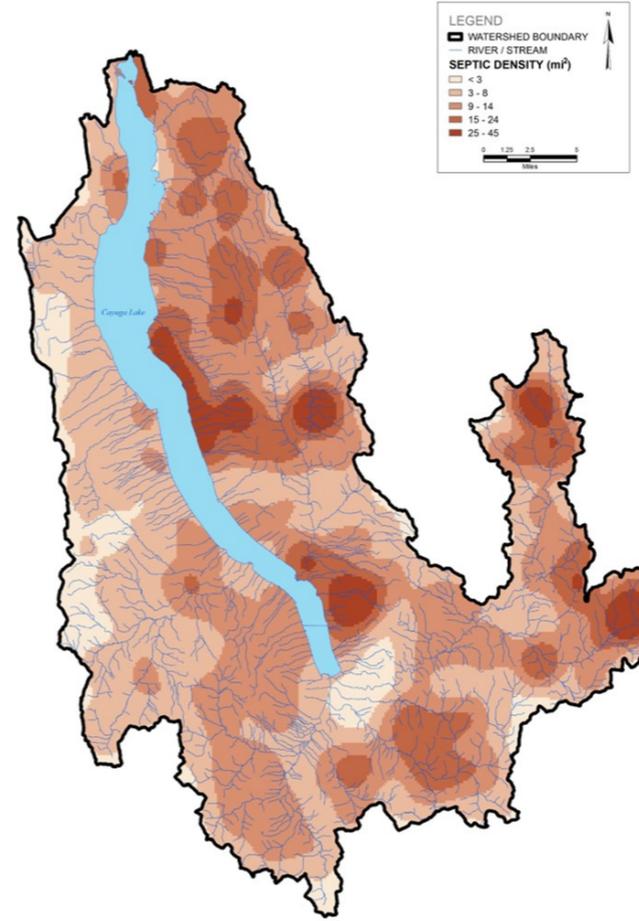


Figure 23. Land uses and percentages in the Cayuga Lake watershed. Natural areas include forests, shrublands, grasslands, and wetlands.

(a) Watershed land use



(b) Septic system density



★ = Location of point source discharge (approximate)

Figure 24. (a) Cayuga Lake watershed land use and (b) septic system density.

10.2 External Pollutant Sources

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 Cayuga Lake. Any completed TMDL or 9E plan developed for Cayuga Lake 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 Cayuga Lake.

The LENS tool indicates that 92% of the annual TP loading to Cayuga Lake occurs through nonpoint sources. Specific phosphorus load estimates include:

- Septic Load = 1%
- Agricultural = 80%

- Natural areas = 6%
- Developed = 5%

Analysis of the data indicates that stormwater runoff from the agricultural portion of the watershed contributes the majority of the TP load to Cayuga Lake.

Septic system loading has been estimated to be 1% of the annual TP load, and the highest septic system density surrounding Cayuga Lake is found at the mid-south and mid-eastern portion of the lake shoreline (**Figure 24b**).

Phosphorus attributable to natural areas such as forests (6% of total annual TP load) and streambank erosion is generally in the form of particulate-bound phosphorus that is substantially less biologically available than dissolved phosphorus associated with agricultural runoff and septic system effluent.

Point sources have been estimated to contribute 8% of the annual TP load to Cayuga Lake. The point sources included in the LENS screening were surface water discharges from wastewater treatment plants within the Cayuga Lake watershed and LSC. Other permitted discharges that discharge to surface water and groundwater (for example, Municipal Separate Storm Sewer Systems [MS4s], Multi-Sector General Permits [MSGPs], CAFOs, or Private, Commercial and Institutional [PCI] State Pollution Discharge Elimination System [SPDES] permits) were not included in the screening tool.

It should be noted that NYSDEC's LENS tool is a screening tool and is intended to be used to assess the relative load contributions by source to help determine the most appropriate watershed management approach and support prioritization of projects. It is a simple steady state model that uses average, assumed conditions and estimated average annual loads from nonpoint sources and point sources. The LENS tool uses the most recent data for the National Land Cover Dataset, septic information collected by NYS Office of Real Property and Tax, and SPDES permit and discharge monitoring report information. An additional source of uncertainty regarding nutrient input includes waterfowl.

Also noteworthy is that 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, nor does it 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 external loading estimates presented above for Cayuga Lake should be interpreted with caution. The TMDL being developed by NYSDEC will replace the loading assessment included in this report.

10.3 Internal Pollutant Sources

A possible data gap in our understanding of nutrient dynamics in Cayuga Lake is the role of dreissenid mussel in internal nutrient cycling. Abundant dreissenid mussels (both

zebra and quagga mussels) can increase the bioavailability of phosphorus concentrations in both nearshore and deep water zones. In particular, increased concentrations of phosphorus at depth can be mixed into the upper waters during mixing events, and can then be used for cyanobacteria growth. The TMDL completed by the NYSDEC provides a more detailed loading assessment and will provide insight into the internal loading associated with dreissenid mussels.

10.4 Summary of Priority Land Uses and Land Areas

As discussed in **Sections 10.2** and **10.3**, loading occurs predominately through nonpoint sources. Of the nonpoint sources, the majority is estimated to be from agricultural land use (80%), followed by forested (6%) and developed (6%) land uses. Note that the TMDL completed by NYSDEC will replace the loading estimates included in this report.

11. Lake Management / Water Quality Goals

The primary lake management/water quality goal for Cayuga Lake is to implement proactive management to minimize HABs through reducing nutrient input through well planned targeted nutrient reduction strategies from **all contributing sources** within the watershed. The necessary reductions will be stipulated in the TMDL. Specific strategies and recommended actions aimed at achieving Cayuga Lake water quality goals are detailed in **Section 13**.

12. Summary of Management Actions to Date

12.1 Local Management Actions

During the late 1990s, the Cayuga Lake Watershed IO, a voluntary partnership of 31 villages, towns, cities and counties in the Cayuga Lake watershed, initiated a collaborative management plan and planning process for the watershed (The Network 2018b, NYSDEC 2018b). The original Cayuga Lake Watershed Restoration and Protection Plan (RPP) was issued in 2001 through a partnership between local municipalities, community groups, interested citizens, and regional planning boards (NYSDEC 2018b). The main purpose of the RPP is to serve as a working guide for stakeholders to manage Cayuga Lake's water resources (NYSDEC 2018b). An updated version of the RPP was completed in March of 2017, and was prepared by the Cayuga Lake Watershed Network (The Network 2017). Since the original RPP was issued, new challenges have arisen stemming from climate change and extreme weather (The Network 2017). However, the main purpose of the RPP remains the same.

As part of the requirements for the Lake Source Cooling (LSC) facility SPDES permit, the CLMP was completed. The intent of the project was to provide information about the sources and fate of phosphorus in Cayuga Lake and to develop a lake-wide water

quality model. The NYSDEC will use the model to develop the TMDL calculations to address phosphorus impairment in the southern end segment while also protecting the entire lake.

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 is 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. Districts within the Cayuga Lake watershed include Cayuga, Seneca, Schuyler, Tompkins, and Cortland. Each district incorporates the fundamental AEM goals and objectives in their plans and then further prioritizes their individual planning efforts to meet the local community and environmental needs of their individual county. Each district’s unique AEM strategic plan plays an important role in protecting and enhancing water quality in the associated watershed. The tiered process is as follows (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
 - **Tier 5B:** Plan evaluation/update, BMP system evaluation

Many AEM-sponsored activities have been undertaken within the Cayuga Lake watershed to address important environmental challenges including improving water quality (**Table 9**).

Table 9. Total number of AEM projects conducted in the Cayuga Lake watershed (2011-2017).							
	Tier 1	Tier 2	Tier 3A	Tier 3B	Tier 4	Tier 5A	Tier 5B
Total number of AEM projects	158	128	57	12	50	18	28

12.3 Funded Projects

Funded projects include those facilitated by programs specifically targeting water quality improvement and the agricultural community in New York State, such as the Water Quality Improvement Program (WQIP) and the Agricultural Nonpoint Source Abatement

and Control (ANSACP) program. Examples of BMP systems implemented that contribute to an improvement in water quality include barnyard runoff management, protection of critical areas, nutrient management, pasture management, silage leachate control, composting, pesticide management, riparian buffers, erosion control, and manure storage systems.

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 SPDES program was authorized to maintain reasonable standards of purity for state waters.

Cayuga Lake watershed is located within NYSDEC Region 7. Permits issued through the SPDES program include general permits and individual permits (including wastewater treatment facilities) that discharge to surface and groundwater within the Cayuga Lake watershed. Several wastewater treatment plants and the LCS discharge directly into Cayuga Lake (NYSDEC 2018h).

For more information about NYSDEC's SPDES program and to view MSGP, CAFO and Individual SPDES permits issued in the Cayuga Lake watershed, visit <http://www.dec.ny.gov/permits/6054.html>.

12.5 Research Activities

As stated in **Section 5.1**, the Finger Lakes Institute of Hobart & William Smith Colleges collects monthly data every summer on eight Finger Lakes including Cayuga Lake. The NYSDEC is also developing a TMDL to address the phosphorus impairment to the southern end of Cayuga Lake. Though the TMDL is focused on water quality in the south end of the lake, the watershed approach to TMDL development is expected to benefit the lake as a whole (DEC/DOW, BWRM, January 2016).

Initial review of Finger Lakes water quality datasets in early 2017 showed that almost no data had been gathered on the state of the lakes in wintertime (November to April). Additional data collection during the winter months may provide additional information on overall water quality and potential for HABs formation during the growing season.

Staff from NYSDEC's Finger Lakes Water Hub, a Region 7-based group focused on HABs and other water quality threats in the Finger Lakes Region, collected water quality samples in February and April 2018 on all eleven Finger Lakes. These sampling efforts were undertaken to characterize important indicators of lake health during winter-early spring and to provide early-year information that can be used for HABs management planning. Temperature, conductivity, pH, dissolved oxygen, and chlorophyll were measured from the surface to the bottom of the lake using a YSI probe; Secchi depth also was recorded. Water samples were collected from just below the surface (1.5-meter depth) and at two-thirds of the total depth at one CSLAP site on each lake for analysis of the standard CSLAP parameters (e.g., TP, TN, NO_x, ammonia, chloride,

calcium, and chlorophyll-a). Samples were either collected from a boat or through the ice. For lakes with surface ice, samples were collected through a hole created by hand-auguring through up to 12 inches of ice. In addition to monitoring water quality, samples also were collected for researchers at SUNY ESF for analysis of algal toxins, zooplankton and phytoplankton, and lake sediments.

While data analysis is ongoing, highlights of observations in the field include: inverse stratification (warmer at the bottom than the top) in the ice-covered lakes, while those remaining ice-free were isothermal (all the same temperature) and well mixed; dissolved oxygen was lower, although not hypoxic, in the lower third of Honeoye and Canadice lakes than the surface during ice cover, whereas the remaining lakes were well oxygenated, even those under ice; and water clarity was generally high with Secchi depths greater than 15 m in both Skaneateles and Seneca lakes (both are generally less than 10 m during the growing season).

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

Clean water plans are a watershed-based approach to outline a strategy to improve or protect water quality. 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 303(d) 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 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).

9E 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 303(d) impaired waters list to initiate a 9E Plan.

The southern section of Cayuga Lake is included on Part 1 of the NYS 2008 Section 303(d) List of Impaired Waters (first listed in 2002), requiring the development of a TMDL or other strategy to address impairments due to phosphorus and silt/sediment. The NYSDEC will apply the Cayuga Lake Model developed by Upstate Freshwater Institute, as part of the Lake Source Cooling SPDES permit requirements, to calculate acceptable phosphorus loadings (TMDL) from various sources into Cayuga Lake. The NYSDEC has held several public meetings to update stakeholders regarding the ongoing Cayuga Lake Modeling Project and phosphorus TMDL efforts. The Cayuga Lake Model is still under review, and the NYSDEC is working with the USEPA to revise a TMDL timeline (NYSDEC 2018i).

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 F**.

For more information about climate change visit DEC'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](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 have worked cooperatively to identify, assess feasibility and costs, and prioritize both in-lake, if applicable, and watershed management strategies aimed at reducing HABs in Cayuga Lake.

