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

HARMFUL ALGAL BLOOM ACTION PLAN LAKE GEORGE

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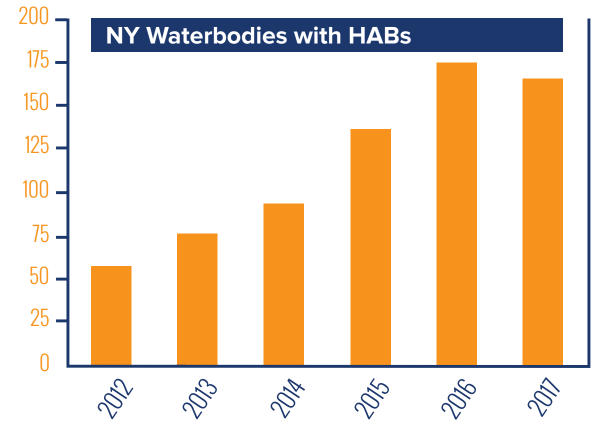
EXECUTIVE SUMMARY

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.

LAKE GEORGE

Warren, Washington, and Essex Counties

Lake George, a 28,160-acre lake in the Adirondacks was identified as a priority area for action because of its vulnerability to HABs.

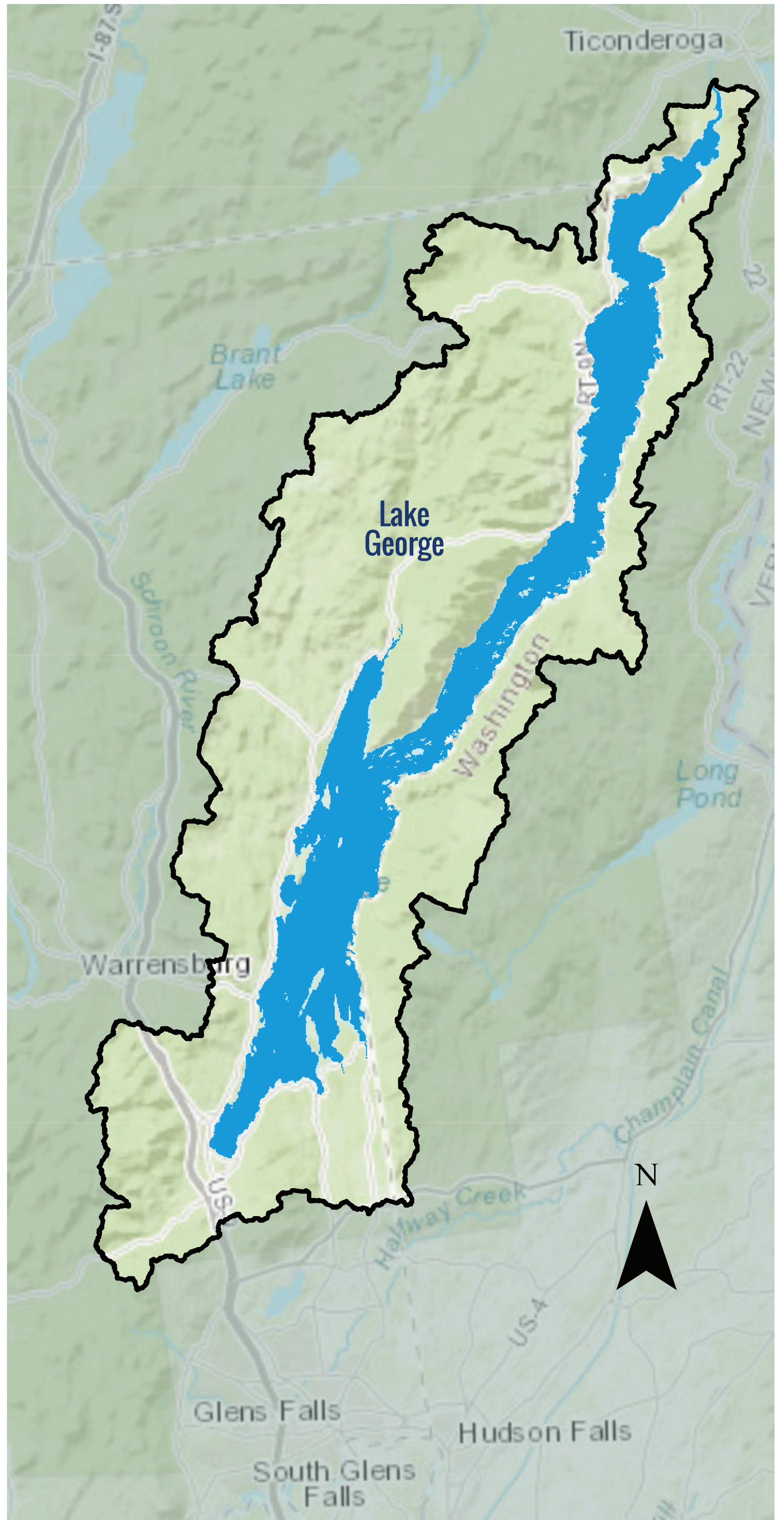
No HABs have been confirmed in Lake George. However, due to the size and popularity of the lake, as well as local infrastructure, watershed management actions should be taken to address the following primary water quality factors in the lake:

- Nutrient loadings associated with wastewater treatment plant discharges;
- Stormwater runoff from developed areas, as well as insufficient stormwater and collection system infrastructure and on-site septic systems to handle wastewater; and
- Nonpoint source sediment and nutrient inputs from the contributing watershed.

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 water quality concerns in Lake George, including the following:

- Upgrade municipal wastewater collection and treatment systems;
- Reduce inflow and infiltration of wastewater within municipal systems;
- Implement an inspection and maintenance program for near-shore septic systems;
- Extend sanitary sewer infrastructure and add service to existing commercial properties; and
- Implement a woodchip bioreactor demonstration project and evaluate the wastewater treatment efficiency.



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.

LAKE GEORGE 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 Lake George 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 Lake George 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

List of Figures

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 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 Lake George has been developed by the New York State Water Quality Rapid Response Team (WQRRT) to:

- describe the physical and biological conditions
- summarize the research conducted to date and the data it has produced
- identify the potential causative factors that may contribute to HABs
- provide specific recommendations to minimize the presence, frequency, duration, and/or 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.

1.2 Scope, Jurisdiction and Audience

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

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

Based on these criteria, the Governor’s HABs initiative has selected 12 New York State waterbodies that are representative of waterbody types, lake conditions, and vulnerability to HABs throughout the State. Lake George, with its public beaches, recreational opportunities, and tourism, was selected as one of the priority waterbodies, and is the subject of this HABs Action Plan.

The intended audiences for this Action Plan are as follows:

- Members of the public interested in background information about the development and implications of the HABs program
- New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health (NYSDOH), and New York State Department of Agriculture and Markets (NYSDAM) officials associated with the HABs initiative
- State agency staff who are directly involved in implementing or working with the NYS HABs monitoring and surveillance program
- Local and regional agencies involved in the oversight and management of Lake George (e.g., Adirondack Park Agency (APA), County Soil and Water Conservation Districts (SWCDs), Departments of Health (DOHs), the Lake George Park Commission, and the Lake George Association)
- Lake residents, managers, consultants, and others that are directly involved in the management and prevention of HABs in Lake George.

There have been no reported HABs in Lake George to date. Analyses conducted in this Action Plan provide insight into the processes that may potentially influence the formation of HABs in Lake George, and their possible spatial extents, durations, and intensities. Implementation of the mitigation actions recommended in this HABs Action Plan are expected to prevent the likelihood of blooms in Lake George.

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 produced this HABs Action Plan to minimize the potential for HABs to occur and avoid the effects that HABs can have on both the users of Lake George and its resident plants and animals.

2. Lake Background

2.1 Geographic Location

Lake George is a 28,160-acre lake located in the southeast corner of the Adirondacks in eastern New York State. Lake George intersects parts of Washington, Warren, and Essex counties and the towns of Ticonderoga, Hague, Putnam, Bolton, Dresden, Fort Ann, and Lake George (NYSDEC 2015). The Lake George watershed includes numerous towns, and parts of Lake George are located 3 miles from the Vermont border (**Figure 2**).

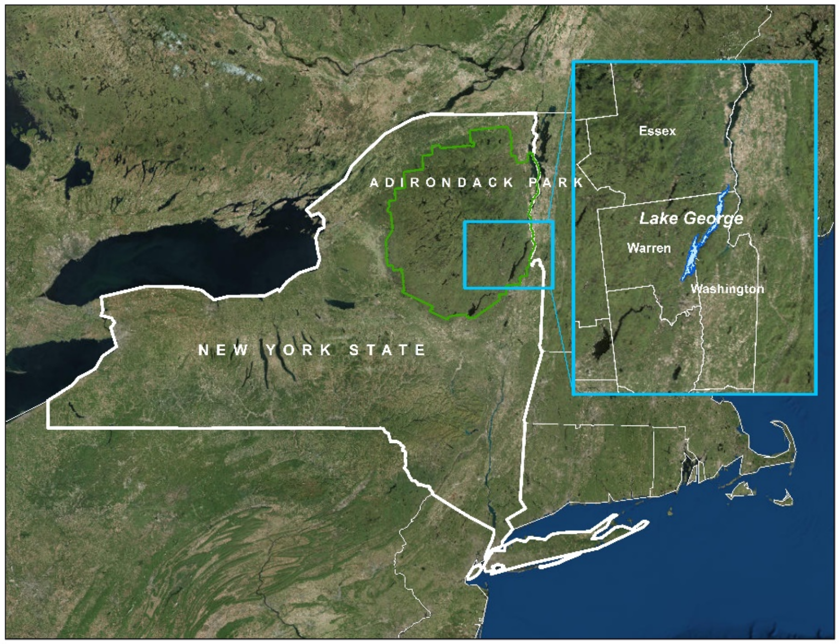


Figure 1. Location of Lake George within New York State.

2.2 Basin Location

Lake George is located within its namesake basin that is formed by the southeast corner of the Adirondack Mountains. The steep slopes of these mountains create a 149,332-acre basin that is tributary to the larger Lake Champlain. The Lake George drainage basin covers portions of Warren, Washington, and Essex counties including twelve municipalities: Towns of Lake George, Bolton, Hague, Ticonderoga, Putnam, Dresden, Fort Ann, Queensbury, and the Village of Lake George. Horicon, Lake Luzerne, and Warrensburg have minor land holdings in the watershed (LGA 2018a).

2.3 Morphology

Lake George is approximately 32 miles long oriented north-northeast with a maximum width of 2 miles and 130 miles of shoreline (Boylen et al. 2014). The surface area of Lake George is approximately 28,160 acres, about one fifth of the basin area. This relatively low watershed to lake ratio is often associated with higher water retention times, as well as relatively low sedimentation rates and land-based loading of phosphorus. Lake George has a volume of 550 billion gallons, a maximum depth of 57 meters (187 feet), and a mean depth of 18 meters (59 feet) (Boylen et al. 2014, NYSDEC 2018a, NYSDEC 2015). Circulation within Lake George is dependent upon several factors, including: thermal stratification, inflow and outflow volumes, wind, and bathymetry (Boylen et al. 2014). Horizontal transport within the upper 20 meters (65 feet) of the water column is expected to occur freely, driven primarily by wind. However, a sill around mid-lake (within the Narrows, as discussed in **Section 2.4**) changes conditions within that specific Lake region. Below 20 meters (65 feet), the Narrows' bathymetry inhibits horizontal movement of deeper water between the northern and southern sections of the lake (Boylen et al. 2014).

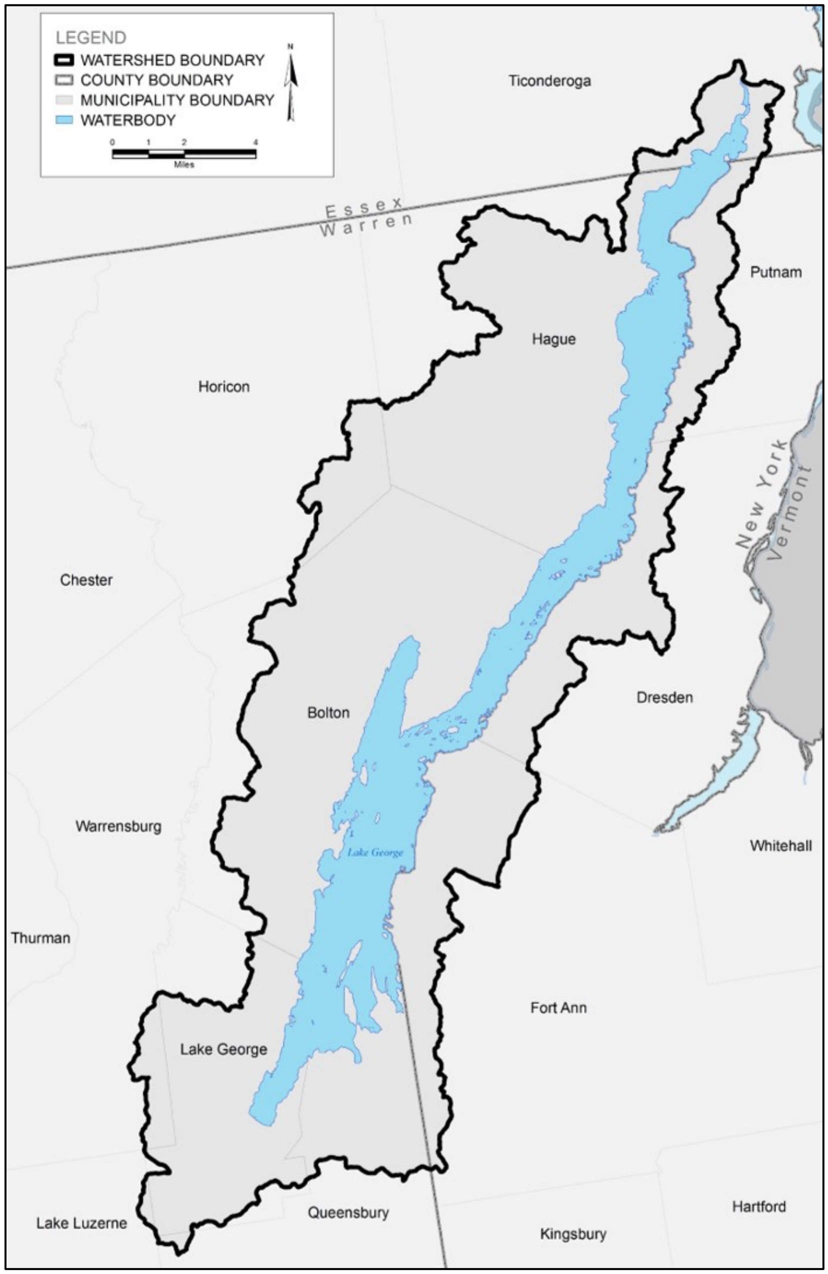


Figure 2. Political boundaries within the Lake George watershed.

The wind rose in **Appendix A** indicates that the stronger prevailing winds influencing Lake George from 2010 to 2017 during the months of June through November were from the south-southwest, as measured from the Floyd Bennett Memorial Airport. This results in a fetch of approximately the total length of Lake George over which wind and wave action can mix the water (potentially influencing thermal stratification) and drive water-borne nutrients and algae, generally towards the northern areas of the lake. Should nutrients and algae accumulate in concentrated areas, nearby beaches and shoreline recreational uses could experience negative impacts (*e.g.*, closures, public health concerns) (**Figure 3**).

2.4 Hydrology

The hydraulic retention time of Lake George, or the amount of time it takes water to pass through the lake, is approximately 8.7 years (NYSDEC 2015). The lake drains north to Lake Champlain via the La Chute River with a 230-foot vertical drop over 3.5 miles (Boylen et al. 2014, Lake Champlain Region 2018). Lake George receives water through three primary sources: streams (57%), direct precipitation (25%), and groundwater (18%). Two large basins compose Lake George (North and South) and five major catchment sub-basins have been documented, as shown in **Figure 3**: Caldwell, Dome Island, Narrows, Sabbath Day, and Rogers Rock (Boylen et al. 2014).

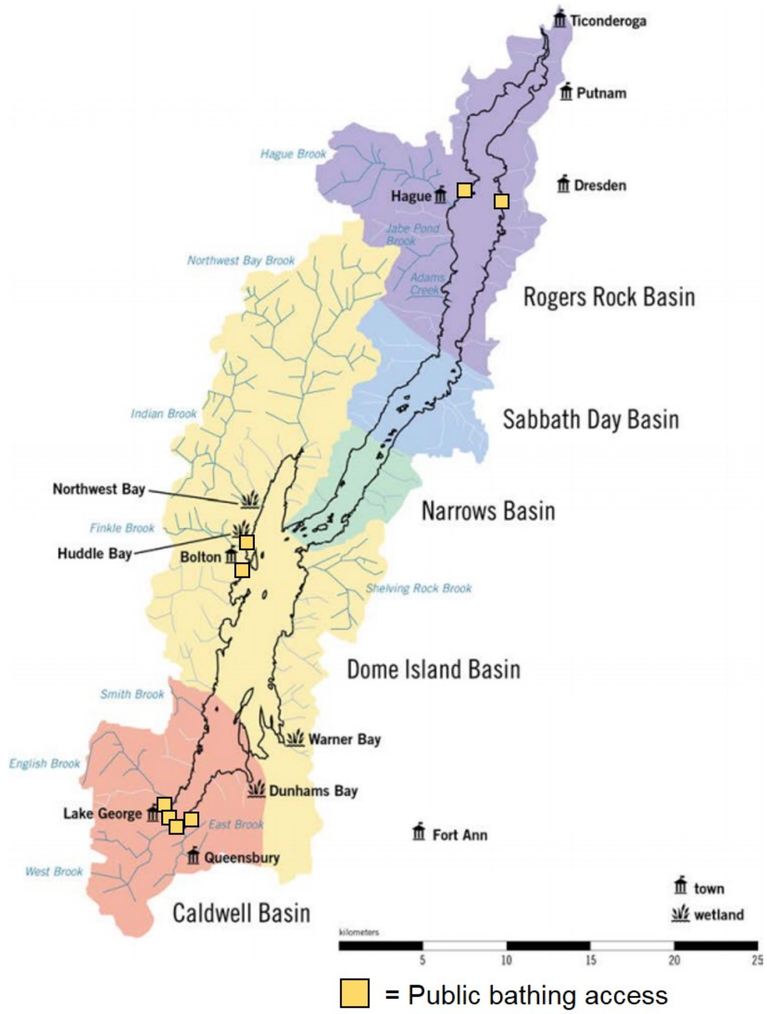


Figure 3. Lake George watershed sub-basins (Modified from Boylen et al. 2014). Public bathing beaches are depicted (yellow squares).

2.5 Lake Origin

The Lake George basin was created by the advance and retreat of glaciers during the Wisconsin period. Their movement altered the drainage patterns of two river systems flowing in opposite directions to create one lake with a single northern outlet. At that time, the lake had two outlet streams, one that flowed north to Lake Champlain, and one that flowed south to the Hudson River. This southern flow was eventually dammed by sediments deposited during glaciation, leaving the La Chute River flow to the north as the primary outlet.

3. Designated Uses

3.1 Water Quality Classification – Lake and Major Tributaries

Lake George is a Class AA-Special waterbody, meaning it is a source of water supply for drinking, culinary or food processing purposes, primary and secondary contact recreation, and fishing. Class AA-Special waterbodies are suitable for fish propagation and survival, and shall not contain, nor be used for the discharge or disposal of, numerous types of solids and wastes. These waterbodies shall not contain phosphorus or nitrogen in amounts that will result in growths of algae, weeds, and surface 'scums' that will impair the waters for their best usages.

The largest tributary streams to Lake George, listed below, are each classified as Class AA-Special waterbodies (Boylen et al. 2014, NYSDEC Environmental Resource Mapper 2018):

1. Northwest Bay Brook
2. Indian Brook
3. Hague Brook
4. West Brook
5. English Brook
6. Shelving Rock Brook
7. Finkle Brook
8. East Brook
9. Sucker Brook
10. Foster Brook

The La Chute River is the lake outlet and is a Class C waterbody, best usage is for fishing, and is suitable for fish propagation and survival, from its mouth to 1.5 miles upstream of the D&H railroad bridge. From this point, upstream to the Lake George dam it is a Class C(TS) waterbody, suitable for trout spawning, given its (TS) classification. The water quality is suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

More information about the New York State classification system is provided in **Appendix B**.

3.2 Potable Water Uses

Lake George serves as the primary drinking water supply for both residents and visitors (Boylen et al. 2014); approximately 75% of homes get their drinking water directly from the lake or private wells within the watershed (LGA 2016). The Towns of Lake George, Bolton, and Ticonderoga and the Village of Lake George utilize municipal water services. Where these services are unavailable, a comparable number of properties throughout the watershed rely on private on-site wells or direct withdrawal from the lake. The water district of Diamond Point draws water from two wells along Diamond Point Road, and the Town of Bolton draws from Edgecomb Pond, directly upstream from Lake George. The Village of Lake George withdraws water directly from the lake, which then goes through a filter system also used by portions of the Town of Lake George. The Village of Lake George water district provides drinking water for approximately

1,800 people through 1,400 service connections with an average daily demand of 700,000 gallons and permitted capacity of 2 million gallons per day (Village of Lake George 2016; LGA 2016). Ticonderoga draws water from a reservoir and the lake (up to 1 million gallons per day) and has the lowest capacity. Ticonderoga recently drilled new wells, and its use of the reservoir will soon be terminated. Ticonderoga is currently aiming to upgrade its filtration plant, with continued use of Lake George water. Bolton and Diamond Point have the largest available capacities. The Village of Lake George has the largest system, measured in gallons drawn per day (LGA 2016).

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

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

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

In 2015, the USEPA also developed 10-day health advisories for the HAB toxin cylindrospermopsin. (USEPA 2015). Although monitoring for cylindrospermopsin continues, it has not been detected in any of the extensive sampling performed in New York State. New York State HAB response activities have focused on the blooms themselves and microcystin given it is by far the most commonly HAB toxin found.

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

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

3.3 Public Bathing Uses

Eight publicly-accessible beaches are open for swimming during the summer months on the shorelines of Lake George: Million Dollar State Beach, Shepard Park Beach, Usher Park, Lake George Dog Beach, Rogers Memorial Park Beach, Veteran’s Park, Hague Town Beach, and Washington County Beach. Lifeguards are on duty at most of the beaches during designated hours. There are also numerous beaches associated with many of the lodging and campground facilities that are located along the Lake George shoreline, including the New York State campgrounds at Hearthstone Point, Rogers Rock, and Lake George Battleground, as well as three island campgrounds (Glen

Island, Narrow Island, and Long Island). Lake George also has many non-public swimming locations that are regulated by the NYSDOH.

3.4 Recreation Uses

Lake George is a popular summer tourism destination that supports a nearly $1 billion annual local tourist economy (Boylen et al. 2014). The Lake provides an array of recreational activities, including boating, swimming, fishing, jet-skiing, kayaking, and paddle boarding for both residents and tourists, due to its size, relatively high water quality, and multiple access points. Regulations require the registration of all watercraft via day use or seasonal permits (NYSDEC 2018b). There are six public boat launches available at Hague Town Beach, Lake George Village, Mossy Point, Northwest Bay Brook, Norowal Marina, and Rogers Rock Campground (Lake George Guide 2018).

3.5 Fish Consumption/Fishing Uses

Both open water and ice fishing are permitted in Lake George. Lake George ranks among the top five bass fishing destinations in New York State, and is popular among ice fisherman for its yellow perch (*Perca flavescens*) and black crappie (*Pomoxis nigromaculatus*) populations in many nearshore bays. (NYSDEC 2018c). General statewide fishing regulations apply to Lake George. **Table 1** details the special fishing regulations that are applicable to Lake George, specifically. The following fish consumption advisories set for the Adirondack Region also apply to Lake George (NYSDEC 2015, NYSDOH 2018a):

- Yellow perch
    - Men over 15 and women over 50: Up to 4 meals/month
    - Women under 50 and children under 15: no consumption if greater than 10”, 4 meals/month if less than 10”
- Largemouth bass, northern pike, smallmouth bass, walleye, pickerel
    - Men over 15 and women over 50: Up to 4 meals/month
    - Women under 50 and children under 15: no consumption
- Brook trout, brown trout, rainbow trout, rock bass, crappie, sunfish, bullhead, all other fish
    - Men over 15 and women over 50: Up to 4 meals/month
    - Women under 50 and children under 15: Up to 4 meals/month

Table 1. Lake George fishing regulations.

Species	Open Season	Minimum Length	Daily Limit	Method
Trout	All year	Any size	5	Ice fishing permitted
Lake Trout	All year	23”	2	
Atlantic Salmon	All year	18”	2	
Yellow Perch	All year	Any size	50	
Sunfish	All year	Any size	50	
Smelt	May 16-Mar 31	Any size	25	
	Apr 1-May 15	Use and possession prohibited		

Note: Includes all tributaries upstream to the first barrier impassible by fish

3.6 Aquatic Life Uses

As a Class AA-Special waterbody, Lake George supports both coldwater and warmwater fish communities, including lake trout (*Salvelinus namaycush*), landlocked Atlantic salmon (*Salmo salar*), rainbow smelt (*Osmerus mordax*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), northern pike (*Esox lucius*), chain pickerel (*E. niger*), yellow perch, brown bullhead (*Ameiurus nebulosus*), pumpkinseed (*Lepomis gibbosus*), rock bass (*Ambloplites rupestris*), and black crappie. NYSDEC stocks Lake George annually with landlocked Atlantic salmon, rainbow trout (*Oncorhynchus mykiss*), and brook trout (*Salvelinus fontinalis*) (NYSDEC 2018d).

Rainbow smelt were introduced to the lake in the early 20th century, and became a self-sustaining population by the early 1970s, potentially shifting the plankton community composition (Siegfried 1987, Boylen et al. 2014). This shift, which improved conditions for cyanobacteria (Boylen et al. 2014), is further discussed in **Sections 6** and **9**.

Bays found along Lake George provide ideal conditions for aquatic plants which offer a variety of benefits for the lake including oxygen production, nearshore energy reduction which can lead to sedimentation, nutrient absorption/sequestration, and wildlife food and habitat (LGA 2018b). Lake George also harbors eight plant species that are classified as endangered, threatened, or rare by New York State (see **Section 6.3**).

3.7 Other Uses

The Towns of Bolton, Dresden, Hague, Putnam and Ticonderoga and the Village of Lake George operate wastewater treatment facilities. None of these directly discharge into Lake George, as per the Class AA-Special regulatory protections. Service is generally provided to only the most densely populated areas of these communities. Service is also provided to a portion of the Town of Lake George by the Village of Lake George and a portion of Putnam served by Ticonderoga. Land areas outside of defined service areas are served by onsite wastewater systems or smaller community systems (LGA 2016).

Many birds and mammals rely on Lake George and its shoreline for foraging, roosting, and nesting. While some birds stay in the area year-round, the majority can be found seasonally during breeding and migration seasons. A variety of species are found in the Lake George area, including a few endangered, threatened, and special concern species (LGA 2018c):

- common loon (*Gavia immer*)
- great blue heron (*Ardea Herodias*)
- American bittern (*Botaurus lentiginosus*)
- mallard duck (*Anas platyrhynchos*)
- American black duck (*A. rubripes*)
- common merganser (*Mergus merganser*)
- peregrine falcon (*Falco peregrinus*)
- bald eagle (*Haliaeetus leucocephalus*)
- osprey (*Pandion haliaetus*)
- red-shouldered hawk (*Buteo lineatus*)

Mammalian species found in the Lake George watershed include:

- white-tailed deer (*Odocoileus virginianus*)
- moose (*Alces alces*)
- black bear (*Ursus americanus*)
- coyote (*Canis latrans*)
- raccoon (*Procyon lotor*)
- fox (*Vulpes, Urocyon cinereoargenteus)*
- bobcat (*Lynx rufus*)
- American beaver (*Castor canadensis*)
- river otter (*Lontra canadensis*)

4. User and Stakeholder Groups

Lake George residents and tourists enjoy abundant recreational opportunities supported by the lake's near-pristine conditions.