Steering committee members:

- Kathleen Cuddy, Cayuga County Health Department
- Doug Kierst, Cayuga County Soil and Water Conservation District (SWCD)
- Steve Lynch, Cayuga County Water Quality Management Agency
- Darby Kiley, Cayuga County Water Resources Council
- Roxanna Johnston, Cayuga Lake Monitoring Partnership
- Tee-Ann Hunter, Cayuga Lake Watershed Intermunicipal Organization
- Hilary Lambert, Cayuga Lake Watershed Network
- Amanda Barber, Cortland County SWCD
- Zack Odell, Finger Lakes Land Trust
- PJ Emerick, NYSDAM
- Karen Stainbrook, NYSDEC
- Matt Kazmierski, NYSDEC
- Pradeep Jangbari, NYSDEC
- Tony Prestigiacomio, NYSDEC
- Keleigh Reynolds, NYSDOH
- Jerry Verringni, Schuyler County SWCD
- Vickie Swinehart, Seneca County Health Department
- James Malyj, Seneca County SWCD
- Liz Cameron, Tompkins County Health Department
- Jon Negley, Tompkins County SWCD
- John Fleming, Walnut Ridge Dairy

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 Cayuga Lake.
2. *Watershed management actions:* Address watershed inputs that influence in-lake conditions that support HABs.

As described throughout this Action Plan, the primary factors that contribute to HABs in Cayuga Lake are nonpoint source sediment and nutrient inputs from the contributing watershed (e.g., agricultural lands, stormwater runoff from developed lands, road ditches). The focus of implementation actions are nonpoint sources. The implementation section of the upcoming Total Maximum Daily Load (TMDL), being conducted by NYSDEC, will address both nonpoint source and point sources within the Cayuga Lake watershed, and will be consistent with this Action Plan's implementation section.

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, funding match, 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 implementation 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 treatment 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 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.

13.3 Cayuga Lake Priority Projects

13.3.1 Priority 1 Projects

Priority 1 projects are considered necessary to manage water quality and reduce HABs in Cayuga Lake, and implementation should be evaluated to begin as soon as possible.

Short-term (3 years)

1. Implement runoff reduction BMPs on agricultural and non-agricultural lands to reduce nutrient runoff and soil erosion in the watershed. These BMPs would be implemented by local SWCDs and other partners, and include:
 - Implementation of cover crops on cropland that is prone to erosion and nutrient runoff when left unprotected. Cover crops are a specific type of vegetative cover that is carefully planted on a field that would otherwise be left bare after a cash crop is harvested. A cover crop diffuses heavy rainfall, protecting the soil surface from erosion. In addition, a cover crop allows for living roots to be present throughout much of the year adding rich organic matter to the soil and trapping nutrients that would otherwise be prone to runoff if the soil is left bare after harvest.
 - Field erosion control systems (grassed waterways, shaping and grading, and water and sediment control basins (WASCoBs) to promote stormwater retention and minimize concentrated runoff (e.g., rills, gullies).

- Stabilization of drainage swales through establishment of vegetation and/or installation of check dams.
 - Stream bank stabilization using both hard armoring and natural stream design methods to lessen the potential for severe and sudden sedimentation from large and/or re-occurring storm events.
 - Installation of control facilities at the outlets of drainage swales (prior to entering the lake or tributaries) to promote sediment and nutrient capture.
 - Implement runoff reduction BMPs for farmsteads: roof runoff management, barnyards, laneways/access roads, and bunk silos.
 - Conduct a pilot test on drainage tile BMPs.
 - Establish vegetated riparian buffers to inhibit or reduce nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams.
 - Rehabilitate degraded vegetated buffers to improve riparian habitat function on tributaries to Cayuga Lake.
2. Implement roadside ditch and culvert improvement projects on currently failing ditch systems to reduce and capture sediment. Best management practices could include:
- Timing of cleanout to minimize soil erosion
 - Properly sizing culverts and channels to avoid headcuts and other erosion.
 - Use of erosion control practices to assist in ditch stabilization
 - Installation of check dams or other facilities to reduce flow velocities, minimize erosion, and promote sedimentation

Mid-term (3 to 5 years)

1. Increase SWCD staffing through appropriations to focus capacity to plan and implement projects (e.g., planners, engineers, technical staff) to mitigate soil erosion and reduce nutrient pollution in subwatersheds through all counties that drain to Cayuga Lake.
2. Implement Agricultural Environmental Management (AEM) Tier 3A Resource Management Plans to reduce sediment and nutrient runoff on crop farms and AEM Tier 3A Nutrient Management Plans (NMPs) on non-Concentrated Animal Feeding Operation (CAFO) beef/dairy operations.
3. Establish a program to monitor, inspect, and sample existing septic systems within the Cayuga Lake watershed to maximize the functional capacity of these systems and minimize nutrient contribution.
 - Replace septic systems within the Cayuga Lake watershed, with priority to those systems identified as deficient in the above program, and are within 250 ft. of Cayuga Lake or tributaries. Cayuga Lake and the Cayuga Lake Watershed counties are participating in the statewide septic repair

program, with funding provided by the counties, administered through EFC.

4. Build capacity of SWCDs in the Cayuga Lake watershed to implement erosion and sediment control measures on agricultural and non-agricultural lands through purchase of conservation equipment. Equipment can be owned and operated by one or more SWCDs and shared across SWCD and municipalities. Needed equipment includes:
 - Bark blowers to effectively mulch soils and stabilize large highly erodible critical areas
 - Wood waste recycling equipment to convert municipal and culvert debris into useful material
 - Specialized seeders for cover crop applications, including independent Highboy seeders or high horsepower tractors for tow behind models
 - Straw mulchers
 - Hydroseeders
 - Manure handling equipment (injection, boom spreader, drag line for immediate incorporation of manure to minimize runoff potential).
5. Implement a comprehensive municipal stormwater program, including hydraulic evaluation and mapping of drainage, as well as the replacement and upgrade of subsurface drainage and culverts to provide improved separation of stormwater from freshwater resources. This project is envisioned to be a collaborative effort among SWCDs and municipalities in the Cayuga Lake watershed.
6. Install stream stabilization facilities (e.g., log or stone revetments or vanes, vegetated riparian buffers) on select tributaries, as identified by local SWCDs and municipalities or other relevant stakeholders, where bed and bank erosion is contributing significant sediment nutrient loads.
7. Plant trees and shrubs, on available municipal lands and willing landowner properties, along the lake shoreline and along tributaries (e.g., Trees for Tribs program) to stabilize riparian habitat and to reduce solar heat load.
8. Implement livestock exclusion programs to reduce livestock direct access to waterbodies.
9. Implement manure management techniques, to be conducted by, but not limited to, local SWCDs, including:
 - Manure incorporation and spreading equipment to minimize runoff potential
 - Manure cover and flare storage systems with solid-liquid separation to expand existing storage capacity and open up extended farmer options for nutrient management

- Satellite manure storage systems to be able to efficiently recycle/incorporate manure on fields located off site from farmsteads
 - Manure storage and transfer lines to implement AEM Tier 3B Comprehensive Nutrient Management Plans designed to recycle manure and other farm nutrients to maximize soil health and crop uptake while minimizing runoff to Cayuga Lake.
10. Acquire and conserve lands within the watershed to protect and maintain existing buffers before increased subdivision and land conversion impacts these functioning systems.

Long-term (5 to 10 years)

1. Acquire and conserve lands within the watershed to reduce existing or future land use impacts on water quality. Potential parcels may include areas to protect established riparian buffer areas, sensitive riparian settings, increase/expand contiguous buffered areas, and/or that offer protection of extensive natural areas providing water quality benefits. Initial analysis and prioritization of acquisition projects is important for selecting lands best situated to provide lasting conservation and water quality benefits.
2. Construct wetlands or enhance/restore existing wetlands within the watershed to reduce nutrient and sediment loads. **Figure 25** shows the locations within the Cayuga Lake watershed that have either hydric, very poor, or poorly drained soils, but are not currently mapped wetland habitats according to 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.
3. Investigate the ability to complete a feasibility study to install municipal sanitary sewer infrastructure to service residences in Seneca County to reduce septic system input to Cayuga Lake in that area. A local municipality could pursue funding through EFC's Engineering Planning Grant to complete feasibility study.
4. Investigate and develop a feasibility study to install municipal sanitary sewer infrastructure to address the homes on Honoco and Lake Roads in the Towns of Ledyard and Genoa. A local municipality could pursue funding through EFC's Engineering Planning Grant to complete feasibility study.
5. Map field drainage tile lines (underground pipes that drain and convey excess soil and water for crop cultivation), where practical, used for agricultural purposes to build a database, conduct a pilot program to test for nutrients, and implement BMPs for tile drain water retention and treatment. This project may be led by, but not limited to, local SWCDs.

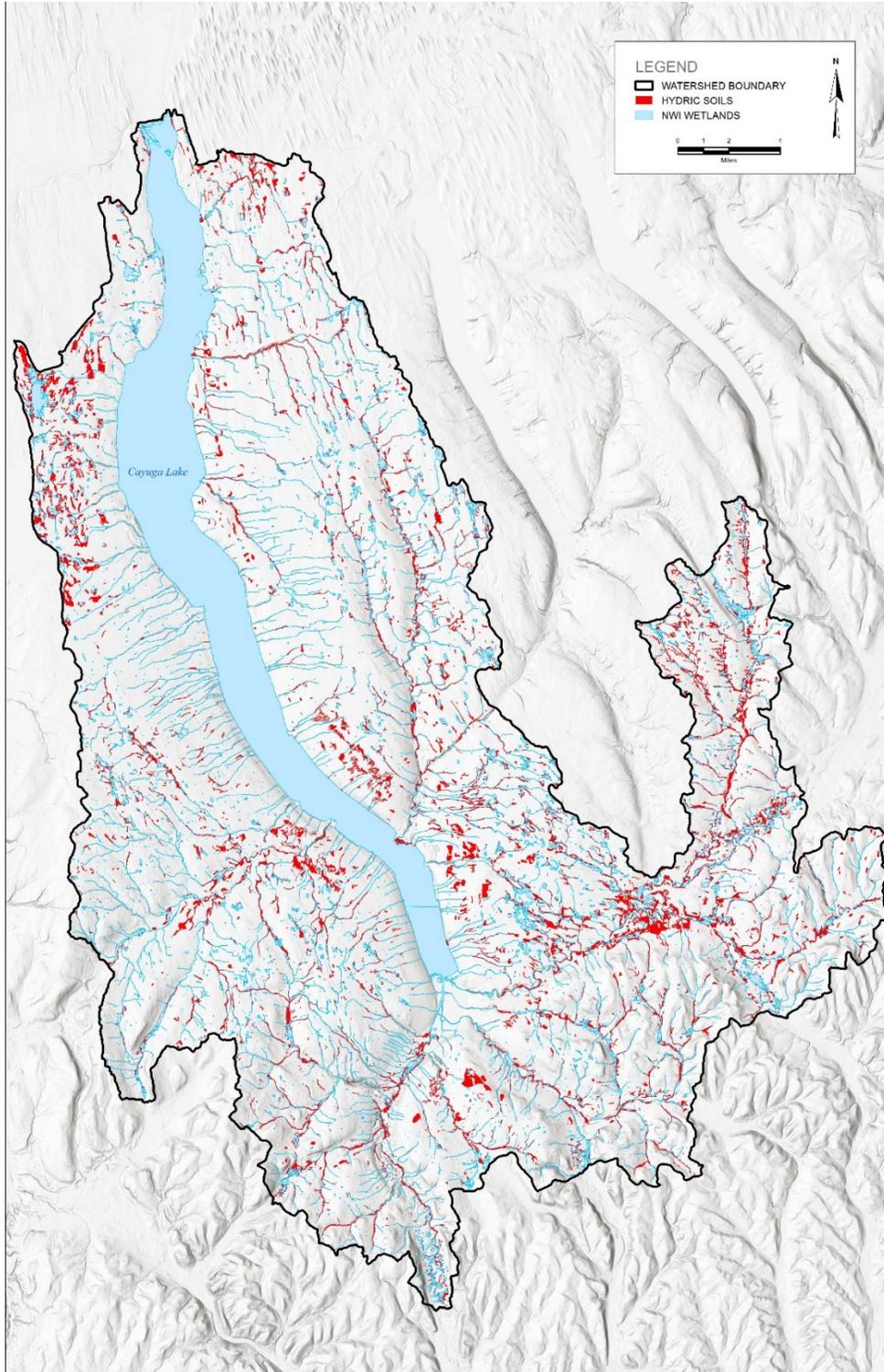


Figure 25. Locations (depicted in red) of either hydric, very poor, or poorly drained soils in the Cayuga Lake watershed, which are not mapped as wetlands per the National Wetland Inventory (NWI).

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. Conduct an interseeder pilot study to evaluate its effectiveness, such as farmer demand and accessibility across the entire watershed, growth and vigor of interseeded cover crops with different cropping systems, and nutrient/sediment potential. This project may be conducted by organizations such as the SWCDs.
2. Purchase and utilize UAVs (drones) according to rules, regulations, and policies for inventory of BMPs. This project may be conducted by local SWCDs, however, in-house resources within NYSDEC may also be considered.