Several citizen advocacy groups have formed with the shared goal of protecting the water resources of Lake George. The Lake George Association (LGA), established in 1885, was the first lake-focused conservation organization in the United States. The LGA consists of year-round and seasonal residents, members of the business community, and local government representatives. It focuses on protecting the waters of Lake George and educating stakeholders about its watershed through on-the-ground projects and a comprehensive education program. The Board of Directors are volunteers, but new members are welcome and made official through membership dues (LGA 2018d, Lake Champlain Basin WI/PWL 2009).

The Lake George Land Conservancy (LGLC) is a not-for-profit land trust that protects lands within the Lake George watershed with the overall goal of preserving the renowned water quality of the lake (LGLC 2018). The LGLC acquires land and encourages the public to responsibly enjoy its properties (e.g., hiking, picnicking, kayaking, dog-walking, fishing, etc.). As of 2009, the LGLC, its partners, and over one thousand concerned individuals have worked together to protect more than 48,500 feet of shoreline and 12,530 acres of land surrounding Lake George (Lake Champlain Basin WI/PWL 2009).

The FUND for Lake George is a not-for-profit, privately funded organization focused on the water quality of Lake George and the overall health of the watershed through scientific research, strategic advocacy, diverse partnerships, and direct investment. Long-term scientific research is supported through a partnership with The Darrin Fresh Water Institute (DFWI) at Rensselaer Polytechnic Institute (RPI). The FUND initiated the Lake George Waterkeeper program to protect the natural resources of Lake George and its watershed through advocacy, outreach, monitoring, and assessment (The FUND 2018).

The Stop Aquatic inVasives from Entering Lake George (S.A.V.E.) Partnership is an alliance between local municipal leaders, conservation groups, and researchers. S.A.V.E.'s goal is to protect Lake George's water quality by preventing the introduction and spread of invasive species. The S.A.V.E. Partnership has initiated and supported programs such as mandatory boat inspections and wash stations at locations of high risk for aquatic invasive species introductions (The FUND 2018).

5. Monitoring Efforts

5.1 Lake Monitoring Activities

Lake George is rather unique in that it has been the subject of scientific study for decades. The State of New York Conservation Commission facilitated a 1920 biological survey of Lake George to study the lake's chemistry and biota in support of a planned fish hatchery, built a few years later (Needham et al. 1922).

The NYSDEC conducted research during the 1960s and 1970s which indicated that nutrient loadings had more than doubled since the area was settled.

DFWI began chemical surveillance of the lake in 1980. The Offshore Chemical Monitoring Program was conducted at least monthly during non-winter months at six mid-water stations from 1980 to 1994, and eight stations from 1995 to 2009: three in the north basin, four in the south basin, and one in the constricted channel connecting the two basins.

The Nationwide Urban Runoff Program (NURP) was a five-year program established by the USEPA in 1978 as a collaborative effort between federal, state, regional, and local agencies distributed across the United States. The goal of the program was to study several facets of urban runoff, including:

- The quality characteristics of urban runoff and similarities or differences at different urban locations
- The extent to which urban runoff is a significant contributor to water quality problems across the country
- The performance characteristics and the overall effectiveness and utility of management practices for the control of pollutant loads from urban runoff

Projects selected were ones where the work would complete the urban runoff elements of formal water quality management plans and the results were likely to be incorporated in future plan updates and lead to implementation of management recommendations. Within USEPA Region 2, Lake George was selected as one of the 28 NURP focus areas. For Lake George, the study focused on the concern that urban runoff from present and potential future development would unacceptably accelerate degradation of existing water quality (USEPA 1983).

The Jefferson Project at Lake George is a partnership between Rensselaer Polytechnic Institute (RPI), IBM Research, and the FUND which focuses on providing and developing scientific insights and technology to help manage and protect Lake George. The project is building a computing platform to capture and analyze data from a network of sensors tracking water quality and movement. These data are then combined with other data to develop a better understanding of the factors impacting the lake's food web and overall water quality (RPI 2018).

Lake George was first sampled as part of the Citizen Statewide Lake Assessment Program (CSLAP) in 2004, although only a single site was evaluated in 2001. Nine sites in Lake George have been the most routinely sampled as part of CSLAP (**Figure 4**). Four of these sampling locations were selected to evaluate water quality in Lake George for this Action Plan based on spatial representation of Lake George (south, middle, and northern extents) and longer temporal extent of available data relative to other locations. The four sampling locations consist of (from south to north):

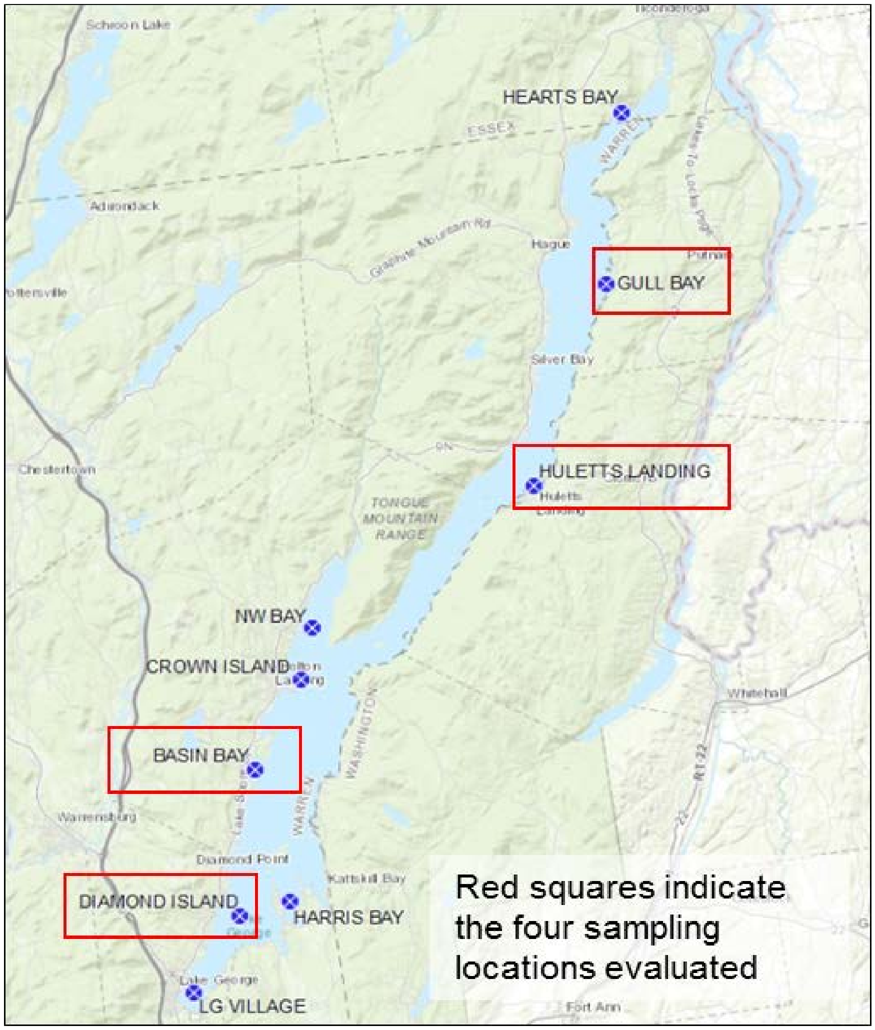


Figure 4. Lake George water chemistry sample locations.

- ***Diamond Island*** – 2004-2014, 2017
- ***Basin Bay*** – 2004-2014, 2017
- ***Huletts Landing*** – 2007-2013
- ***Gull Bay*** – 2007-2009; 2011-2014, 2017

Section 6 details the physical, chemical, and biological condition of Lake George based on data collected through the CSLAP program. HABs monitoring was conducted through CSLAP starting in 2008 in some lakes, and in 2012 in all CSLAP lakes.

Additional monitoring programs that provide additional context for interpreting results of Lake George monitoring and research programs include, among others:

- The State of New York Conservation Department conducted a 1929 biological survey of the Lake Champlain watershed, including Lake George, to acquire a scientific basis to assist in creating a constructive fish stocking policy (Conservation Department 1929).

- Experimental Lakes Area in Ontario, Canada demonstrated the paramount role of phosphorus loading in causing eutrophication (Schindler and Fee 1974).
- The Vermont and New York State Departments of Environmental Conservation conducted a program from 1992 to 2012 to evaluate the effects of phosphorus and other nutrient loading in Lake Champlain, as well as effects of acid rain from fossil fuel combustion.
- The Adirondack Lakes Survey Corporation (ALSC) studied the impacts of acid rain in the early 1980s.
- Burdick et al (1964) identified the collapse of the lake trout fishery in the lake due to DDT.
- Lake George Ecosystem volumes 1-3 from 1980-1983 described all of the efforts of RPI, Skidmore, Union, NYSDOH, NYSDEC and others in the basin from the 1970s.
- Lake George Offshore chemistry, 1980-present, RPI measures a suite of lake parameters throughout the Lake.

5.2 Tributary Monitoring Activities

A number of the tributaries to Lake George have been monitored every five years through the NYSDEC Rotating Integrated Basin Studies (RIBS) since the early 1990s. Similar monitoring was conducted on several of the tributaries prior to that. Results indicate that water quality, sediment, and the macroinvertebrate community are in generally good condition with no pollutant concentrations above the established guidance values, and no contaminants identified as parameter(s) of concern. Aquatic life is generally considered to be fully supported in monitored streams, with a balanced distribution of all expected species. Some replacement of sensitive ubiquitous species by more tolerant species was noted, although the community composition and nutrient biotic evaluation suggests low levels of nutrient enrichment. These tributaries are scheduled to be sampled again as part of the RIBS monitoring between 2018 and 2020.

Additional stream monitoring includes:

- Lake George streams study, 1970-1972, NYSDOH studied chemistry of streams throughout the basin
- Additional stream studies conducted by NYSDEC and collaborating partners since the 1980s.
- Lake George Streams, 2008-2012, RPI measured baseline and event chemistry in 8 streams in the basin.

Lake George and its tributaries were added to the NYS 2002 Section 303(d) List of Impaired Waters due to sediment loading from various nonpoint sources and eroding steep gradient streams. They are included on Part 1 of the List as waterbody segments requiring the development of a Total Maximum Daily Load (TMDL) or other strategy to attain water quality standards for silt/sediment. A draft TMDL for similarly impacted tributaries to Lake George identified the need to dredge sediment deltas in order to fully restore recreational uses. However, this non-traditional approach was not considered by the USEPA to meet the requirements of a TMDL.

6. Water Quality Conditions

General long-term trends in water quality conditions were assessed using available data collected at the four CSLAP locations (**Figure 4**). Trends were evaluated using a nonparametric correlation coefficient (Kendall's tau, τ) to determine if time trends were significant (assumed for p-values less than 0.05). Water quality data used in these analyses were limited to those that were collected under a State-approved Quality Assurance Project Plan (QAPP), and analyzed at an Environmental Laboratory Accredited Program (ELAP) certified laboratory.

Table 2 provides a regional summary of surface total phosphorus (TP) concentrations (mg/L) from the four water quality sampling locations in Lake George compared to New York State lakes. In freshwater lakes, phosphorus is typically the nutrient that limits plant growth; therefore, when excess phosphorus becomes available from point sources or nonpoint sources, primary production can continue unchecked leading to algal blooms. Note that phosphorus form is an important consideration when evaluating management alternatives (**Section 13**).

Table 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 the select Lake George sample locations.

Region	Number of Lakes	Average TP (mg/L)	Average TP Diamond Island (mg/L) 2004-2014, 2017	Average TP Basin Bay (mg/L) 2004-2014, 2017	Average TP Huletts Landing (mg/L) 2007 to 2013	Average TP Gull Bay (mg/L) 2007-2009, 2011-2014, 2017
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)	0.008 (± 0.001)	0.006 (± 0.0003)	0.005 (± 0.0003)	0.005 (± 0.0003)
Western Adirondack	88	0.012 (± 0.001)	-	-	-	
Central NY	60	0.024 (± 0.005)	-	-	-	
Finger Lakes region	45	0.077 (± 0.022)	-	-	-	-
Finger Lakes	11	0.015 (± 0.003)	-	-	-	
Western NY	47	0.045 (± 0.008)	-	-	-	

The data provided in **Table 2** indicate that the average TP concentration in Lake George is significantly less than the average concentration found throughout the Eastern Adirondack region. Further, the average TP concentration in Lake George is less than half the New York State water quality guidance value of 0.02 mg/L, which suggests that the average concentration to protect water quality as part of future management actions in Lake George may best be targeted at concentrations lower than the State guidance value.

Water clarity (based on Secchi depth), TP, and chlorophyll-a concentrations are used to assess trophic state using New York State criteria (**Table 3**). Based on water quality sampling in Lake George, these indicators reflect oligotrophic (low productivity) conditions.

Table 3. New York State criteria for trophic classification (NYSFOLA 2009) compared to average (± standard error) Lake George values.