Mid-term (3 to 5 years)

1. Increase staffing for the Stormwater Coalition of Tompkins County Municipal Separate Storm Sewer Systems (MS4) communities to expand the group's capacity to implement measures such as public education and outreach, pre- and post-construction site runoff control, illicit discharge detection and elimination, and pollution control techniques.
2. Increase SWCD staffing to develop nutrient management plans for non-CAFO farms and to assist small non-CAFO farms to plan and implement BMPs.

Long-term (5 to 10 years)

1. Increase SWCD staffing to assist with mapping and monitoring projects. Improve education and outreach regarding stormwater management (including MS4 programs) and agricultural BMPs.

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. Efforts to control stormwater should emphasize phosphorus control (BMPs) at the source (not all "end of pipe" solutions) and targeting areas with high levels of phosphorus runoff. Emphasis should be placed on locations within the Cayuga Lake watershed that have a combination of relatively high percentages of impervious cover, small lot sizes, and/or compacted soils. This may be completed by municipalities.
2. Develop a regional nursery/greenhouse that can be used to raise conservation plantings for use throughout the watershed. A tree planting program can then be established where fresh tree and shrub stock could be used for:

- Creating vegetated buffers along the lake shoreline and along tributaries (e.g., Trees for Tribes program) to stabilize riparian habitat
 - Landscape plantings in urban areas
 - Plantings associated with green infrastructure projects
3. Develop curriculum for K-12 to educate students about water resources, nutrient pollution, harmful algal blooms, and personal and community actions that can help reduce nutrient pollution to waterbodies.

13.5 In-Lake Management Actions

Internal loading in Cayuga Lake is unconfirmed, thus in-lake management actions are not currently recommended. There is no direct evidence (such as dissolved oxygen [DO] monitoring for the large shallow shelf at the north end of the lake) available to support or refute the possibility of internal loading as a driver for the observed high chlorophyll-a at the north end of the lake.

13.6 Monitoring Actions

To help determine the stresses that lead to potential HABs in Cayuga Lake and to assess improvements associated with management actions, the following monitoring actions are recommended for evaluation:

Short-term

1. Develop a HAB monitoring network covering multiple portions of Cayuga Lake.
2. Supplement the understanding of the cyanobacteria species that are prevalent in Cayuga Lake. Additionally, a greater temporal resolution of algal density in Cayuga Lake could help to identify seasonal trends and inform management strategies.
3. Maintain and enhance community and/or volunteer monitoring efforts of water quality conditions in the lake, particularly during the growing season. Align in-lake water quality data collection efforts with overpasses of NASA's Landsat 8 satellite (**Table 10**), to the extent possible. This alignment will allow for the effective use of satellite imagery when characterizing lake conditions based on corresponding field data.
4. Expand CSLAP sampling locations to nearshore zones. Current sample locations are offshore and may not provide the most useful data and information for identifying area-specific triggers for HABs in the lake. Water sample analyses should include at a minimum: total phosphorus, total dissolved phosphorus, total nitrogen, temperature, pH and alkalinity.

TABLE 10. LANDSAT 8 OVERPASSES OF CAYUGA LAKE FROM MAY THROUGH OCTOBER, 2018.

MONTH	Dates			
MAY	May 5	May 12	May 21	May 28
JUNE	June 6	June 13	June 22	June 29
JULY	July 8	July 15	July 24	July 31
AUGUST	August 9	August 16	August 25	
SEPTEMBER	September 1	September 10	September 17	September 26
OCTOBER	October 3	October 12	October 19	October 28

5. Collect additional DO data and develop depth profiles for each sub-basin within Cayuga Lake.
6. Conduct comprehensive tributary monitoring in portions of the Cayuga Lake watershed to better understand nutrient loading as a function of watershed conditions. Supplement volunteer’s activities with NYSDEC follow up.
7. Identify certified laboratories where water samples can be sent to locally to streamline the testing process and response.

Long-term

1. Develop and maintain long term monitoring (decadal) programs in-lake and in the watershed to provide valuable data in the assessment of future water quality and trends.

13.7 Research Actions

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 the water quality within Cayuga Lake. 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.

The NYSDEC should encourage and support research into management options for dreissenids and better understanding of their natural population cycles.

13.8 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

1. Encourage public participation in initiatives for reducing phosphorus and documenting/tracking HABS, such as volunteer monitoring networks and/or increasing awareness of procedures to report HABS to NYSDEC.
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 involved personnel to underscore the importance of water quality protection as well as associated tools and strategies.

Long-term

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. Support Land Trusts through volunteering and financial support to facilitate land protection measures and purchases/acquisitions of conservation preserves within the Cayuga Lake watershed.
3. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.
4. Coordinate with Department of Health to support the local health departments to implement onsite septic replacement and inspection activities.

5. 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.
6. Support evaluation of watershed rules and regulations.

13.9 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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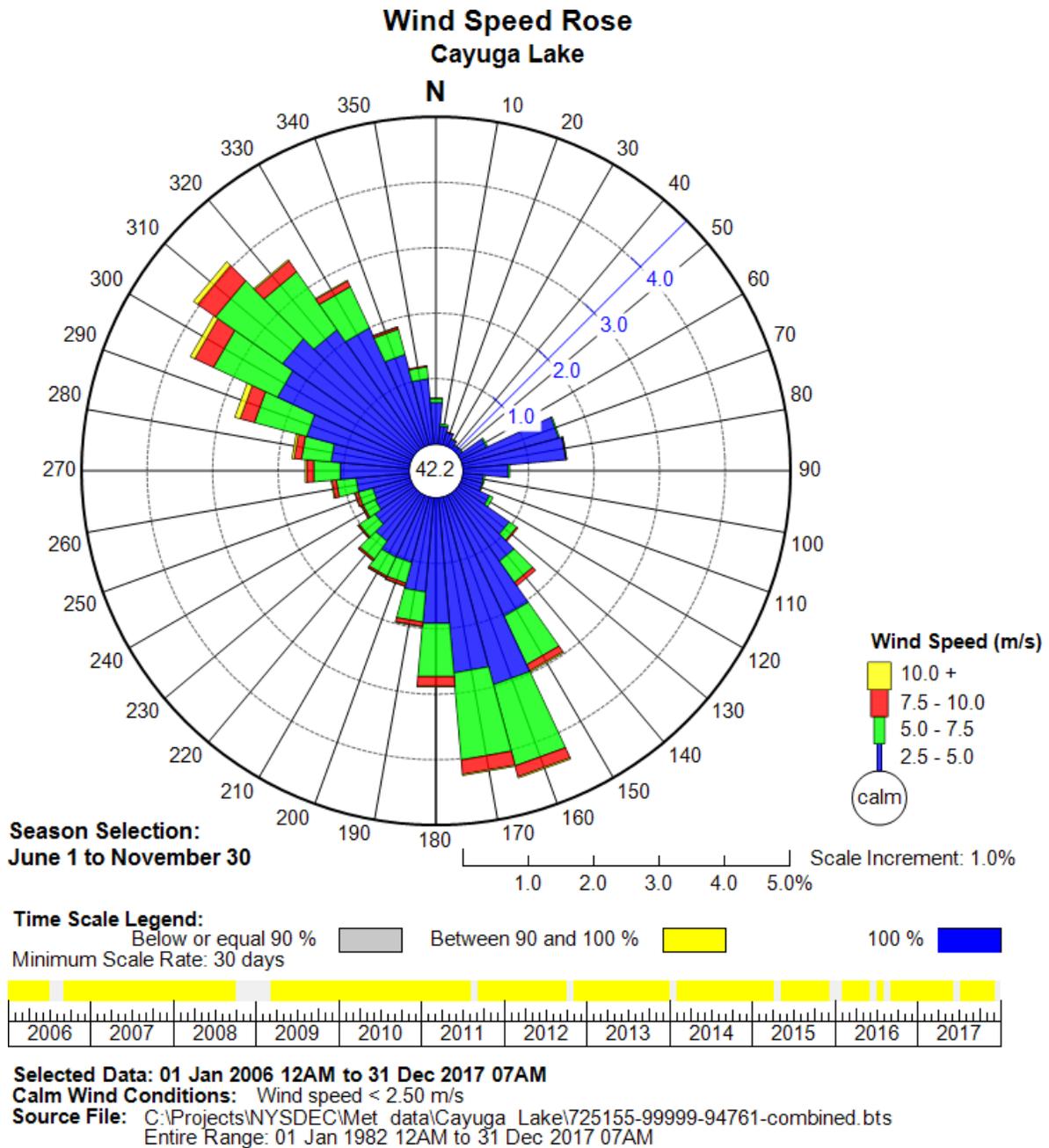
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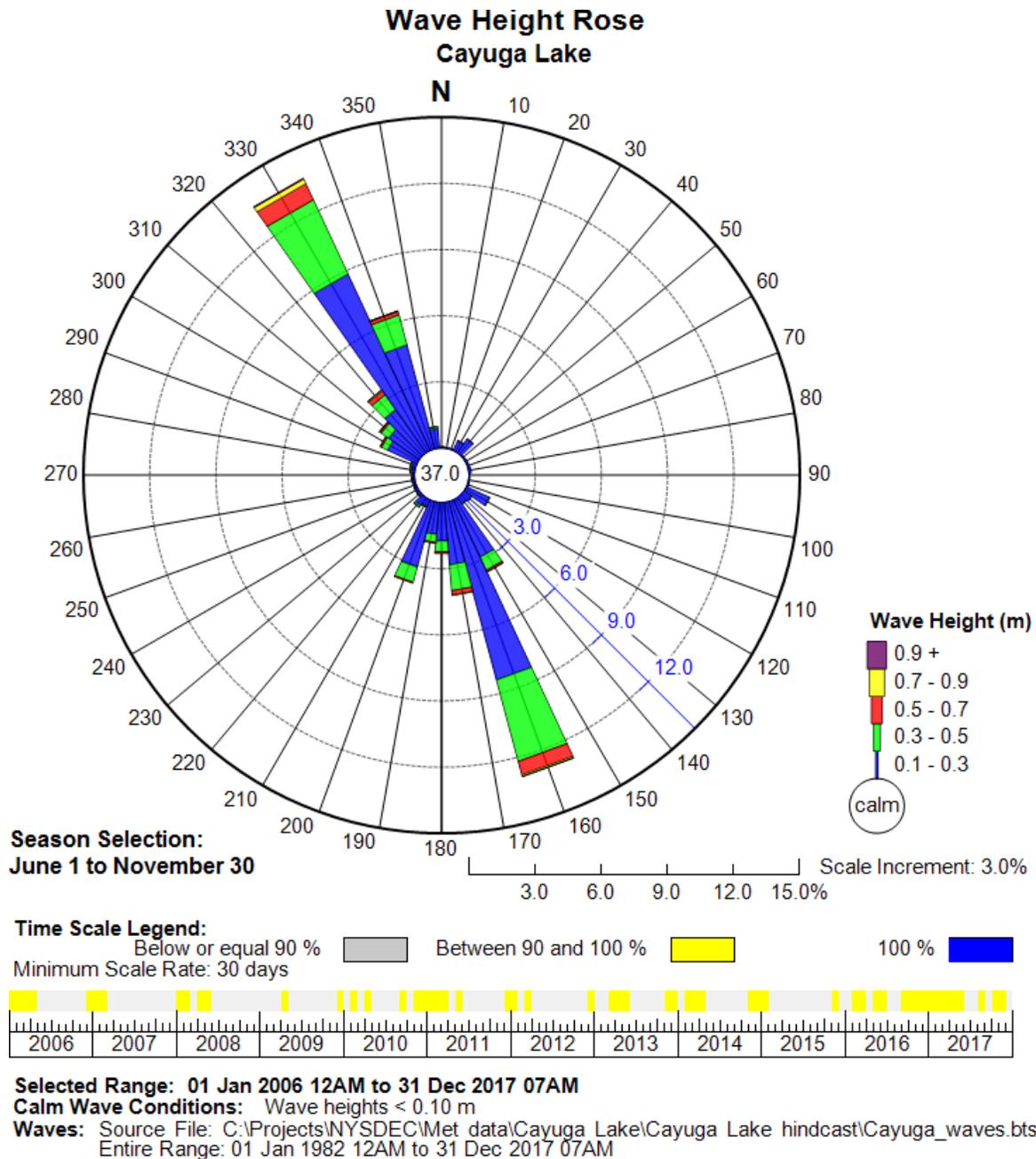
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Appendix A. Wind and Wave Patterns



Wind speeds at Cayuga Lake from 2006 to 2017, during the months of June through November, indicate that stronger winds were generally out of the northwest, and south-southeast.



Wave height patterns from 2006 to 2017, during the months of June through November, indicate wave heights were greater in the northwestern and southeastern portions of Cayuga Lake.

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. Remote Sensing Methodology

Relative chlorophyll-a concentrations were estimated for eight water bodies using remote sensing methods. The analysis involved processing the spectral wavelengths of satellite imagery to estimate the amount of chlorophyll-a at the water surface. The analysis is based on the ratios of reflected and absorbed light for discrete spectral bands (i.e. blue, green, and red) and is thus a measure of green particles near the water surface.

The analysis was completed for seven water bodies, with dimension larger than 1 km in both length and width. These include: Conesus Lake, Honeoye Lake, Chautauqua Lake, Owasco Lake, Lake Champlain, Lake George, and Cayuga Lake.

The remote sensing analysis provides an overview of the spatial distribution and relative concentration of chlorophyll-a on specific dates. Imagery was acquired for the past three summer seasons (2015-2017) to gain a better understanding of the development of chlorophyll-a concentrations over the summer and potential Harmful Algal Bloom (HAB) triggers. This information may be used to:

- Understand the spatial extent, temporal coverage, and magnitude of historical HAB events;
- Identify regions of each lake susceptible to HABs due to the location of point source inputs, prevailing winds, etc.;
- Identify conditions which may trigger a HAB (e.g. rainfall, temperature, solar radiation, wind, water chemistry, etc.);
- Guide monitoring plans such as location and frequency of in-situ measurements;
- Guide the development of water quality assessment programs, for which HAB extent, intensity, and duration are relevant;
- Guide management plans such as prioritizing remedial actions, locating new facilities (e.g. water intakes, parks, beaches, residential development, etc.) and targeting in-lake management efforts.

At this time, the estimated chlorophyll-a concentrations are reported as a concentration index due to the limited number of in-situ measurements (+/- 1 day of the satellite images) to calibrate the method. Chlorophyll-a concentrations can be quantified using this method, but more in-situ data is required from New York State lakes to calibrate/validate the method. Once the calibration/validation is completed, the quantified chlorophyll-a concentrations would give an improved understanding of the spatial and temporal dynamics of chlorophyll-a concentrations.

Analysis could be conducted to estimate cyanobacteria in addition to chlorophyll-a. However, there are a lot less cyanobacteria measured data than chlorophyll-a. As more

measured cyanobacteria concentration data becomes available, remote sensing analysis of cyanobacteria could be investigated.

Overview of the Method

Chlorophyll-a concentrations were estimated using a remote sensing algorithm/model developed by the University of Massachusetts (Trescott 2012) for Lake Champlain. The model was calibrated and cross-validated using four years of in-situ chlorophyll-a measurements from fifteen locations on the lake. The samples were collected from the water surface to a depth equal to twice the Secchi depth.

Chlorophyll-a has a maximum spectral reflectance in the green wavelength (~560 nm) and absorbance peaks in the blue and red wavelengths (~450 nm & ~680 nm). There is an additional secondary reflectance peak in the near infrared spectrum at ~700 nm that was not incorporated in the University of Massachusetts study². The model was then calibrated and cross-validated to field data collected within one day of the satellite overpasses using only images with clear skies. This was done to minimize the uncertainty and complexity with atmospheric correction for the satellite imagery. The chlorophyll-a model developed for Lake Champlain using Landsat 7 color bands is shown in Eq. 1.

$$Chla = -46.51 + 105.30 \left(\frac{RB_{green}}{RB_{blue}} \right) - 40.39 \left(\frac{RB_{red}}{RB_{blue}} \right) \quad [Eq. 1]$$

The model has a coefficient of determination (R^2) of 0.78, which indicates that 78% of the variation in measured chlorophyll-a can be explained by Eq. 1. The relationship between measured and modeled chlorophyll-a concentrations for Lake Champlain is shown in **Figure C1**.

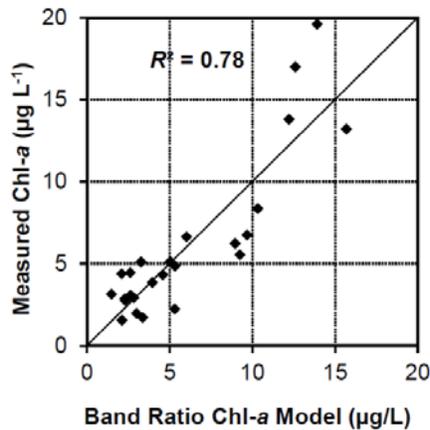


Figure C1. Measured and modeled chlorophyll-a concentrations for Lake Champlain, from Trescott 2012.

² The accuracy of the model could potentially be improved by incorporating data from the near infrared band.

Application of the Method

Landsat 8 was launched in February 2013 and provides increased spectral and radiometric resolution compared to Landsat 7. In this study, Landsat 8 imagery were downloaded from the USGS website, Earth Explorer, for the months of May through October 2015 to 2017. These scenes were visually examined for extensive cloud cover and haze over the project lakes, discarding those that had 100% cloud coverage³. The selected images were processed to Top of Atmosphere (TOA) reflectance as per the Landsat 8 Data Users Handbook (USGS 2016). TOA reflectance reduces the variability between satellite scenes captured at different dates by normalizing the solar irradiance.

The TOA corrected images were processed using the chlorophyll-a model (Eq. 1) developed for Lake Champlain using Landsat 7 imagery (Trescott 2012). The blue, green, and red spectral bands are very similar for Landsat 7 and Landsat 8 and the model was used without adjustment.

The Landsat 8 Quality Assessment Band was used to remove areas designated as cloud or haze. However, this method is not able to remove the shadows of clouds that are seen in some of the images. Modeled chlorophyll-a concentrations may be lower in areas adjacent to cloud or haze due to less reflected light being received by the satellite sensors. The shadowed areas can be identified by their proximity, size, and shape relative areas of no data (clouds).

The modeled chlorophyll-a concentrations were clipped to the lake shorelines using a 100 m buffer of the National Hydrography Dataset (NHD) lake polygons. This step was used to exclude pixels that may overlap between land and water and possibly contain shoreline and shallow submerged aquatic vegetation. Landsat 8 spectral imagery is provided at a 30 m resolution.

A comparison of measured and modeled chlorophyll-a concentrations for five of the study lakes for 2016 and 2017 is shown in **Figure C2**. Based on the 22 field measurements that occurred within one day of the satellite imagery, the model appears to under estimate chlorophyll-a concentrations in some situations.

³ NASA's quality assurance band algorithm was used to mask out clouds and cirrus (black/no data patches on figures).

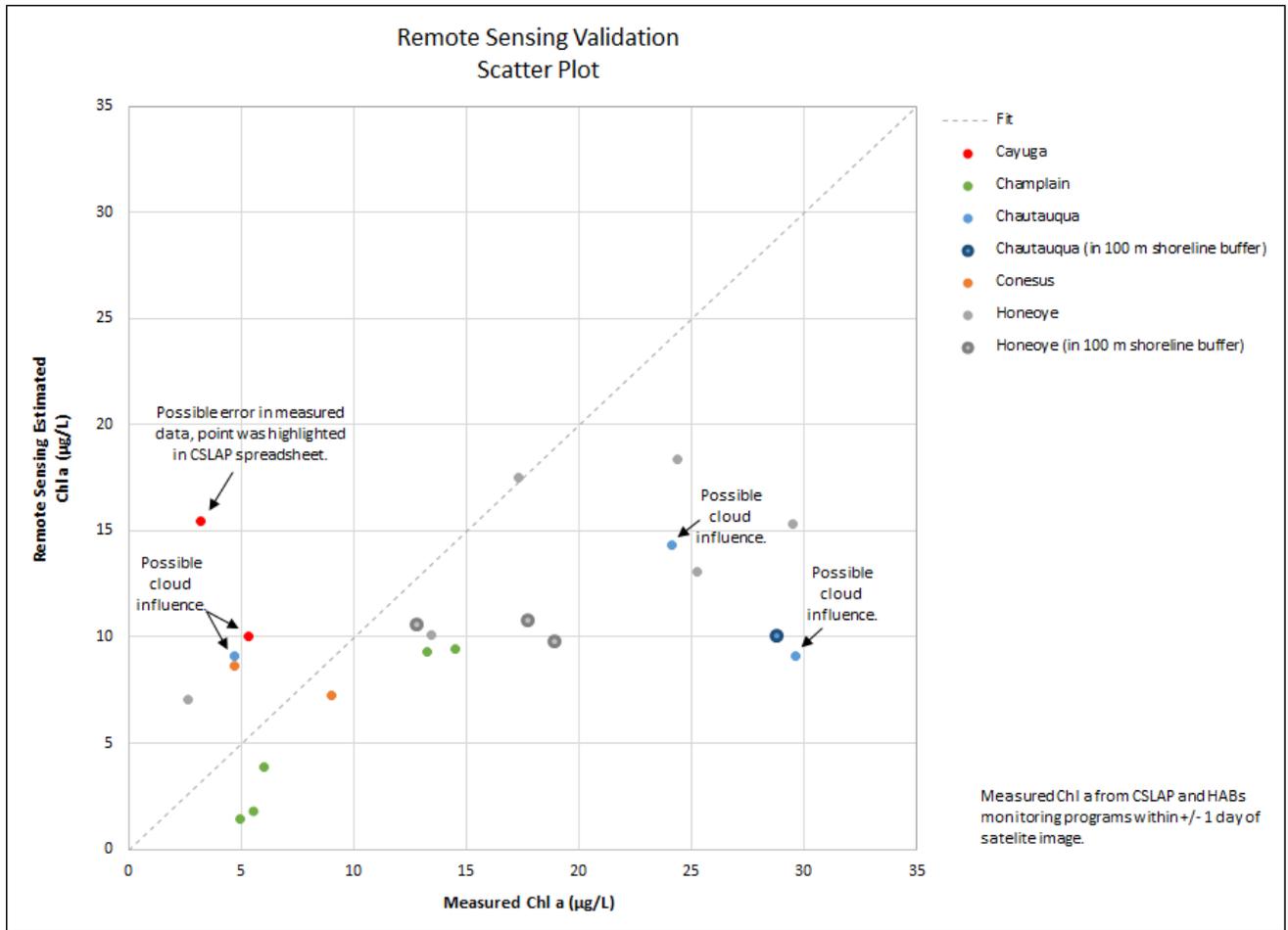


Figure C2. Measured and modeled chlorophyll-a concentrations for Cayuga Lake, Lake Champlain, Chautauqua Lake, Conesus Lake, and Honeoye Lake (2016-2017 data).