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Diamond Island 2004-2014, 2017	Basin Bay 2004-2014, 2017	Huletts Landing 2007-2013	Gull Bay 2007-2009, 2011-2014, 2017
Transparency (m)	>5	2-5	<2	7.2 (± 0.1)	8.0 (± 0.1)	8.9 (± 0.2)	10.2 (± 0.2)
TP (mg/L)	<0.010	0.010-0.020	>0.020	0.008 (± 0.001)	0.006 (± 0.0003)	0.005 (± 0.0003)	0.005 (± 0.0003)
Chlorophyll-a (µg/L)	<2	2-8	>8	0.89 (± 0.05)	0.88 (± 0.05)	0.47 (± 0.03)	0.54 (± 0.04

6.1 Physical Conditions

Results from Past Studies

The physical condition of Lake George has remained largely unchanged over the years that it has been monitored. Although some sample sites along the lake have experienced slight long-term decreases in water clarity, Lake George's water clarity is much higher than most nearby lakes due to low algal levels. Lakewide, water clarity has decreased by about 6% over the past thirty years (Boylen et al. 2014).

Monitoring data collected by DFWI indicate average surface water temperature increased 3.2°F (1.8°C) from 1980 to 2009, which can result in a longer growing season for primary producers, including cyanobacteria taxa that cause HABs (Boylen et al. 2014).

Current Analysis

Water clarity measurements, as represented by Secchi depth, in Lake George indicate oligotrophic (low productivity) conditions (**Figures 5a** and **5b**). Water clarity generally increases from south to north. At the Diamond Island sampling location (**Figure 5a**), water clarity has significantly decreased over time (p = 0.028, τ = -0.485, **Figure 5a**). A decrease in water clarity may indicate increasing sediment loading or increases in algal abundance that decrease Secchi depth. The annual minimum Secchi depth, or the lowest recorded value for a given year, has significantly decreased over time (p = 0.011, τ = -0.574) at Diamond Island, further suggesting that water is becoming less clear. However, average annual water clarity measurements at the Diamond Island sampling location in 2017 (mean = 7.1 m ± 1.3 m) are still indicative of an oligotrophic condition (**Figure 5a**). CSLAP Secchi disk transparency readings exceed the New York State Sanitary Code requirements for siting new bathing beaches (1.2-meter or 4 ft.) (NYSDOH 2018b). However, such trophic indicators should continue to be monitored for any changes.

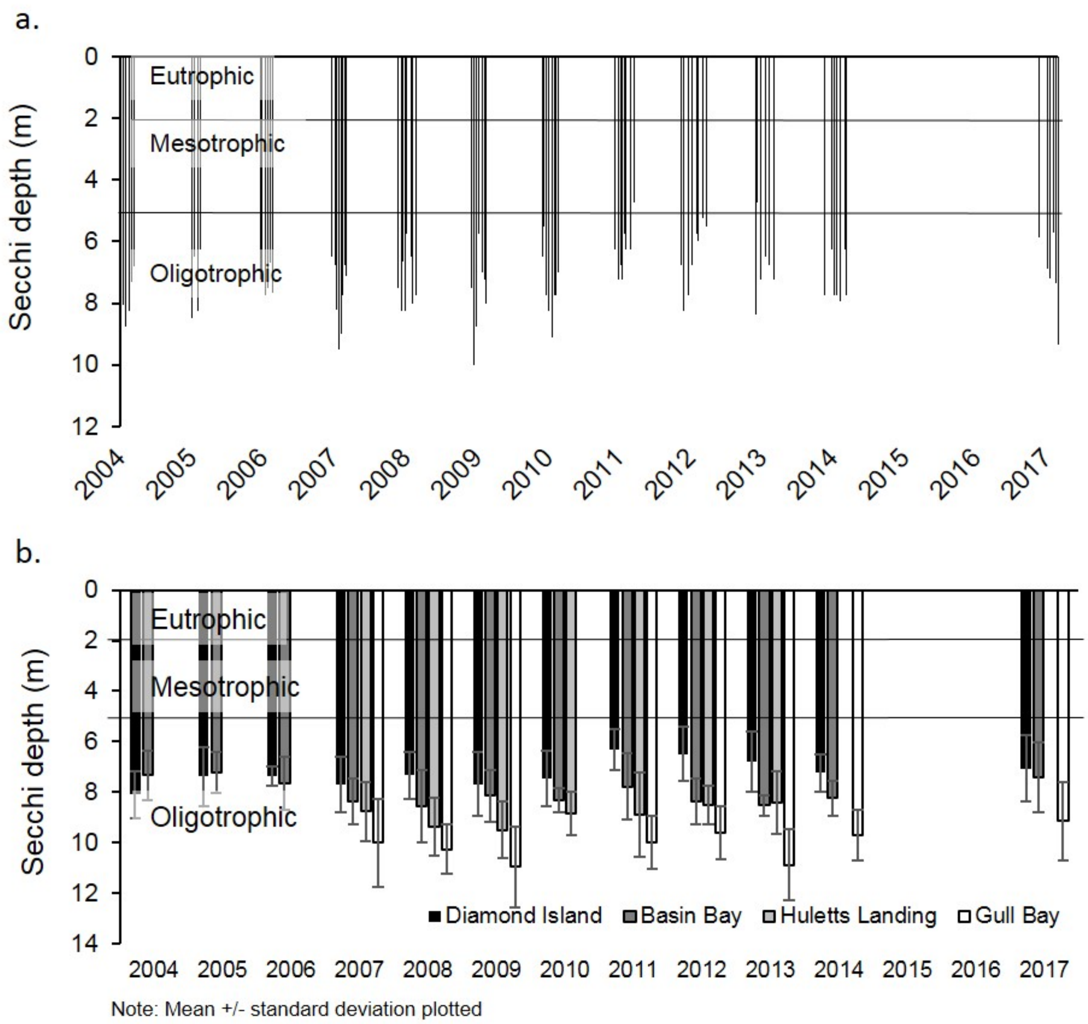


Figure 5. (a) Secchi depth measured at the Diamond Island sampling location in Lake George from 2004-2014, and 2017. (b) Annual average Secchi depth (m) from the four sampling locations in Lake George. Note the NYS standard for swimming is 1.2 m Secchi depth.

There were no statistically significant long-term trends in water clarity at the three other Lake George sampling locations. For example, annual average Secchi depth at Basin Bay showed an increasing non-significant trend in water clarity (p = 0.337, τ = 0.212) from 2004 to 2017 (**Figure 5b**). In contrast, Secchi depth at Huletts Landing (p = 0.176, τ = -0.429) and Gull Bay (p = 0.170, τ = -0.400) showed a decreasing non-significant trend over time (**Figure 5b**).

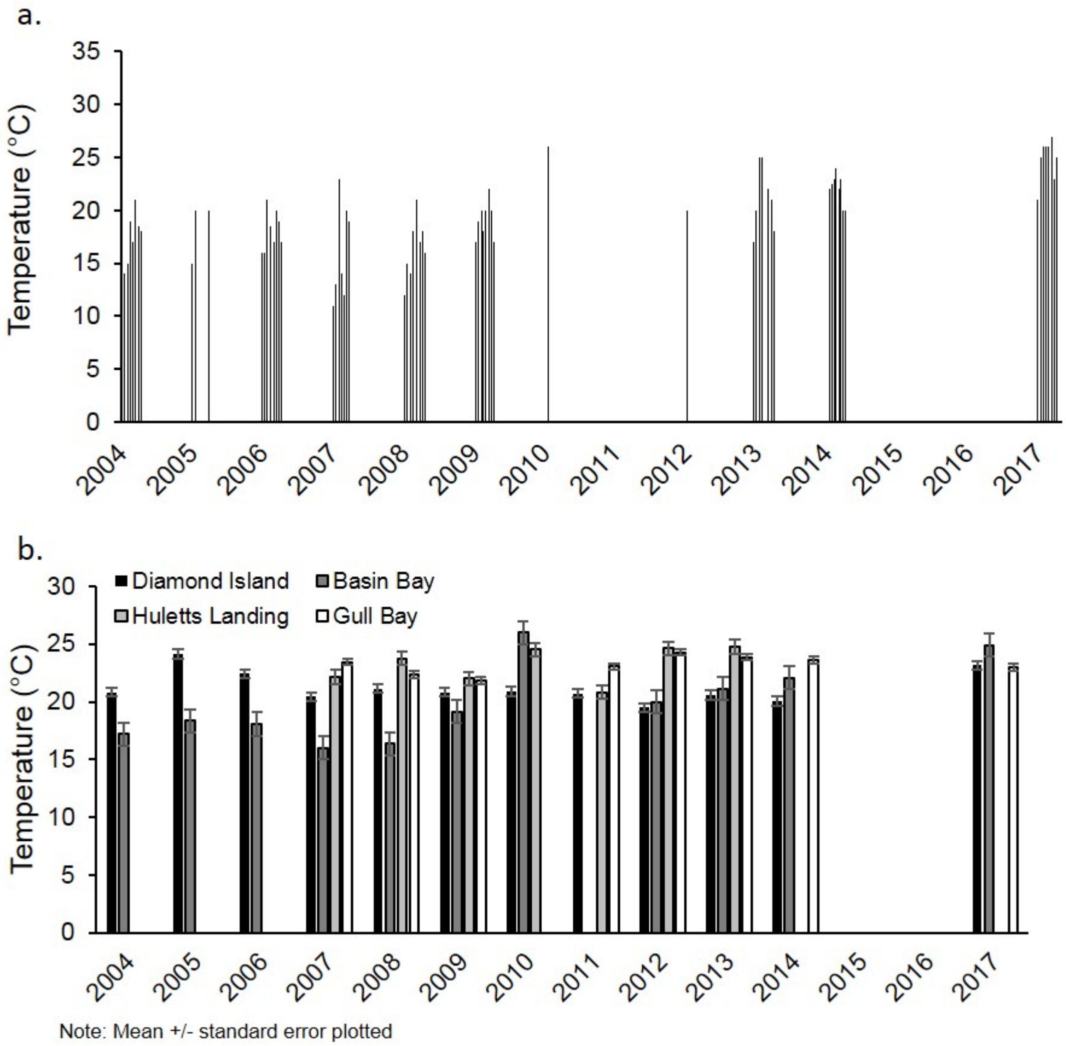


Figure 6. (a) Surface temperature (˚C) measured at the Basin Bay location 2004-2014, and 2017. (b) Annual average surface temperature (˚C) from the four sampling locations in Lake George 2004-2014, and 2017.

Monitoring data collected by DFWI indicate average surface water temperature in Lake George increased 3.2°F (1.8ºC) from 1980 to 2009 (Boylen et al. 2014). Understanding both seasonal and long-term temperature patterns within a waterbody seasonally is important in understanding HABs. Most cyanobacteria taxa grow better at higher temperatures than other phytoplankton, providing them a competitive advantage at higher temperatures (typically above 25ºC) (Paerl and Huisman 2008). Seasonal and long-term trends in CSLAP surface water temperature data were variable at the Lake George sampling locations. In general, seasonal temperature trends in surface water in Lake George followed typical patterns, with increasing temperatures from spring to summer and decreasing temperatures in the fall. However, the following additional annual trends were observed:

- Basin Bay annual average surface water temperatures have increased over time (p = 0.010, τ = 0.600, **Figure 6**). Annual maximum surface temperature (p = 0.008, τ = 0.725) and the percentage of temperature records that were above 20°C (p = 0.009, τ = 0.730) have also significantly increased from 2004 to 2017.
- Huletts Landing and Gull Bay showed an increasing trend in surface water temperatures over time (p = 0.176, τ = 0.429 and p = 0.621, τ = 0.143, respectively), though these trends were not statistically significant. In contrast, surface water temperatures at Diamond Island showed a non-significant decreasing trend in surface water temperature (p = 0.131, τ = -0.333).
- Of note, the three sampling locations that had increasing surface water temperatures over time (Basin Bay, Huletts Landing, and Gull Bay) are nearshore sampling locations (**Figure 4**). In contrast, Diamond Island is in a more open water, offshore location (**Figure 4**). The nearshore areas in Lake George, with increasing trends of water temperatures, may be 'sentinel' locations to monitor and evaluate the potential for HABs in the future.

6.2 Chemical Conditions

Results from Past Studies

As an oligotrophic (i.e., low-nutrient) lake, Lake George is susceptible to strong biological responses from chemical changes. Depleted dissolved oxygen (DO) levels not suitable for fish (2-3 mg/L) can occur within the hypolimnion of Caldwell Basin (Note: The Diamond Island sampling location is located within this basin [**Figures 3** and **4**]) during late summer and early fall, although the depth of hypoxia varies annually (Boylen et al. 2014). More severe DO depletion could potentially cause legacy phosphorus to be released from the bottom sediments, which could then stimulate phytoplankton productivity. Limited dissolved oxygen profile data are available for Lake George and should be supplemented in future monitoring to inform management planning and implementation of specific actions.

The data obtained by DFWI's monitoring efforts (Boylen et al. 2014) indicate the following:

1. The clearest trend evident from the monitoring is an increase in chloride which nearly tripled from about 6 mg/L in 1980 (well above the background of < 1 mg/L chloride typical of Adirondack lakes in undeveloped watersheds) to 16 mg/L in 2009. The primary source of chloride is road de-icing applications within the watershed during winter months. There is not currently a well-established relationship between chloride and HABs although relevant research is ongoing in this area. It is likely that other factors associated with HABs (**Section 9**), such as nutrients, dreissenid mussels, and fetch length, play a more important role in HABs formation than chloride.
2. Concentrations of TP declined by approximately 60% between 1960 and 1980. TP concentrations remained consistent from 1980 through 2009, suggesting that

measures to reduce TP loading during the 1970s were effective. Concentrations of total nitrogen (TN) also declined during this period.

3. Concentrations of TN and sulfate declined in the 1990s, potentially due to reductions in nitrogen and sulfur oxide emissions associated with the Clean Air Act. This brought about an associated decrease in acidity and increase of alkalinity (or acid-neutralizing capacity of the water).
4. Concentrations of chlorophyll-a increased by about 33% from 1980 to 2009. These changes may be due to one or more of the following factors:
    a. Changes in the composition of the lake’s fish community, due in part to the introduction of rainbow smelt, may have increased phytoplankton populations due to increased consumption of zooplankton by fish.
    b. A shift in the phytoplankton community composition towards species that exhibit higher chlorophyll-a concentrations.
5. Phosphorus levels vary slightly seasonally from year to year and site to site without a clear spatial pattern. Long-term surface phosphorus variations at both northern (Gull Bay) and southern (Diamond Island) sites are mostly synchronized with changes in deepwater phosphorus levels (NYSDEC 2015).

Current Analysis

Total phosphorus (TP) concentrations in Lake George are largely indicative of oligotrophic conditions (**Figure 7**). Seasonal patterns of TP concentrations at Lake George sampling locations were variable (e.g., mid-season TP peak at Diamond Island in 2006, compared to late-season TP peak in 2011, **Figure 7a**).

There was not a statistically significant trend in TP over time at any of the sampling locations (p-values > 0.05). However, at the Huletts Landing location, there was a non-significant increasing trend in annual average TP from 2007 to 2013 ($p = 0.062$, $\tau = 0.617$, **Figure 7b**). Thus, the Huletts Landing segment of Lake George has shown signs of increasing surface water temperature, total phosphorus concentrations, and given the prevailing wind patterns in Lake George (**Appendix A**), this location may be more vulnerable to HABs caused by downwind accumulations of cyanobacteria. However, HABs have not been reported at any locations in Lake George, including the Huletts Landing portion of the lake.

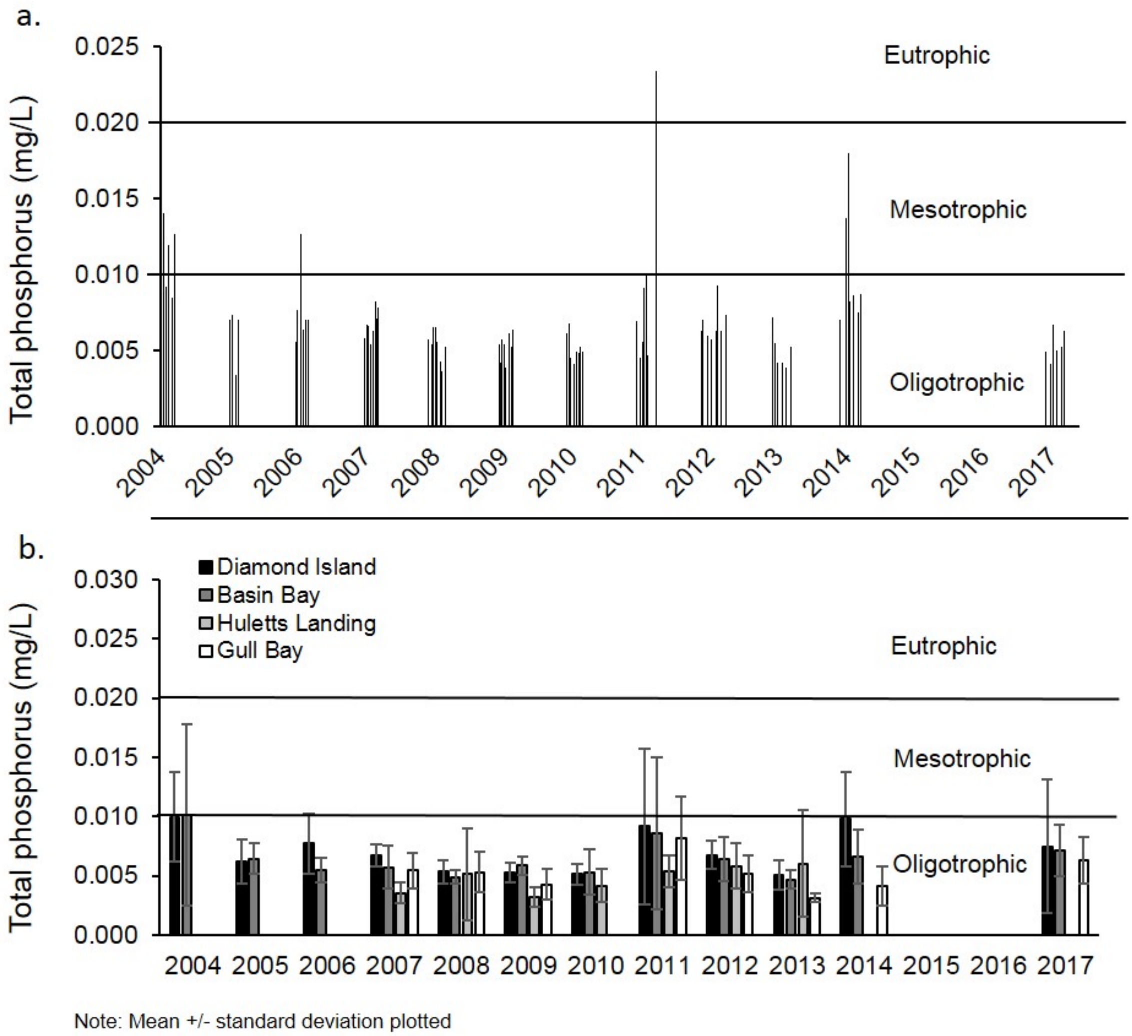


Figure 7. (a) Total phosphorus (mg/L) measured at the Diamond Island sampling location in Lake George from 2004-2014, and 2017. (b) Annual average total phosphorus (mg/L) from the four sampling locations in Lake George.

Total nitrogen (TN) concentrations showed a general seasonal trend of increased nitrogen concentrations during mid-year sample events (e.g., **Figure 8a** for Diamond Island). Long-term trends of average annual TN concentrations were not significantly different over time at the four sampling locations (p-values > 0.05).

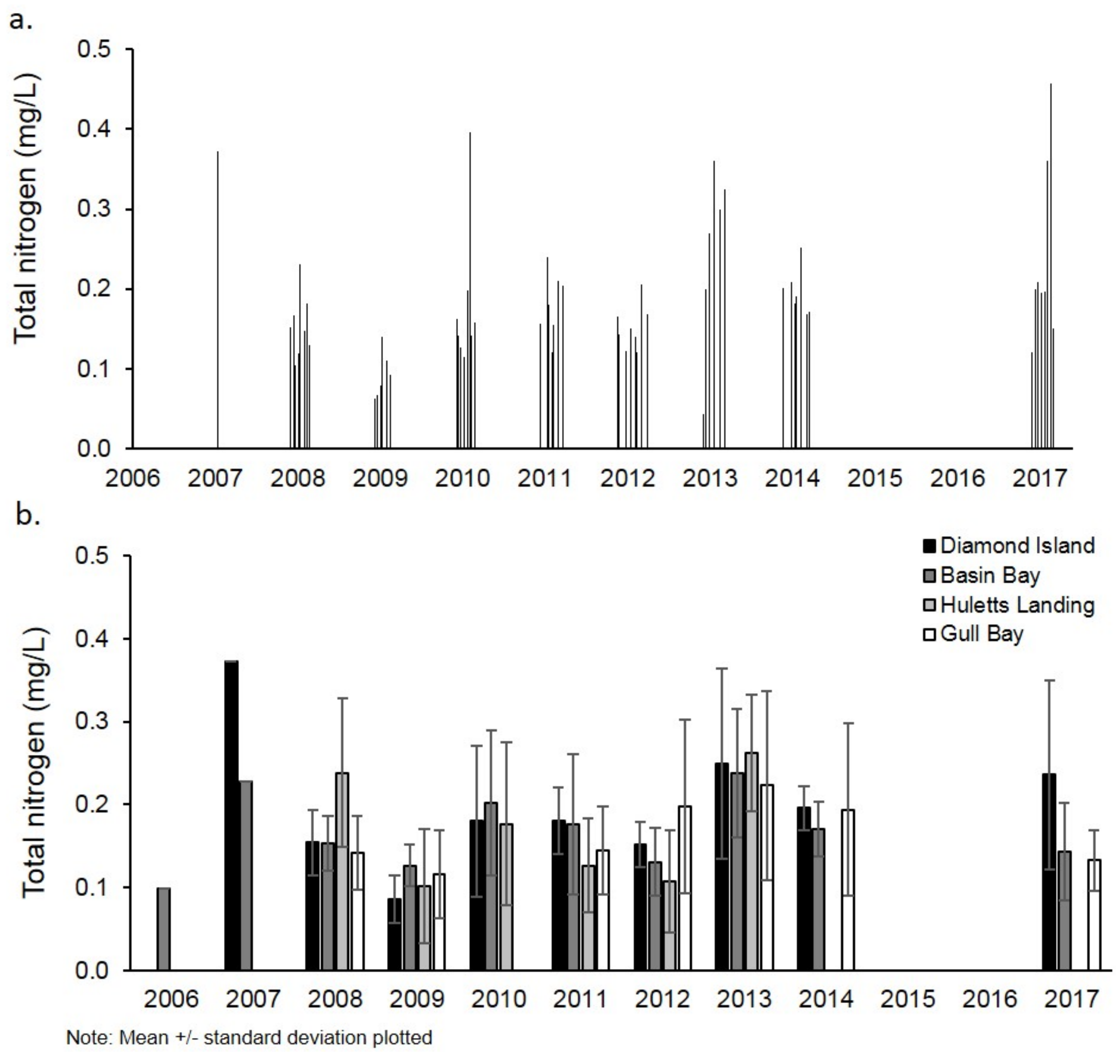


Figure 8. (a) Total nitrogen (mg/L) measured at the Diamond Island sampling location in Lake George from 2007-2017. (b) Annual average total nitrogen (mg/L) from the four sampling locations in Lake George.

The relative concentrations of nitrogen and phosphorus can influence algal community composition and the 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) may determine if 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 are capable of utilizing atmospheric dinitrogen (N_2), which is unavailable to other phytoplankton, providing a competitive advantage to N-fixing cyanobacteria when nitrogen becomes limiting. Ratios (by mass) of TN:TP at the four Lake George sampling locations typically ranged between 20 to 80, suggesting that algal biomass is likely not limited by nitrogen (**Figure 9**). There were no significant long-term trends in TN:TP at any of the four sampling locations.

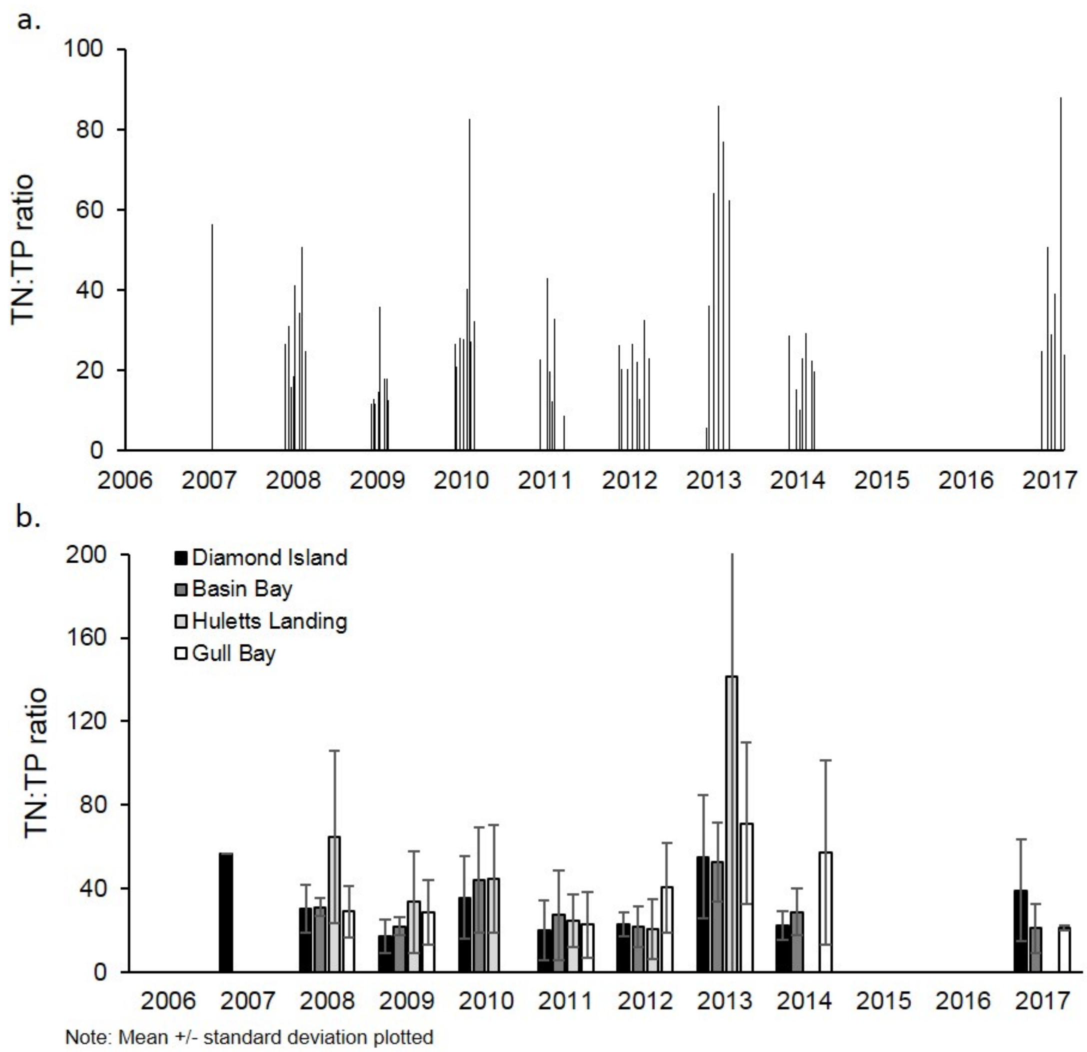


Figure 9. (a) TN:TP measured at the Diamond Lake sampling location in Lake George from 2007-2017. (b) Annual average TN:TP from the four sampling locations in Lake George. [Note the y-axis scale difference between the two figures].