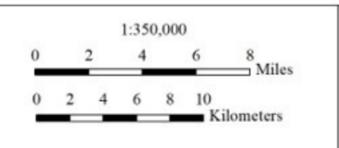
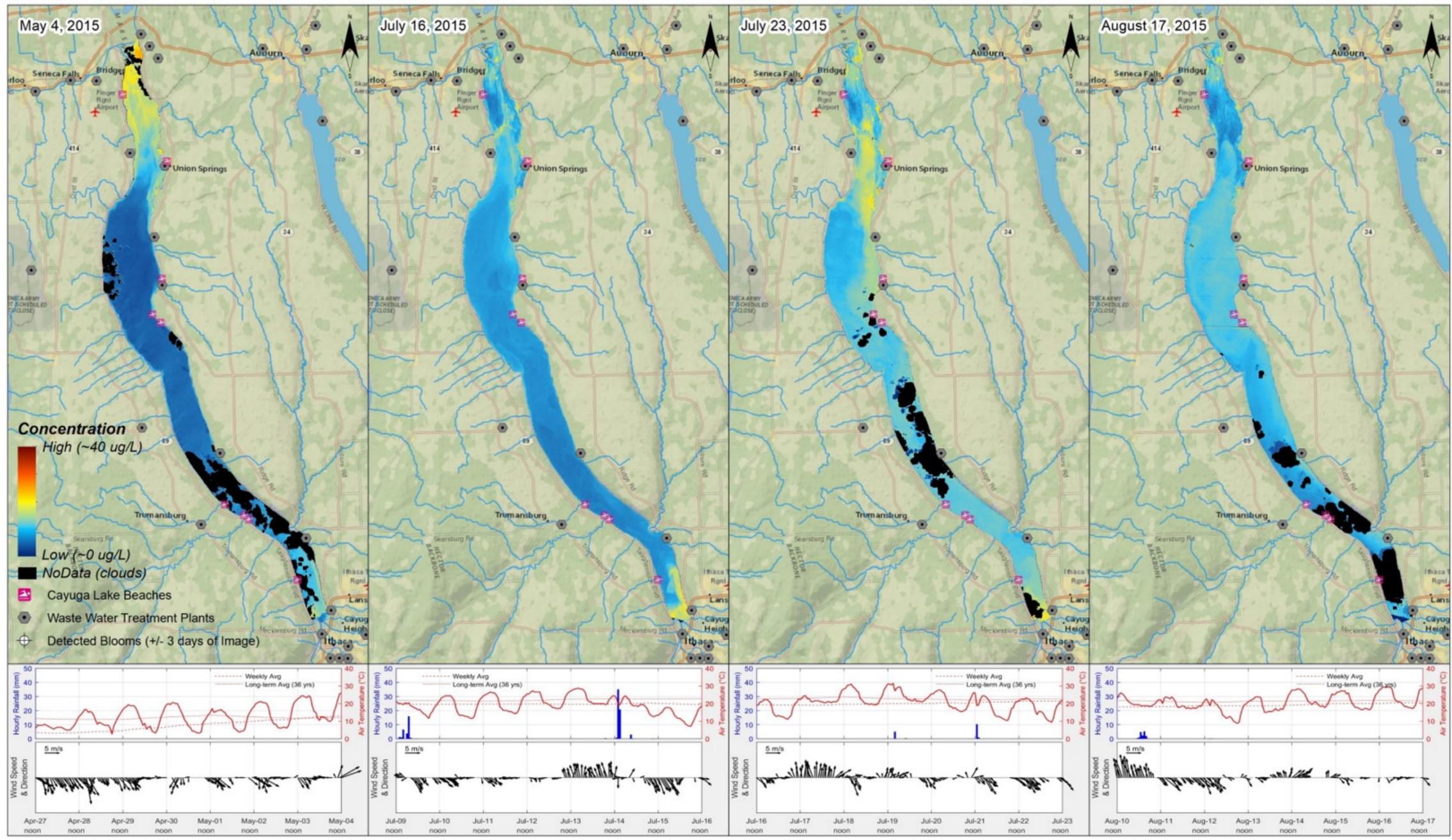
Limitations of the Method

The remote sensing chlorophyll-a model was developed for Lake Champlain using four years of coincident in-situ chlorophyll-a measurements and Landsat 7 imagery. The model was calibrated and cross-validated using samples that were collected within one day of the satellite overpasses and imagery that was free of cloud and haze. The maximum in-situ chlorophyll-a concentration was 20 µg/L.

The method was applied to eight freshwater lakes in New York State (including Lake Champlain). These lakes have excess phosphorus loading from sources similar to Lake Champlain, including agricultural runoff and septic systems. The method is expected to be most accurate under clear sky conditions and chlorophyll-a concentrations less than 20 µg/L (until validated for higher concentrations).

Further development and application of the method to New York State lakes should consider the following:

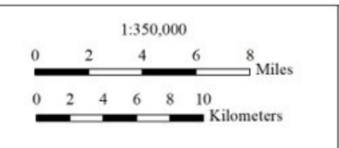
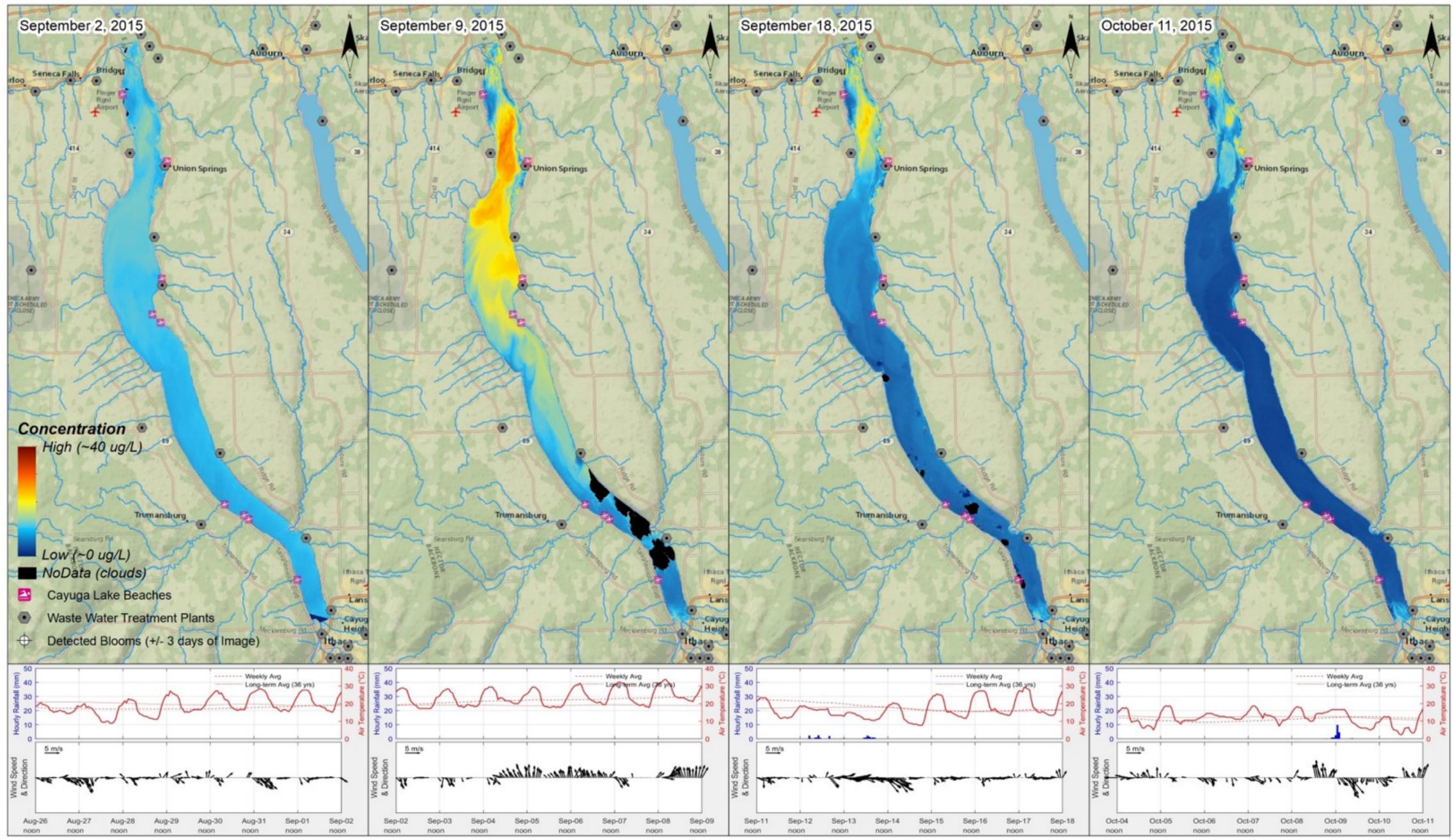
- The model estimates chlorophyll-a concentrations rather than HABs species directly. Remote sensing studies tend to use abnormally high chlorophyll-a concentrations as a first step in detecting possible HABs (Trescott 2012; USGS 2016).
- The model was developed for Lake Champlain and hasn't been fully validated for other New York State lakes. In the future, field sampling should be conducted on the dates of the Landsat 8 satellite overpasses for the lakes of interest.
- Different algae species may be present in the Lake Champlain calibration dataset than in the other New York State lakes. The model may be less accurate for the other lakes if different algae species are present.
- The model was calibrated using chlorophyll-a measurements taken within one day of the satellite overpasses as wind and precipitation are expected to change the composition of the algal blooms (Trescott 2012). Measurements greater than one day could potentially be used to validate the model for other lakes if winds were calm and there was no rain over the extended period.
- The model was developed using cloud and haze-free imagery. Estimated chlorophyll-a concentrations are expected to be less accurate when clouds and haze are present.
- The model was calibrated to depth-integrated chlorophyll-a measurements (from twice the Secchi depth to the water surface). Estimated chlorophyll-a concentrations are expected to compare better with measurements taken over the depth of light transmission (i.e. Secchi depth) than measurements taken from a predefined depth (e.g. CSLAP grab samples are collected at a water depth of 1.5 m).
- Estimated chlorophyll-a concentrations are expected to be less accurate in shallow water where light may be absorbed and reflected by submerged aquatic vegetation and the lake bed.
- The influence from turbidity caused by inorganic suspended solids on the modeled chlorophyll-a concentrations was not thoroughly investigated. However, it is unlikely to affect the results since there are distinct differences in the reflection pattern of chlorophyll-a versus inorganic turbidity (Karabult and Ceylan 2005).
- The estimated chlorophyll-a concentration from the nearest remote sensing pixel was used in the validation plot (**Figure C2**) because many of the measurements were near the shoreline. A 5-by-5 pixel averaging window was used previously for Lake Champlain (Trescott 2012) to filter the satellite noise and patchiness in the algae.



Plots
 Plots show meteorological data 7 days prior to the satellite passing over the lake.

Satellite Derived Chlorophyll a
 Chl-a Data is Derived from NASA's LandSat 8 Satellite
 Data Gaps are Caused by Haze and Clouds

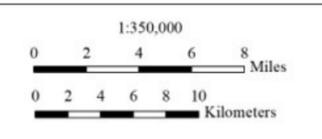
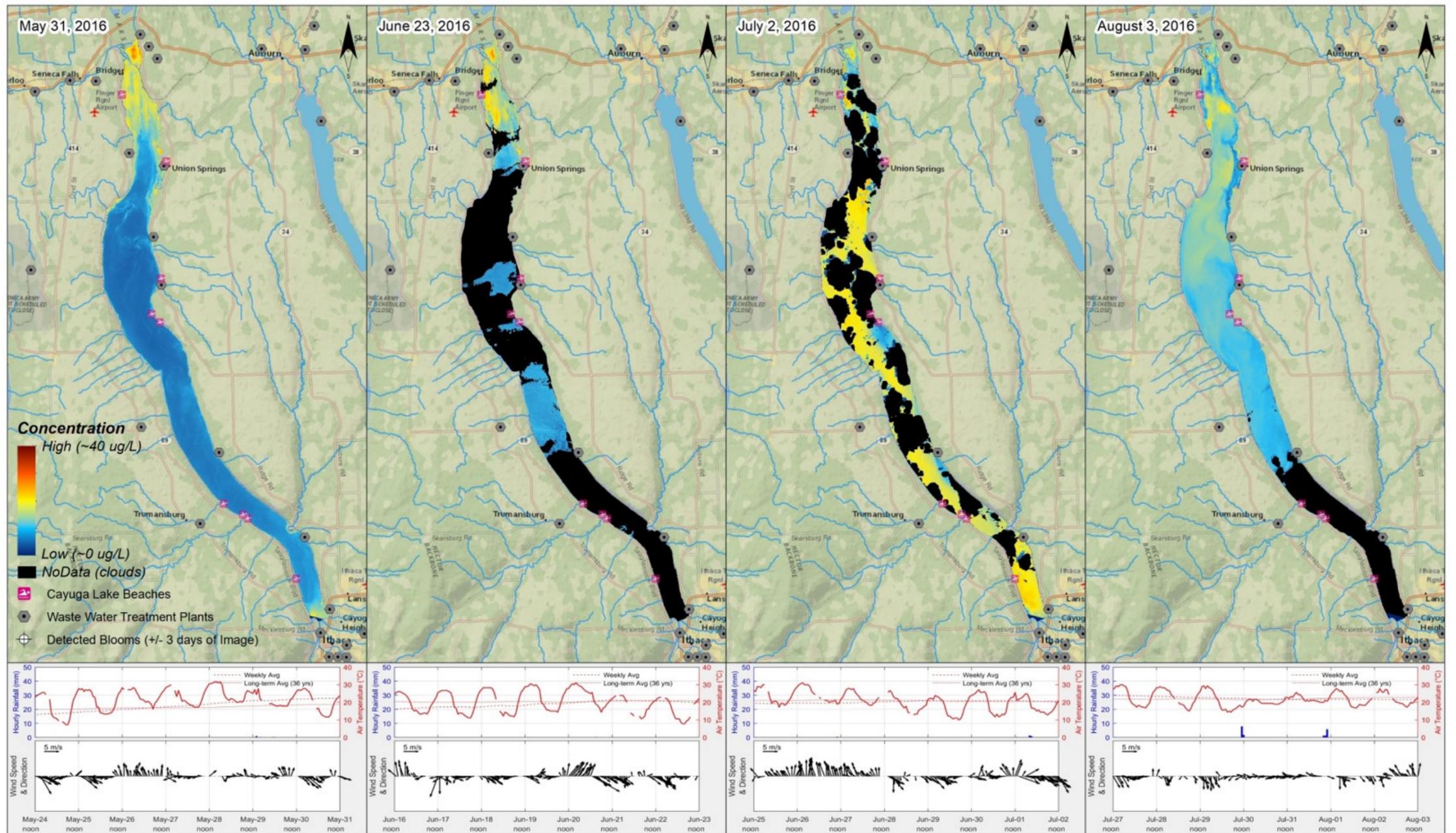
Disclaimer
 These maps represent an estimate of chlorophyll-a concentration and are meant for discussion purposes to aid in management decisions and planning.
 Basemap: National Geographic World Imagery Layer.
 Spatial Reference: WGS 1984 UTM Zone 18N



Plots
 Plots show meteorological data 7 days prior to the satellite passing over the lake.