Note that dissolved oxygen profiles for Lake George were not available to assess seasonal variation in available oxygen at depth. It has been suggested that dissolved oxygen concentrations can be limiting in deeper water locations in Lake George (Boylen et al. 2014). However, hypoxia has only been recorded in <0.1% of samples collected in deep-water locations over 36 years (The Jefferson Project, undated).

6.3 Biological Conditions

Results from Past Studies

Data collected during the State of New York Conservation Commission’s 1920 biological study indicate Lake George has an abundance of bottom fauna and extensive weed beds that provided food, shelter, and, for some fish species, spawning areas. According to the survey, lake trout, smallmouth black bass, yellow perch, and bullheads had perfectly adapted to the conditions of the lake. Data regarding DO, carbon dioxide, and the distribution of organisms and plankton indicate the lake does not have an uninhabitable bottom, as may be the case in deepwater lakes (Needham et al. 1922).

Presence and abundance of aquatic plants is spatially variable within Lake George (NYSDEC 2015). The macrophyte assemblage is diverse, including up to 45 plant species, seven of which are protected in New York (LGA 2018b):

- Water marigold (*Megalodonta beckiiI*)
- Alternate flower watermilfoil (*Myriophyllum alterniflorum*)
- Lake cress (*Neobeckii aquatica*)
- Northern pondweed (*Potamogeton alpinus*)
- Water awlwort (*Subularia aquatic* var. *americana*)
- Lesser bladderwort (*Utricularia minor*)
- Large spored quillwort (*Isoetes lacustris*)

Lake George does contain aquatic invasive species, including two macrophytes:

- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Curly-leaf pondweed (*Potamogeton crispus*)

In addition, benthic aquatic invasive species are present in Lake George, including zebra mussels (*Dressenia polymorpha*), Chinese mystery snails (*Cipangopaludina chinensis malleata)*, and Asian clams (*Corbicula fluminea*) (LGA 2018e). Finally, the invasive zooplankton, spiny water flea (*Bythotrephes longimanus*) was discovered in Lake George in 2012.

Zebra mussels can influence phytoplankton composition by selectively filter feeding algae, preferentially selecting phytoplankton, which can result in increased prevalence of cyanobacteria (Vanderploeg et al. 2001). Additionally, zebra mussels are often found on hard substrates 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). While zebra mussels were first discovered in the southern basin of Lake George in 1999 and have since been documented from several other locations in the lake, they have not spread like they have in other lakes due in part to an early and rapid response to that first invasion and subsequent ones with hand harvesting of colonies. In addition, low calcium concentrations and algal abundance limit the potential for a large expansion. Continued control of zebra mussels will help to limit their influence on potential HABs. In addition, Asian clams were first discovered in Lake George in 2010; this species also has high filtration rates and can concentrate nutrients in nearshore zones where they are found (NYSISI 2018).

Similarly, the spiny water flea can dramatically alter the lower food web by feeding on zooplankton, limiting the availability of this prey for juvenile fish, as well as by being unlikely to be consumed by small fish due to their spine (Michigan Sea Grant 2004).

This invader can negatively affect the growth rates and survival of young fish, potentially altering the predator prey dynamics.

A lake's fish community structure can influence the balance of zooplankton and phytoplankton within the system. Factors that affect zooplankton, including an abundance of fish that feed on them, can result in increased phytoplankton populations that can lead to HABs. It has been hypothesized that the introduction of rainbow smelt altered fish community dynamics resulting in a reduced zooplankton population from the mid-1970s to the mid-1980s as rainbow smelt prey on large-bodied zooplankton more efficiently than the indigenous fish species in Lake George (Siegfried 1987, Boylen et al. 2014). Because zooplankton feed on phytoplankton, their reduced population resulted in an increase in phytoplankton, which increased nutrient competition in the already nutrient-poor waters of Lake George (Boylen et al. 2014). Studies indicate that smelt populations declined in the 1980s-2000s, resulting in a harvesting ban placed by the NYSDEC in the late 1980s. Currently, the coldwater fish community is managed by the NYSDEC with landlocked Atlantic salmon, brook trout, and rainbow trout stocked annually and fishing regulations in place to maintain rainbow smelt, the primary prey for these salmonids. The restrictions were modified in 2016 to allow jigging in open water or through the ice and a limit of 25 per day; fishing/dip netting within the tributaries during spawning season remains prohibited. These current management practices suggest that rainbow smelt abundance is not high enough to exert excessive grazing pressure on zooplankton. As described in **Section 9**, insufficient data are available to more fully understand the existing community structure and its influence on cyanobacteria that can lead to HABs and should be supplemented to allow development of potential management strategies that maintain food web balance and minimize HABs.

Current Analysis

Chlorophyll-a is a photosynthetic pigment common to all algae and cyanobacteria. Seasonal trends in chlorophyll-a generally follow a pattern of higher concentrations both early and late in the season with a decline during the middle season (**Figure 10a**). This may be indicative of zooplankton grazing following a spring bloom as temperatures increase (Lampert et al. 1986). Chlorophyll-a concentrations at all four locations in the lake are consistently low, indicating limited phytoplankton productivity.

There were no significant long-term trends of annual average chlorophyll-a concentrations at Basin Bay ($p = 0.493$, $\tau = -0.152$), Diamond Island ($p = 0.131$, $\tau = -0.333$), or Gull Bay ($p = 0.805$, $\tau = -0.071$) (**Figure 10b**). However, annual average chlorophyll-a concentrations in Huletts Landing have significantly increased ($p = 0.024$, $\tau = 0.714$) from 2007 to 2013, although all concentrations measured were indicative of oligotrophic (low productivity) conditions (**Figure 10a**).

As noted in **Section 2.3** and depicted in **Appendix A**, the prevailing wind patterns from 2010 to 2017 (during the months of June through November) indicate that wind was predominately out of the south-southwest, and algae, including cyanobacteria, may accumulate at the northeastern Huletts Landing location through wind activity. Thus, the increasing trend of chlorophyll-a may be due, in part, to algae accumulating at the Huletts Landing location, but generated in southern portions of Lake George. However, there is no evidence at this time to indicate that any HABs have been found in the downwind portions of the lake (or in any other lake locations).

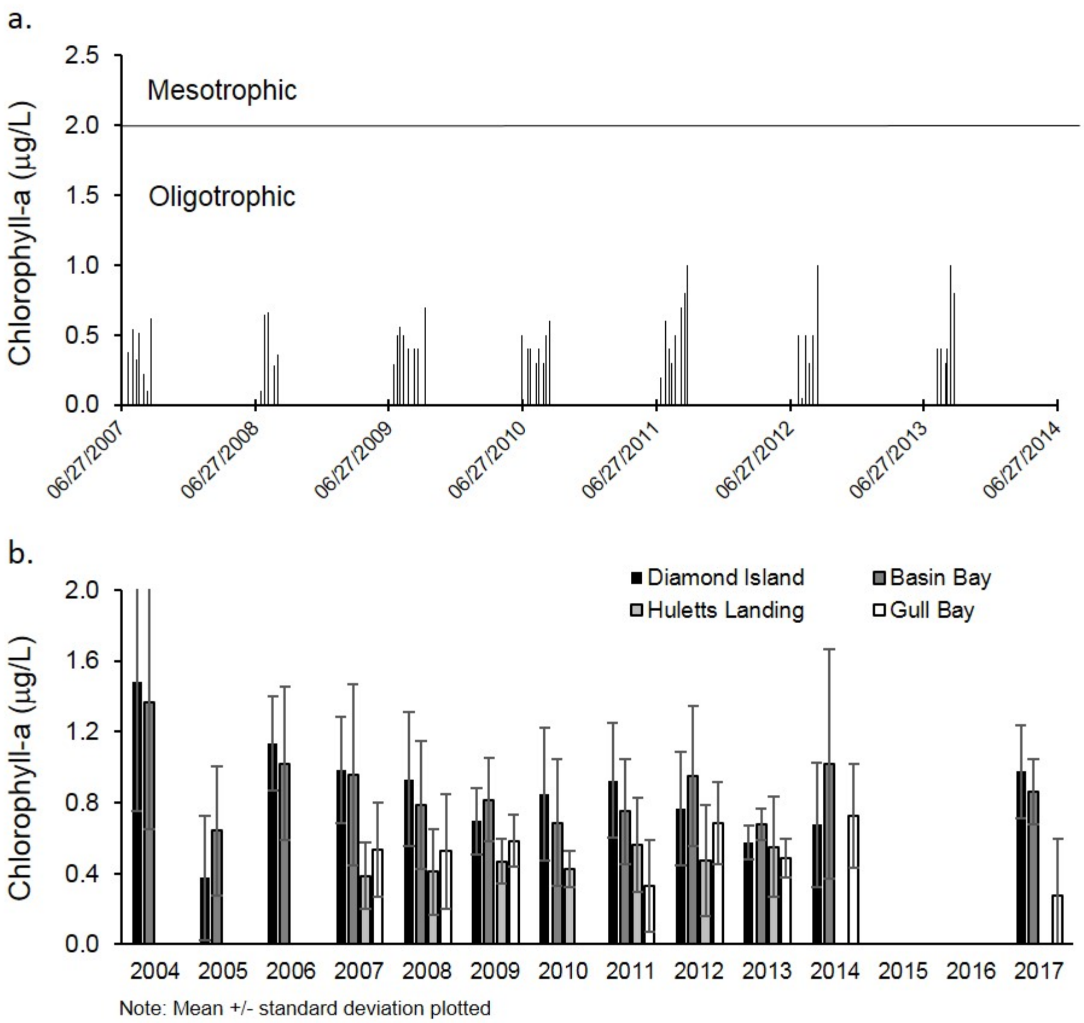


Figure 10. (a) Chlorophyll-a (µg/L) measured at the Huletts Landing sampling location in Lake George from 2007 to 2013. (b) Annual average chlorophyll-a concentrations (µg/L) at the four select sampling locations in Lake George.

6.4 Other Conditions

Of particular note, data collected during DFWI's monitoring indicated a reduction in the density of macroalga (*Nitella* spp.) on the lake bottom. *Nitella* and other macroalga extract nutrients from the water column, while many rooted macrophytes (such as Eurasian watermilfoil) extract nutrients from deeper sediments. Hence, *Nitella* may outcompete phytoplankton, including benthic cyanobacteria, for nutrients. A decline in the abundance of *Nitella* may release phytoplankton, including benthic cyanobacteria, from past levels of competition. Future research and monitoring efforts should focus on improving understanding of primary producer community dynamics.

Significant sedimentation deltas have formed at the mouths of many tributary segments. These deltas impeded recreational boat navigation and present opportunities for the establishment of non-native aquatic vegetation. Therefore, secondary contact recreation (boating, fishing) use for Lake George is assessed as impaired by silt/sediment. In addition, habitat condition is evaluated as fair due to those same impacts from silt/sediment pollutant and invasive plants. Urban stormwater runoff and streambank erosion are identified as the known sources of pollutants.

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. The chlorophyll-a model was developed based on data with concentrations less than 20 µg/L. The accuracy of the model for chlorophyll-a concentrations exceeding 20 µg/L has not been tested. 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 11**, the majority of Lake George typically has low chlorophyll-a concentrations. Based on remote sensing images, the highest chlorophyll-a concentrations tend to be at the north end of the lake near the outlet where the depth is less than 16 ft. and near the shore at Huletts Landing.

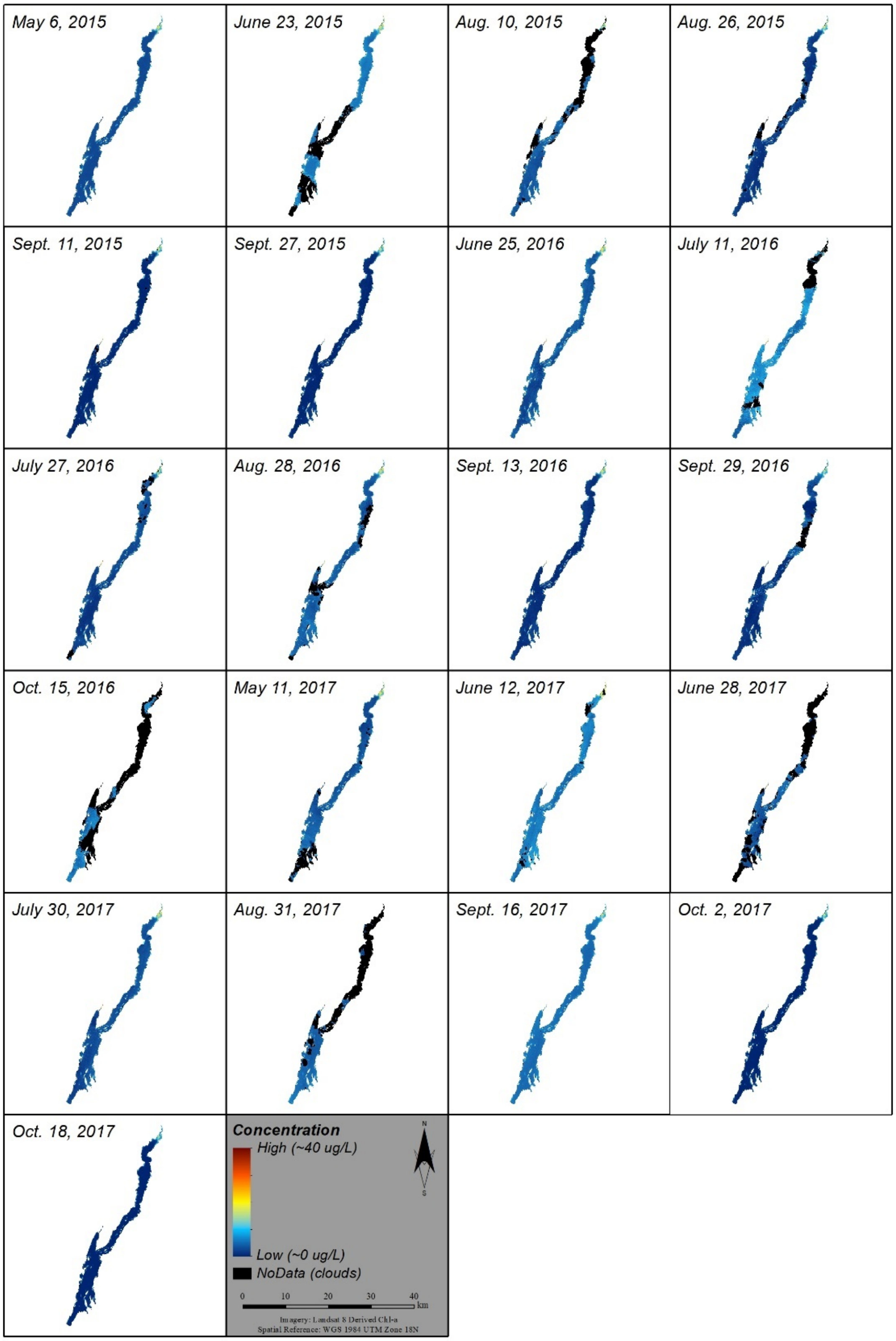


Figure 11. Estimated chlorophyll-a concentrations in Lake George, 2015 to 2017.

The estimated chlorophyll-a concentrations from the remote sensing analysis were extracted at the CSLAP monitoring stations (Basin Bay, Gull Bay and Diamond Island) to compare the estimates with the measured chlorophyll-a concentrations (**Figure 12**). There were no CSLAP measurements that aligned with remote sensing images for direct comparison. However, the data trends indicate that remote sensing estimates are higher than CSLAP monitoring samples. This could be because the modelled estimates are averaged over the depth of light transmission (e.g. twice the Secchi depth) while the measured concentrations were taken at a specified depth of 1.5 m. The water clarity in Lake George is generally high, which means the satellite can penetrate the water column further and therefore is not expected to compare well to CSLAP measurements taken at a specific depth.

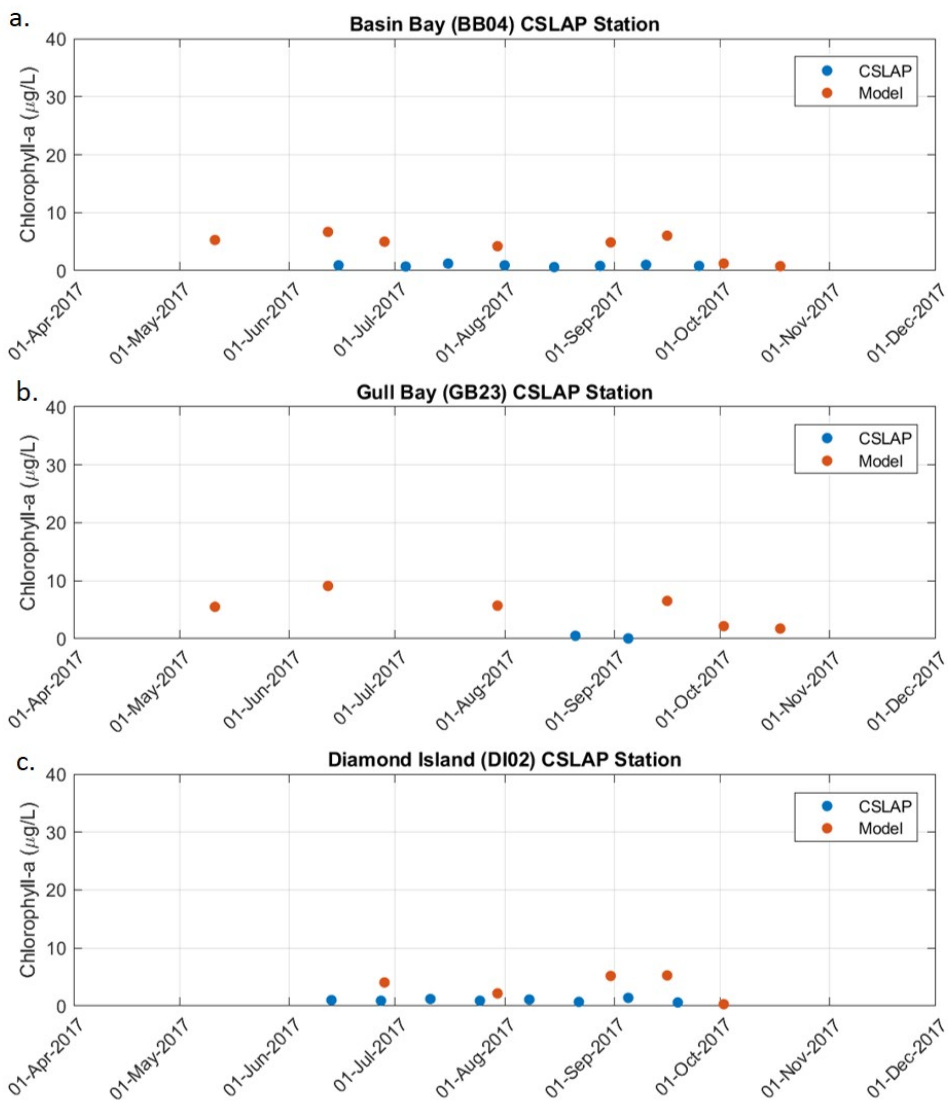


Figure 12. Measured (CSLAP, blue circles) and modeled (Landsat 8, orange circles) chlorophyll-a concentrations from the (a) Basin Bay, (b) Gull Bay, and (c) Diamond Island sampling locations.

7. Summary of HABs

New York State possesses one of, if not the most comprehensive HABs monitoring and notification programs in the country. The NYSDEC and NYSDOH collaborate to document and communicate with New Yorkers regarding HABs. Within NYSDEC, staff in the Division of Water, Lake Monitoring and Assessment Section oversee HAB monitoring and surveillance activities, identify bloom status, communicate public health risks, and conduct outreach, education, and research regarding HABs. 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 µg/L and/or microscopic confirmation that majority of sample is cyanobacteria and present in bloom-like densities). For the purposes of evaluating HABs sample, chlorophyll-a is quantified with a Fluoroprobe (bbe Moldaenke) which can effectively differentiate relative contributions to total chlorophyll-a by phytoplankton taxonomic group (Kring et al. 2014). BGA chlorophyll-a concentrations (attributed to most types of cyanobacteria) are utilized by the NYSDEC HABs Program for determining bloom status. This method provides an accurate assessment of cyanobacteria density and can be accomplished more quickly and cost effectively than traditional cell counts.
- **Confirmed with High Toxins Bloom**: Water sampling results have confirmed that there are toxins present in sufficient quantities to potentially cause health effects if people and animals come in contact with the water through swimming or drinking (microcystin ≥ 20 µg/L (shoreline samples) or microcystin ≥ 10 µg/L (open water samples).

The spatial extent of HABs are categorized as follows:

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

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

7.1 HABs History

Lake George is oligotrophic, rarely exhibits shoreline algal blooms, and there is no record of any HABs being observed or reported on the lake. Screening samples analyzed for algae, cyanobacteria, and algal toxin levels, including phycocyanin, and microcystin, by the State University of New York College of Environmental Science and Forestry (SUNY ESF) since 2012 found low overall algae levels and low cyanobacteria levels at each of the sampling sites (NYSDEC 2015). Cyanobacteria have been measured in benthic samples associated with *Cladophora* and other filamentous algae, but they have not comprised the major taxa in the phytoplankton community in these samples.

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

7.2 Drinking Water and Swimming Beach HABs History

Across New York, NYSDOH first sampled ambient water for toxin measurement in 2001, and raw and finished drinking water samples beginning in 2010. Two public water supplies were sampled in a 2012 pilot study that included both fixed interval and bloom based event criteria. While microcystin has been detected in pre-treatment water occasionally, rarely have any detects been found in finished water. To date, no samples of finished water have exceeded the 0.3 µg/L microcystin health advisory limit (HAL). Many different water systems using different source waters have been sampled, and drinking water HABs toxin sampling has increased substantially since 2015 when the 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 Environmental Laboratory Approval Program (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).

CSLAP data indicate that potable water usage, swimming, and contact recreation at Lake George have not been impacted by harmful algal blooms and should be fully supported. Lake George is a drinking source for residents and visitors and is designated as moderately susceptible to contamination despite a lack of direct impacts, reflecting the need to protect the resource (Lake Champlain WI/PWL 2009). Open water samples are routinely tested for algal toxins as part of the CSLAP program, whether a bloom is present or not, and these results do not indicate any concerns for drinking water intake (no evidence of toxin results that approach the EPA 10-day drinking water thresholds).

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.

To date, there have been no beach closures in Lake George associated with harmful algal blooms. **Table 4** provides a summary of the guidance criteria that the NYSDEC and NYSDOH use to advise local beach operators.

Table 4. 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 HABs and Remote Sensing

Remote sensing results were plotted together with hourly rainfall, wind speed and direction, locations of recreational beaches, locations of wastewater treatment plants. Hourly rainfall is plotted with hourly air temperature. The weekly average and long-term average (8 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.

In 2015, images were available in May through September, except July which was mostly covered by clouds. From May to June 2015 there was a slight increase in the lake-wide chlorophyll-a concentration as shown in **Figure 13**. The increased chlorophyll-a concentration observed on June 23, 2015 may be related to recent rainfall as 5 out of the previous 7 days were rainy combined with warmer temperatures from June 20 to 23, 2015. For the rest of the summer, the lake-wide chlorophyll-a concentrations were lower. The highest chlorophyll-a concentrations were found in shallow locations close to shore (e.g. Sandy Bay, Cotton Island, Basin Bay, Huletts Landing, Heart Bay, Weeds Bay, Asas Island, Lenni-Lenape Island, Arcady Country Cub) and the north end of Lake George around Prison Island. Note that in these shallow areas, the remote sensing might be picking up suspended algae, algal mats, or submerged aquatic vegetation as opposed to chlorophyll-a concentrations.

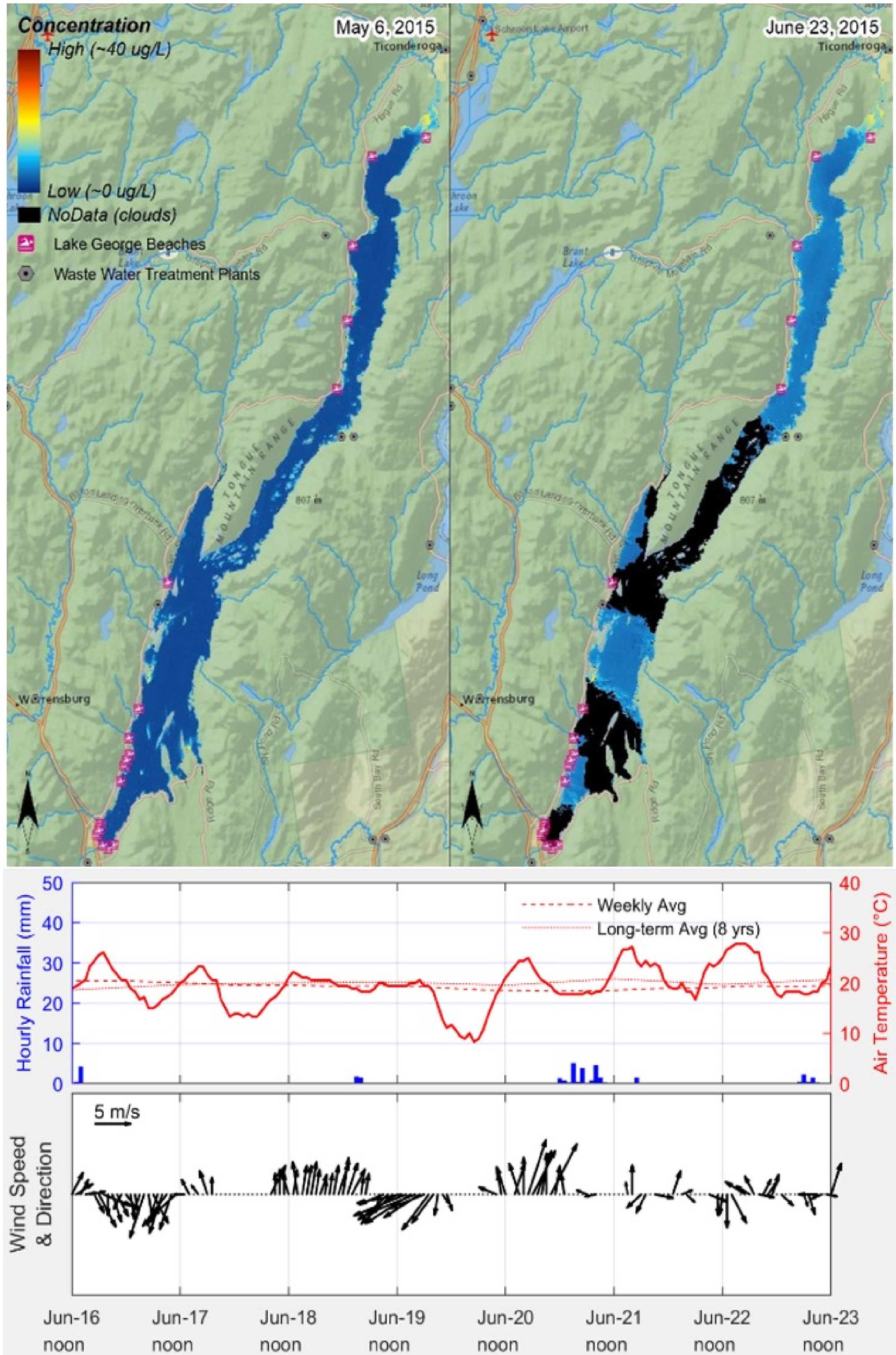


Figure 13. Modeled chlorophyll-a concentrations in on May 6, 2015 and June 23, 2015 in Lake George.