Satellite Derived Chlorophyll a
 Chl-a Data is Derived from NASA's LandSat 8 Satellite
 Data Gaps are Caused by Haze and Clouds

Disclaimer
 These maps represent an estimate of chlorophyll-a concentration and are meant for discussion purposes to aid in management decisions and planning.
 Basemap: National Geographic World Imagery Layer.
 Spatial Reference: WGS 1984 UTM Zone 18N



Plots
 Plots show meteorological data 7 days prior to the satellite passing over the lake.

Satellite Derived Chlorophyll a
 Chl-a Data is Derived from NASA's Landsat 8 Satellite
 Data Gaps are Caused by Haze and Clouds

Disclaimer
 These maps represent an estimate of chlorophyll-a concentration and are meant for discussion purposes to aid in management decisions and planning.
 Basemap: National Geographic World Imagery Layer.
 Spatial Reference: WGS 1984 UTM Zone 18N

Appendix D. NYSDEC Water Quality Monitoring Programs

Additional information available from <http://www.dec.ny.gov/chemical/81576.html>.

Appendix E. WI/PWL Summary

Cayuga Lake, Northern End (0705-0030)

Minor Impacts

Waterbody Location Information

Revised: 05/01/2018

Water Index No:	Ont 66-12-P296 (portion 1)	Water Class:	B(T)
Hydro Unit Code:	Yawger Creek-Cayuga Lake (0414020112)	Drainage Basin:	Oswego-Seneca-Oneida
Water Type/Size:	Lake/Reservoir 888.2 Acres	Reg/County:	8/Seneca (50)

Description: portion of lake, as described below

Water Quality Problem/Issue Information

Uses Evaluated	Severity	Confidence
Water Supply	N/A	-
Public Bathing	Stressed	Known
Recreation	Stressed	Known
Aquatic Life	Fully Supported	Known
Fish Consumption	Unassessed	-
Conditions Evaluated		
Habitat/Hydrology	Poor	
Aesthetics	Fair	

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

Known: ---
Suspected: Algal/Plant Growth, Aquatic Invasive Species (cladophora)
Unconfirmed: ---

Source(s) of Pollutant(s)

Known: ---
Suspected: Agricultural runoff, Habitat Alteration, Non-point source runoff, Other source, On-site septic systems, streambank and ditch erosion
Unconfirmed: ---

Management Information

Management Status: Strategy Implementation Scheduled or Underway
Lead Agency/Office: DOW/BWAM
IR/305(b) Code: Water Attaining All Standards (IR Category 1)

Further Details

Overview

This portion of Cayuga Lake is assessed as having minor impacts due to primary and secondary contact recreation uses that are stressed by algal/plant growth and aquatic invasive species. Fishing use appears to be supported, but may be threatened by zebra and quagga mussels and other invasive animals.

Use Assessment

Cayuga Lake, Northern End is a Class B waterbody required to support and protect the best use of primary contact recreation, secondary contact recreation, and fishing. The waterbody is also designated as a cold water (trout) fishery.

Primary and secondary contact recreation use are stressed due to the closure of public beaches from the occurrence of harmful algal blooms, excessive algae growth, and poor water clarity.

Impacts from habitat and hydrologic modification are also thought to contribute to the weed and algal growth and the impact on recreational uses. Zebra mussel infestation of the lake has increased lake clarity. The increased clarity allows for greater penetration of light which supports plant growth into the lake. In addition, mussels filter particulate-bound phosphorus and release soluble phosphorus that is more readily available for plant growth. Quagga mussels are now present in the lake, but the extent of quagga mussel growth in this segment is not known.

Fishing use is considered to be fully supported based on a healthy fishery. The main lake supports warm and cold water species. Gamefish include lake trout, rainbow trout, landlocked salmon, brown trout, northern pike, chain pickerel, largemouth and smallmouth bass. Panfish include crappies, bluegill, pumpkinseed, yellow perch and bullheads. Carp, channel catfish and longnose gar are also found in the lake. The main forage base is alewives, smelt and yellow perch. Cayuga is stocked annually with approximately 60,000 lake trout, 25,000 brown trout and 40,000 landlocked salmon. Cayuga's tributaries are stocked with 50,000 rainbow trout. (NYSDEC/DFWMR, Region 7 Fisheries, December 2014)

There are no health advisories in place limiting the consumption of fish from this waterbody (beyond the general advice for all waters). Fish consumption is considered to be fully supported based on the absence of any waterbody-specific advisory, but is noted as unconfirmed since routine monitoring of contaminants in fish is limited. (NYS DOH Health Advisories and NYSDEC/DOW, BWAM, January 2014)

Aesthetic conditions are evaluated as fair to poor due to turbidity plumes during wet-weather events and rooted plant growth. Aesthetics in some locations may be poor due to shoreline HABs during calm and dry periods (NYSDEC/DOW, BWAM and Region 7, October 2014).

Water Quality Information

Water quality sampling of Cayuga Lake was conducted through NYSDEC's Citizen Statewide Lake Assessment Program (CSLAP) from 2002 to 2007, and from June through September in 2017. While no CSLAP sites were sampled within this segment, it is likely that water sampling results from the Cayuga Lake Mid-North site (near Union Springs) are similar to those in this segment. Results of this nearby site indicate the lake is best characterized as mesotrophic or moderately productive. Chlorophyll/algal levels occasionally exceed criteria corresponding to impacted recreational uses, while phosphorus concentrations are somewhat high. Lake clarity measurements indicate water transparency occasionally exceed the recommended minimum criteria for swimming beaches. Readings of pH typically fall within the range established in state water quality standards for protection of aquatic life. (NYSDEC/DOW, BWAM/CSLAP 2017).

The NYSDEC HABs Notification Program confirmed the presence of HABs in Cayuga Lake during the recreational seasons of 2013 through 2017. In 2017, Cayuga Lake was on the HABs Notification List for 10 weeks. The blooms observed in 2017 were mostly localized and did become widespread at certain times. Elevated levels of Microcystin were found in 2017. The extent of blooms within this segment were not well documented during the summer of 2017, but blooms were reported throughout the lake at times. (NYSDEC/DOW, BWAM, March 2018).

Invasive species remain a concern in the lake, though there are currently no significant impacts on recreational or other uses. Cladophora has been noted along some shoreline reaches in recent years. (Cayuga County WQMA, 2015). Hydrilla found in other (southern) portions of the lake has not been observed in this segment (NYSDEC/DOW, BWAM, March 2018).

Source Assessment

Concerns have been raised regarding nonpoint runoff of nutrients into the lake, although in-lake concentrations of phosphorus and other productivity indicators remain low. Sediment plumes have been documented during storm events, but these do not represent conditions that are typical of the lake. Continued practices to minimize runoff are recommended, however there are no apparent sources of significant pollutant loading to this segment.

Management Actions

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

In 2017, a collaboration of local municipalities, community groups, interested citizens, and regional planning boards updated and completed a management plan, the Cayuga Lake Watershed Restoration and Protection Plan (RPP) for the protection of the Cayuga Lake watershed. This effort coincided with the establishment of the Cayuga Lake Watershed Intermunicipal Organization (IO), a voluntary partnership of 31 villages, towns, cities and counties in the watershed working together to implement the RPP. The main purpose of the RPP is to serve as a working guide for the public, elected officials, farmers, the business community, environmentalists and others to manage Cayuga Lake's valuable water resources (Cayuga Lake Watershed Intermunicipal Organization, March 2017).

An effort to develop a Total Maximum Daily Load (TMDL) is underway. (NYSDEC/DOW, BWRM, January 2016)

Section 303(d) Listing

This portion of Cayuga Lake is not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. There are no impacts/impairments that would justify the listing of this waterbody. (NYSDEC/DOW, BWAM/WQAS, January 2016)

Segment Description

This segment includes the portion of the lake south of Lock 1 in Mud Lock and north of an east-west line extending from Bridgeport-Seneca Falls Road on the west shore to the Village of Cayuga on the east shore.

Cayuga Lake, Main Lake, Mid-North (0705-0025)

Minor Impacts

Waterbody Location Information Revised:	05/01/2018	Water
Index No: Ont		66-12-P296
(portion 2)		Water
Class:		A(T)
Hydro Unit Code: Yawger Creek-Cayuga Lake (0414020112)	Drainage Basin: Oswego-Seneca-Oneida	
Water Type/Size: Lake/Reservoir 7861 Acres	Reg/County: 8/Seneca (50)	
Description: portion of lake, as described below		

Water Quality Problem/Issue Information

Uses Evaluated	Severity	Confidence
Water Supply	Threatened	Suspected
Public Bathing	Stressed	Known
Recreation	Stressed	Known
Aquatic Life	Fully Supported	Suspected
Fish Consumption	Unassessed	-
Conditions Evaluated		
Habitat/Hydrology	Fair	
Aesthetics	Poor	

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

Known: ---

Suspected: Algal/Plant Growth, Aquatic Invasive Species, Other Pollutants

Unconfirmed: ----

Source(s) of Pollutant(s)

Known: ---

Suspected: Agricultural runoff, Habitat Alteration, Non-point source runoff, On-site septic systems, Other source, Streambank erosion, Other Source

Unconfirmed: ---

Management Information

Management Status: Strategy Implementation Scheduled or Underway

Lead Agency/Office: DOW/BWAM

IR/305(b) Code: Water Attaining All Standards (IR Category 1)

Further Details

Overview

This portion of Cayuga Lake is assessed as having minor impacts due to primary and secondary contact recreation uses that are stressed by algal/plant growth and aquatic invasive species. The evaluation of the water supply as threatened is reflective of a need to protect its resource value, rather than specifically identify threats.

Use Assessment

Cayuga Lake, Main Lake, Mid-North is a Class A(T) required to support and protect the best use as a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. This

waterbody is also designated as a cold water (trout) fishery.

The evaluation of water supply focuses on the source water prior to treatment, and does not necessarily reflect 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 of Cayuga Lake is considered to be threatened due to an elevated potential for several pollutants that can impact source water, increase the cost and effort to deliver high quality drinking water, and produce post-treatment compounds of concern. This assessment is based on land use and activities in the watershed. It is not known if any of the potable water intakes in this segment are compromised by existing water quality conditions.

The NYSDOH Source Waters Assessment Program (SWAP) 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. These reports do not address the safety or quality of treated finished potable tap water. Drinking water supplies in this waterbody include the Village of Seneca Falls water supply. This assessment found an elevated susceptibility to contamination for this source of drinking water. Specifically the amount of agricultural lands in the assessment area results in elevated potential for phosphorus, DBP precursors, and pesticides contamination. In addition, the total amount of wastewater discharged in the assessment area results in elevated potential for nutrients, and DBP precursors. Some susceptibility associated with other sources, such as landfills, was also noted. (NYSDOH, Source Water Assessment Program, 2004). However, the most recent (2016) published Consumer Confidence Report for the Village of Seneca Falls indicated that the system was in compliance with applicable State drinking water operating and monitoring requirements (NYSDEC/DOW, BWAM, March 2018).

Primary and secondary contact recreation use are stressed and impacts may rise to the level of being impaired due to the periodic closure of public bathing beaches for swimming due to harmful algal blooms, and excessive algae growth. It is not yet known if the significant extent and duration of shoreline harmful algal blooms (HABs) reported in 2017 indicate a long-term change in the lake or were a temporary phenomenon. However, visual evidence of HABs resulted in beach closures for two weeks at Frontenac Park in this segment in 2017.

Impacts from habitat and hydrologic modification are also thought to contribute to the weed and algal growth and the impact on recreational uses. Zebra mussel infestation of the lake has increased lake clarity. The increased clarity allows for greater penetration of light which supports plant growth into the lake. In addition, mussels filter particulate-bound phosphorus and release soluble phosphorus that is more readily available for plant growth. In addition to zebra mussels, quagga mussels are now present, but the extent of quagga mussel growth in this segment is not known.

Fishing use is considered to be fully supported based on a healthy fishery. The main lake supports warm and cold water species. Gamefish include lake trout, rainbow trout, landlocked salmon, brown trout, northern pike, chain pickerel, largemouth and smallmouth bass. Panfish include crappies, bluegill, pumpkinseed, yellow perch and bullheads. Carp, channel catfish and longnose gar are also found in the lake. The main forage base is alewives, smelt and yellow perch. Cayuga is stocked annually with approximately 60,000 lake trout, 25,000 brown trout and 40,000 landlocked salmon. Cayuga's tributaries are stocked with 50,000 rainbow trout. (NYSDEC/DFWMR, Region 7 Fisheries, December 2014)

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. (NYS DOH Health Advisories and NYSDEC/DOW, BWAM, April 2018)

Aesthetic conditions are evaluated as fair to poor due to turbidity plumes during wet-weather events and rooted plant growth. Aesthetics in some locations may be poor due to shoreline HABs during calm and dry periods

(NYSDEC/DOW, BWAM and Region 7, March 2018).

Water Quality Information

Water quality sampling of Cayuga Lake was conducted through NYSDEC's Citizen Statewide Lake Assessment Program (CSLAP) from 2002 through 2007, and from June through September in 2017. Results of this sampling indicate the lake is best characterized as is mesotrophic or moderately productive. Chlorophyll/algal levels occasionally exceed criteria corresponding to impacted recreational uses, while phosphorus concentrations are somewhat high. Lake clarity measurements indicate water transparency occasionally exceed the recommended minimum criteria for swimming beaches. Readings of pH typically fall within the range established in state water quality standards for protection of aquatic life. (NYSDEC/DOW, BWAM/CSLAP 2017).

The NYSDEC HABs Notification Program confirmed the presence of HABs in Cayuga Lake during the recreational seasons of 2013 through 2017. In 2017, Cayuga Lake was on the HABs Notification List for 10 weeks. The blooms observed in 2017 were mostly localized and did become widespread at certain times. Elevated levels of Microcystin were found in 2017. The extent of blooms within this segment were not well documented during the summer of 2017, but blooms were reported throughout the lake at times. (NYSDEC/DOW, BWAM, March 2018).

Source Assessment

Concerns have been raised regarding nonpoint runoff of nutrients into the lake, although in-lake concentrations of phosphorus and other productivity indicators remain low. Sediment plumes have been documented during storm events, but these do not represent conditions that are typical of the lake. Continued practices to minimize runoff are recommended, however there are no apparent sources of significant pollutant loading to the waterbody.

Management Actions

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

In 2017 a collaboration of local municipalities, community groups, interested citizens, and regional planning boards updated and completed a management plan, the Cayuga Lake Watershed Restoration and Protection Plan (RPP) for the protection of the Cayuga Lake watershed. This effort coincided with the establishment of the Cayuga Lake Watershed Intermunicipal Organization (IO), a voluntary partnership of 31 villages, towns, cities and counties in the watershed working together to implement the RPP. The main purpose of the RPP is to serve as a working guide for the public, elected officials, farmers, the business community, environmentalists and others to manage Cayuga Lake's valuable water resources (Cayuga Lake Watershed Intermunicipal Organization, March 2017).

An effort to develop a Total Maximum Daily Load (TMDL) for the lake is currently underway. (NYSDEC/DOW, BWRM, January 2016)

Section 303(d) Listing

This portion of Cayuga Lake is not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. There are no impacts/impairments that would justify the listing of this waterbody. (NYSDEC/DOW, BWAM/WQAS, January 2016)

Segment Description

This segment includes the portion of the lake south of an east-west line extending from Bridgeport–Seneca Falls Road on the west shore to the Village of Cayuga on the east shore and north of an east-west line extended from Coonley Corners Road in Coonley Corners.

Cayuga Lake, Main Lake, Mid-South (0705-0050)

Minor Impacts

Waterbody Location Information

Revised: 05/01/2018

Water Index No: Ont
(portion 3)

66-12-P296

Class:

Water
AA(T)

Hydro Unit Code: Yawger Creek-Cayuga Lake (0414020112)

Drainage Basin: Oswego-Seneca-Oneida

Water Type/Size: Lake/Reservoir 33082.7 Acres
portion of lake, as described below

Reg/County: 8/Seneca (50)**Description:**

Water Quality Problem/Issue Information

Uses Evaluated	Severity	Confidence
Water Supply	Threatened	Suspected
Public Bathing	Stressed	Known
Recreation	Stressed	Known
Aquatic Life	Fully Supported	Known
Fish Consumption	Unassessed	-

Conditions Evaluated

Habitat/Hydrology	Fair
Aesthetics	Poor

Type of Pollutant(s)

(CAPS indicate Major Pollutants/Sources that contribute to an Impaired/Precluded Uses)

Known:	---
Suspected:	Algal/Plant Growth, Aquatic Invasive Species, Other Pollutants
Unconfirmed:	---

Source(s) of Pollutant(s)

Known:	---
Suspected:	Agricultural runoff, Habitat Alteration, Non-point source runoff, On-site septic systems, Streambank Erosion
Unconfirmed:	---

Management Information

Management Status:	Strategy Implementation Scheduled or Underway
Lead Agency/Office:	DOW/BWAM
IR/305(b) Code:	Water Attaining All Standards (IR Category 1)

Further Details

Overview

This portion of Cayuga Lake is assessed as having minor impacts due to primary and secondary contact recreation uses that are stressed by algal/plant growth and aquatic invasive species. The evaluation of the water supply as threatened is reflective of a need to protect its resource value, rather than specifically identify threats.

Use Assessment

Cayuga Lake, Main Lake, Mid-South is a Class AA(T) required to support and protect the best use as a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. This waterbody is also designated as a cold water (trout) fishery.

The evaluation of water supply use focuses on the source water prior to treatment, and does not necessarily reflect 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. However, water supply use of Cayuga Lake is considered to be threatened due to an elevated potential for several pollutants that can impact source water, increase the cost and effort to deliver high quality drinking water, and produce post-treatment compounds of concern. This assessment is based on land use and activities in the watershed.

The NYSDOH Source Waters Assessment Program (SWAP) 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. These reports do not address the safety or quality of treated finished potable tap water. Drinking water supplies in this segment include the Bolton Point (City of Ithaca), and Aurora water supplies. This assessment found an elevated susceptibility to contamination for this source of drinking water. Specifically, the chlorophyll a data collected through the LSC project and CSLAP demonstrates that the algal biomass in this segment both routinely exceeds and shows increasing frequency of exceeding the 4 µg/l threshold associated with impairment of class AA waters. The increase in chlorophyll a indicates algal biomass in excess of “naturally present impurities” acceptable in the designation of Class AA lakes.

The Bolton Point water treatment processes have been modified on several occasions in recent years to address TTHM issues, and summer to fall TTHM levels continue to be elevated. This includes a modification in the facility’s pre-oxidant- moving from liquid chlorine to chlorine dioxide, representing an elevated health risk. Elevated TTHMs represent a risk of triggering the operational evaluation level (OEL) criteria, a provision in the Stage 2 Disinfection/Disinfection By-Product rule that requires a more stringent assessment of DBP data. These operational difficulties in meeting MCLs, and 3rd quarter spikes in TTHMs in Bolton Point and Aurora correspond to elevated chlorophyll a levels in the lake, and indicate the need to intervene beyond conventional treatment and disinfection associated with Class AA waters.

In addition, the amount of agricultural lands and the total amount of wastewater discharged in the assessment area results in elevated potential for nutrients, DBP precursors, and pesticides contamination. Some susceptibility associated with other sources, such as landfills, was also noted. (NYSDOH, Source Water Assessment Program, 2004)

Primary and secondary contact recreation use are stressed and impacts may rise to the level of being impaired due to the periodic closure of public bathing beaches for swimming due to harmful algal blooms, and excessive algae growth. It is not yet known if the significant extent and duration of shoreline harmful algal blooms (HABs) reported in 2017 indicate a long-term change in the lake or were a temporary phenomenon. However, visual evidence of HABs resulted in beach closures from 6 to 14 days at several beaches within this segment in 2017, including the Wells College Bathing Beach, Camp Caspar Gregory Bathing Beach, Long Point State Park, Ithaca Yacht Club, and Taughannock Falls State Park (NYSDEC/DOW, BWAM, March 2018).

Impacts from habitat and hydrologic modification are also thought to contribute to the weed and algal growth and the impact on recreational uses. Zebra mussel infestation of the lake has increased lake clarity, although this may be offset by higher algae levels in many years associated with excessive nutrients. This may have been exacerbated by the more recent introduction of quagga mussels. The increased clarity allows for greater penetration of light which supports plant growth into the lake. In addition, mussels filter particulate-bound phosphorus and release soluble phosphorus

that is more readily available for plant growth.

Fishing use is considered to be fully supported based on a healthy fishery. The main lake supports warm and cold water species. Gamefish include lake trout, rainbow trout, landlocked salmon, brown trout, northern pike, chain pickerel, largemouth and smallmouth bass. Panfish include crappies, bluegill, pumpkinseed, yellow perch and bullheads. Carp, channel catfish and longnose gar are also found in the lake. The main forage base is alewives, smelt and yellow perch. Cayuga is stocked annually with approximately 60,000 lake trout, 25,000 brown trout and 40,000 landlocked salmon. Cayuga's tributaries are stocked with 50,000 rainbow trout. (NYSDEC/DFWMR, Region 7 Fisheries, December 2014)

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. (NYS DOH Health Advisories and NYSDEC/DOW, BWAM, April 2018)

Water Quality Information

Water quality sampling of Cayuga Lake was conducted through NYSDEC's Citizen Statewide Lake Assessment Program (CSLAP) from 2002 through 2007, and from June through September in 2017. Results of this sampling indicate the lake is best characterized as mesotrophic or moderately productive. Chlorophyll/algal levels occasionally exceed criteria corresponding to impacted recreational uses, while phosphorus concentrations are somewhat high. Lake clarity measurements indicate water transparency occasionally exceed the recommended minimum criteria for swimming beaches. Readings of pH typically fall within the range established in state water quality standards for protection of aquatic life. (NYSDEC/DOW, BWAM/CSLAP 2017).

Water quality monitoring was conducted from 1998 through 2013 in up to three locations in the Mid-South segment (0705-0050) by Upstate Freshwater Institute (UFI) (through 2006) and Cornell University (from 2007 to 2013) as part of the requirements for the Cornell Lake Source Cooling (LSC) facility SPDES permit. This monitoring consisted of approximately biweekly samples collected from the surface waters of the lake from mid-April through late October analyzed for total and soluble reactive phosphorus, chlorophyll *a*, turbidity, and Secchi disk transparency. Water chemistry samples were analyzed by UFI. This is the primary source of data to evaluate water quality changes in this segment, and the primary source of water quality information for this updated assessment.

These data showed that chlorophyll *a* readings in a representative Mid-South site averaged 5.8 µg/l in the 2008-2012 period, an increase above the 4.9 µg/l average from 1998 through 2002. This occurred despite total phosphorus readings in this section that averaged around 13 µg/l from 2008 to 2012, essentially unchanged from the period from 1998 to 2002. However, soluble phosphorus levels appear to have increased over this period in both the surface and bottom waters in this segment. (NYSDEC/DOW, BWAM, March 2018).

The NYSDEC HABs Notification Program confirmed the presence of HABs in Cayuga Lake during the recreational seasons of 2013 through 2017. In 2017, Cayuga Lake was on the HABs Notification List for 10 weeks. The blooms observed in 2017 were mostly localized but did become widespread at certain times. Elevated levels of the cyanotoxin, microcystin were found in 2017. The extent of blooms within this segment were not well documented during the summer of 2017, but blooms were reported throughout the lake at times. (NYSDEC/DOW, BWAM, March 2018).

In 2015, an approximately 20 acre stand of Hydrilla was discovered near Aurora (lake eastern shore). Herbicides have been applied in efforts to control spread of this invasive plant. This highly invasive plant was found in Cayuga Inlet, the south end of Cayuga Lake, and other connected waterways in the early 2010s, and has been aggressively managed through several local and state initiatives. (NYSDEC/DOW, BWAM, March 2018).

Source Assessment

Concerns have been raised regarding nonpoint runoff of nutrients into the lake, although in-lake concentrations of

phosphorus and other productivity indicators remain low. Sediment plumes have been documented during storm events, but these do not represent conditions that are typical of the lake. Continued practices to minimize runoff are recommended, however there are no apparent sources of significant pollutant loading to the waterbody.

Management Actions

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

In 2017, a collaboration of local municipalities, community groups, interested citizens, and regional planning boards updated and completed a management plan, the Cayuga Lake Watershed Restoration and Protection Plan (RPP) for the protection of the Cayuga Lake watershed. This effort coincided with the establishment of the Cayuga Lake Watershed Intermunicipal Organization (IO), a voluntary partnership of 31 villages, towns, cities and counties in the watershed working together to implement the RPP. The main purpose of the RPP is to serve as a working guide for the public, elected officials, farmers, the business community, environmentalists and others to manage Cayuga Lake's valuable water resources (Cayuga Lake Watershed Intermunicipal Organization, March 2017).

An effort to develop a Total Maximum Daily Load (TMDL) plan for Cayuga Lake is currently underway. (NYSDEC/DOW, BWRM, January 2016)

Section 303(d) Listing

This portion of Cayuga Lake is not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. There are no impacts/impairments that would justify the listing of this waterbody. (NYSDEC/DOW, BWAM/WQAS, January 2016)

Segment Description

This segment includes the portion of the lake south of an east-west line extended from Coonley Corners Road in Coonley Corners and north of an east-west line through McKinneys Point in McKinneys.

Cayuga Lake, Southern End (0705-0040)

Impaired

Waterbody Location Information

Revised: 05/01/2018

Water Index No: Ont 66-12-P296 (portion 4)
Hydro Unit Code: Yawger Creek-Cayuga Lake (0414020112)
Water Type/Size: Lake/Reservoir 968.2 Acres
Description: portion of lake, as described below

Water Class: A
Drainage Basin: Oswego-Seneca-Oneida
Reg/County: 7/Tompkins (55)

Water Quality Problem/Issue Information

Uses Evaluated	Severity	Confidence
Water Supply	Threatened	Known
Public Bathing	Impaired	Known
Recreation	Impaired	Known
Aquatic Life	Fully Supported	Suspected
Fish Consumption	Unassessed	-
Conditions Evaluated		
Habitat/Hydrology	Fair	
Aesthetics	Poor	

Type of Pollutant(s) (CAPS indicate Major Pollutants/Sources that contribute to an Impaired/Precluded Uses)
Known: Algal/Plant Growth, Aquatic Invasive Species (Hydrilla), NUTRIENTS (PHOSPHORUS), SILT/SEDIMENT
Suspected: ---
Unconfirmed: ---

Source(s) of Pollutant(s)
Known: AGRICULTURE, Habitat Alteration, Municipal Discharges, Onsite Septic Systems, Other Source, Roadbank Erosion, Streambank/Ditch Erosion, URBAN/STORM RUNOFF
Suspected: ---
Unconfirmed: ---

Management Information

Management Status: Strategy Implementation Scheduled or Underway
Lead Agency/Office: DOW/BWAM
IR/305(b) Code: Impaired Water Requiring a TMDL (IR Category 5)

Further Details

Overview

This portion of Cayuga Lake is assessed as an impaired waterbody due to primary and secondary recreational uses that are known to be impaired due to excessive nutrients (phosphorus) and silt/sediment loads from various sources throughout the watershed. Aquatic invasive species (Hydrilla) have also been identified in the Southern End of the Lake and its tributaries. Water supply use is also considered to be threatened.

Use Assessment

This portion of Cayuga Lake is a Class A waterbody required to support and protect the best use as a source of water

supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and for fishing.

Public Water Supply for this portion of Cayuga Lake is assessed as threatened. The NYSDOH Source Water Assessment Program (SWAP) compiles, organizes, and evaluates information regarding possible and actual threats to the quality of public water supply 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. These reports do not address the safety or quality of treated finished potable tap water. Drinking water supplies in this waterbody include the Southern Cayuga Lake Intermunicipal Water Commission water supply. The SWAP assessment found a moderate susceptibility to contamination for this source of drinking water. Some susceptibility associated with other sources, such as salt mines, was also noted. (NYSDOH, Source Water Assessment Program, 2004). Although no active water intakes are located within this segment, water quality data collected through the Lake Source Cooling (LSC) project suggests that ecological processes in the south shelf impact the Bolton Point MWS, which is located approximately one mile north of this segment and has been experiencing problems with DBPs (disinfection by products). In addition, chlorophyll-*a* data collected through the LSC project demonstrates that the algal biomass in this segment both routinely exceeds and shows increasing frequency of exceeding the 6 µg/l threshold associated with impairment of Class A waters. Furthermore, the City of Ithaca has rejected the use of this segment as a potential water supply in recent deliberations.

Primary and secondary contact recreation are considered to be impaired due to elevated nutrients (phosphorus), excessive algae, and poor water clarity. These uses have not been sustained through public beaches or other designated swimming areas since Stewart Park was closed for swimming more than 50 years ago. Secondary contact recreation is also affected by excessive aquatic vegetation of invasive plant growth (hydrilla). Hydrilla verticillatum (hydrilla, or water thyme) was discovered in Cayuga Inlet in August of 2011 and in the southern end of Cayuga Lake in 2013. Hydrilla restricts recreational activities and has created significant ecological and economic problems throughout the country, and is particularly challenging to control due to abundant and persistent modes of reproduction, spread, and transport. (NYS DOW/DEC, BWAM, March 2018)

Impacts from habitat and hydrologic modification are also thought to contribute to the weed and algal growth and the impact on recreational uses. Zebra mussel infestation of the lake may have increased lake clarity, although this ecological change may have been further altered by elevated algae growth associated with high nutrient levels. The increased clarity allows for greater penetration of light which supports plant growth into the lake. In addition, mussels filter particulate-bound phosphorus and release soluble phosphorus that is more readily available for plant growth. In addition to zebra mussels, quagga mussels are now present in the deeper waters of the lake.

Fishing use is considered to be fully supported based on the support of a healthy fishery. The main lake supports warm and cold water species. Gamefish include lake trout, rainbow trout, landlocked salmon, brown trout, northern pike, chain pickerel, largemouth and smallmouth bass. Panfish include crappies, bluegill, pumpkinseed, yellow perch and bullheads. Carp, channel catfish and longnose gar are also found in the lake. The main forage base is alewives, smelt and yellow perch. Cayuga is stocked annually with approximately 60,000 lake trout, 25,000 brown trout and 40,000 landlocked salmon. Cayuga's tributaries are stocked with 50,000 rainbow trout. (NYSDEC/DFWMR, Region 7 Fisheries, December 2014)

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. (NYS DOH Health Advisories and NYSDEC/DOW, BWAM, April 2018)

Water Quality Information

Water quality sampling of Cayuga Lake was conducted through NYSDEC's Citizen Statewide Lake Assessment Program (CSLAP) from 2002 through 2007, and from June through September in 2017; however, no sites in this segment were included in CSLAP in 2017 or in previous years.

Water quality monitoring was conducted from 1998 through 2013 in up to six locations in the Southern End segment (0705-0040) by Upstate Freshwater Institute (UFI) (through 2006) and Cornell University (from 2007 to 2013) as part of the requirements for the Cornell Lake Source Cooling (LSC) facility SPDES permit. This monitoring consisted of approximately biweekly samples collected from the surface waters of the lake from mid-April through late October analyzed for total and soluble reactive phosphorus, chlorophyll *a*, turbidity, and Secchi disk transparency. Water chemistry samples were analyzed by UFI. This is the primary source of data to evaluate water quality changes in this segment, and the primary source of water quality information for this updated assessment.

These data showed that chlorophyll *a* readings in the six Southern End sites averaged 6 µg/l (computed as a weighted spatial average) in the 2008-2012 period, an increase above the 5 µg/l average from 1998 through 2002. This occurred despite total phosphorus readings in this section that averaged around 18 µg/l from 2008 to 2012 (compared to an average of about 21 µg/l in the period from 1998 to 2002). However, soluble reactive phosphorus levels may have increased over this period (NYSDEC/DOW, BWAM, March 2018).

As part of a more comprehensive effort to address algal growth and other recreational impairments in the South End of the lake, a water quality/modeling study of Cayuga Lake to support the development of a phosphorus TMDL began in 2013. The Cayuga Lake Modeling Project (CLMP) includes considerable lake and watershed monitoring components (completed in 2013), and associated model development efforts that are anticipated to continue through 2018. (NYSDEC/DOW, BWAM and BWP, January 2015).

The lake and watershed has been the focus of on-going monitoring by a number of other groups, including the Community Science Institute. A significant NYSDEC monitoring effort, entitled Water Quality Study of the Finger Lakes (Callinan, NYSDEC, 2002), provides a previous comparison of water quality in all the Finger Lakes. These studies, which included sites within the southern end of the lake, showed water quality conditions that were mostly comparable to those reported in the LSC study (NYSDEC/DOW, BWAM, January 2015)

The NYSDEC HABs Notification Program confirmed the presence of HABs in Cayuga Lake during the recreational seasons of 2013 through 2017. In 2017, Cayuga Lake was on the HABs Notification List for 10 weeks. The blooms observed in 2017 were mostly localized but did become widespread at certain times. Elevated levels of Microcystin were found in some shoreline bloom samples in 2017. The extent of blooms within this segment were not well documented during the summer of 2017, but blooms were reported throughout the southern portion of the lake at times. (NYSDEC/DOW, BWAM, March 2018).

Source Assessment

The sources of pollutant loadings to this segment of Cayuga Lake are numerous. Agricultural activity in the Southern Cayuga Lake watershed is significant and includes, dairy farming, poultry farms and cropland. This portion of the lake also receives discharges from three large point sources: The Ithaca Area WWTP, Cayuga Heights WWTP, and the Cornell Lake Source Cooling Facility. In addition, two wastewater treatment facilities (Dryden STP and Freeville STP) discharge to Fall Creek which discharges to this segment. Urban/storm runoff from the City of Ithaca also impacts the lake. Increasing development and stream erosion are also identified as contributors of pollutant loadings to the tribs and to the lake. (Tompkins County Planning Department, 2003).

Management Actions

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

An effort to develop a Total Maximum Daily Load (TMDL) plan to address the phosphorus impairment to the southern end of Cayuga Lake is currently underway. The Cayuga Lake Modeling Project (CLMP) represents the first step in this

effort. The model development component of the CLMP was completed in 2016, with formal development of a TMDL by NYSDEC underway. (NYSDEC/DOW, BWAM, January 2018)

The CLMP/TMDL effort evolved from negotiations for a final SPDES permit to address water releases from Cornell University's Lake Source Cooling (LSC) facility. The permit includes a limit on the amount of phosphorous the Cornell LSC facility draws from the deeper lake and discharges to the shallower southern shelf. An interim limit holds Cornell's discharge of phosphorus at its then-current levels. Once the TMDL is completed, a final limit will be developed based on the results of the TMDL. The permit includes a requirement outlining Cornell's commitment to fund the water quality/modeling study of Cayuga Lake to assist NYSDEC with the development of the TMDL for the South End of the Lake. (NYSDEC/DOW, BWAM, January 2014)

The discovery of the highly invasive aquatic plant Hydrilla in Cayuga Inlet in 2011 prompted immediate and forceful action, due to the great concern that this plant could move into Cayuga Lake and the Great Lakes ecosystem. A state and local Task Force was quickly established to delineate the hydrilla populations, identify appropriate management actions, and proceed with an aggressive strategy to eradicate the 166 acre infestation found in the Inlet and some connected waterways, using federal, state, and local resources. Key members of the Task Force include the City of Ithaca, the Tompkins County Soil and Water Conservation District and Department of Health, Racine-Johnson Aquatic Ecologists, NYSDEC, Canal Corps, and other local and state organizations. Recommendations of the Task Force led NYSDEC to conduct emergency rule-making to allow for a Hydrilla infestation treatment effort. Despite these efforts, hydrilla spread to the southern end of the lake and other tributaries, including Cascadilla Creek, Fall Creek, Six Mile Creek, and was also found further north in the lake. The Task Force is presently engaged in a multi-pronged eradication strategy, including the use of aquatic herbicides, hand removal, boat inspections, and extensive public education, outreach and monitoring. (NYSDEC/DOW, BWAM/LMAS, March 2018)

Section 303(d) Listing

The Southern End of Cayuga Lake is included on the current (2016) NYS Section 303(d) List of Impaired Waters. The waterbody is included on Part 1 of the List as a waterbody segment requiring the development of a TMDL or other strategy to attain water quality standards; the segment is listed for phosphorus and silt/sediment. These waterbody/pollutants were first listed on the 2002 List.

Segment Description

This segment includes the portion of the lake south of an east-west line through McKinneys Point in McKinneys.

Appendix F. 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 Cayuga Lake 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.