In 2016, images were available from June to October. A noticeable increase in lake-wide chlorophyll-a concentrations, although relatively low, can be observed on July 11, 2016 as shown in **Figure 14**. The increased chlorophyll-a concentration observed on July 11, 2016 may be related to recent rainfall on July 8 through to July 11, 2015. For the remainder of the images the lake-wide Chlorophyll-a concentrations dropped back down to near zero values. The highest chlorophyll-a concentrations were found in the same locations as observed in 2015.

In 2017, images were available from May to October. There was a noticeable increase in lake-wide chlorophyll-a concentrations from May through to September. In October, the lake-wide chlorophyll-a concentrations dropped back down to near zero values as shown in **Figure 15**. The wind speeds picked up leading up to October 2, 2017 which may have promoted mixing; in addition, air temperature dropped. The combination of the winds and air temperature may have contributed to decreased chlorophyll-a concentrations. The highest chlorophyll-a concentrations were found in the same locations as were observed in 2015 and 2016.

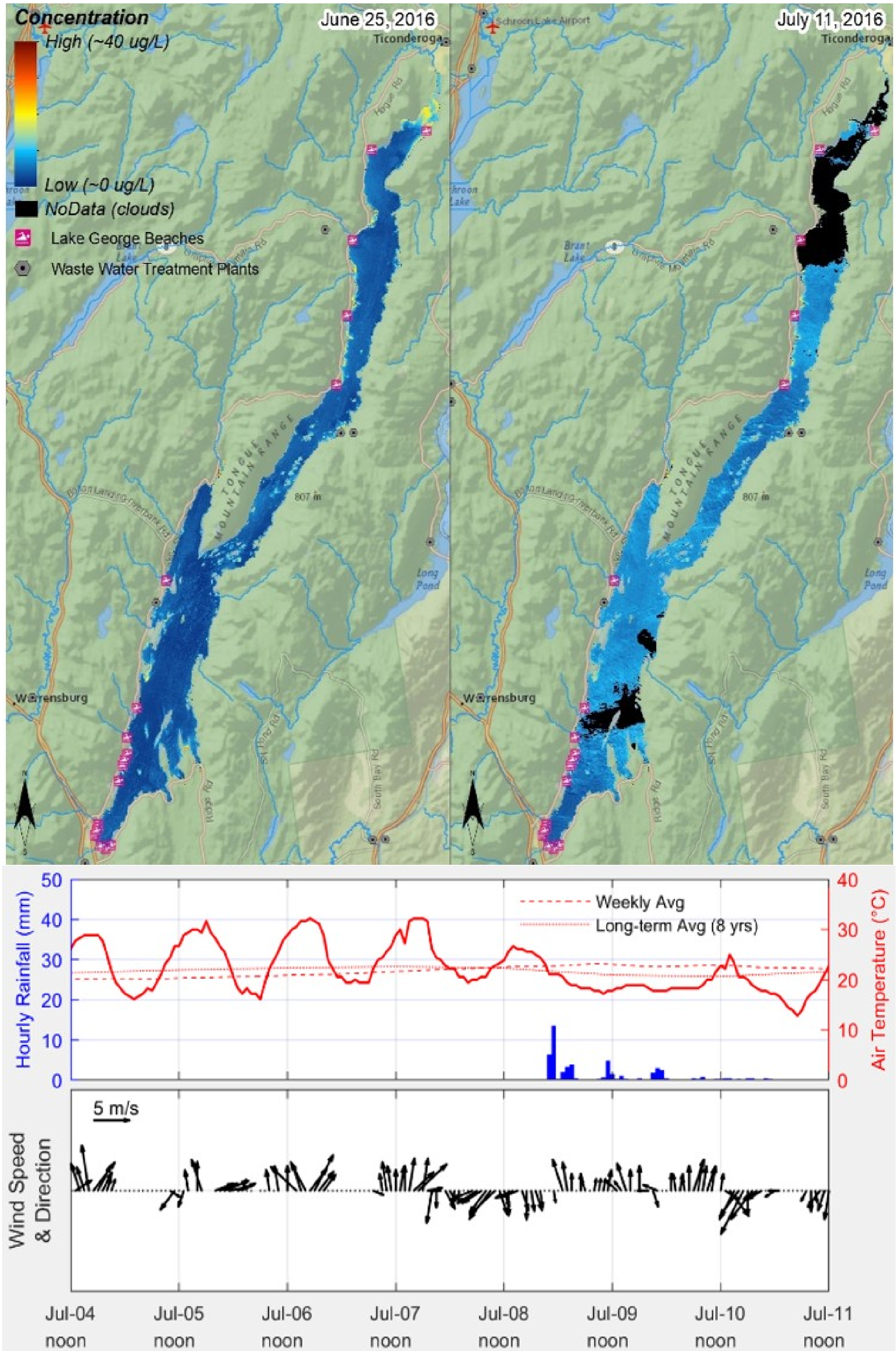


Figure 14. Modeled chlorophyll-a concentrations from June 25, 2016 and July 11, 2016 in Lake George.

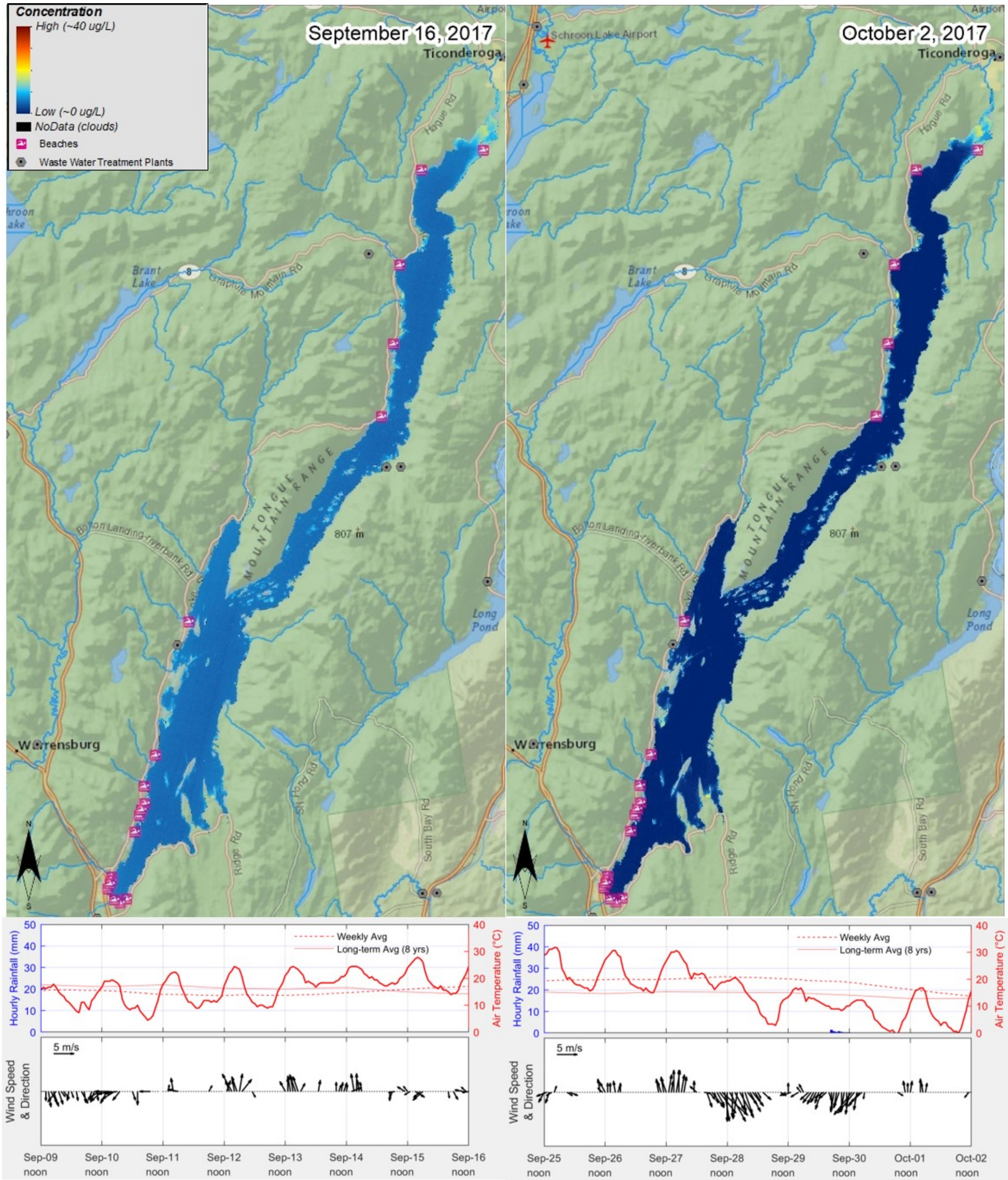


Figure 15. Modeled chlorophyll-a concentrations from September 16, 2017 and October 2, 2017 in Lake George.

In summary, Lake George tends to have very low chlorophyll-a concentrations. However, there are some locations that tend to have consistently higher (though still low) chlorophyll-a concentrations relative to the rest of the lake (**Figure 16**). These locations include: Sandy Bay, Cotton Island, Basin Bay, Huletts Landing, Heart Bay, Weeds Bay, Asas Island, Lenni-Lenape Island, Arcady Country Cub, and the north end of the Lake around Prison Island. In these shallow areas the remote sensing might be picking other interferences as opposed to chlorophyll-a concentrations. Additional analysis may be of interest to investigate these locations further.

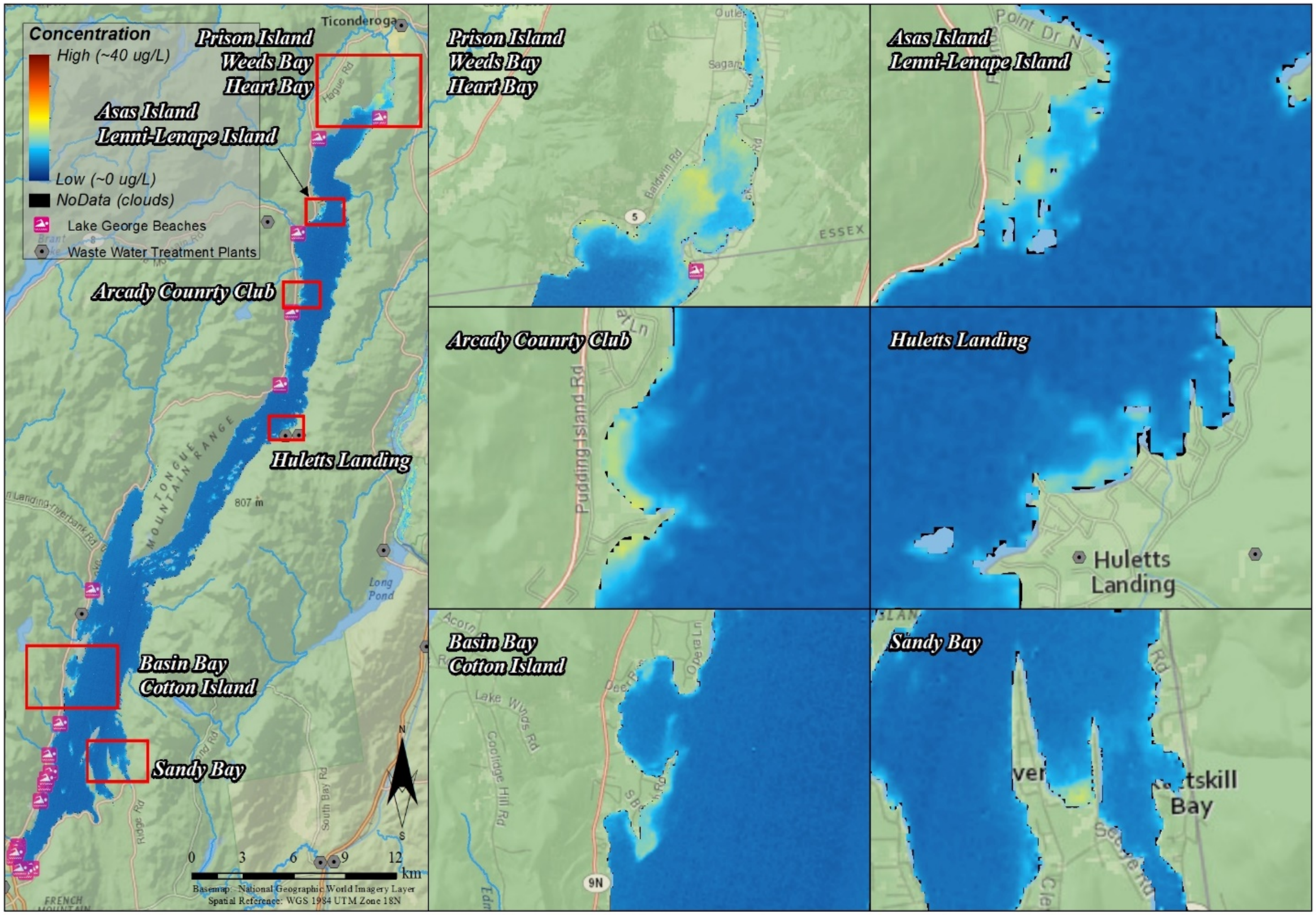


Figure 16. Locations of persistently higher chlorophyll-a concentrations in Lake George, as modeled from Landsat 8 remote sensing images.

The percentage of the lake surface area with an estimated chlorophyll-a concentration greater than 10 µg/L and 25 µg/L is summarized in **Table 5**. Cyanobacteria cell counts and/or chlorophyll-a concentrations (e.g., BGA chlorophyll-a) less than 25 µg/L are 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 µg/L.

Table 5. Percent (%) of water surface area with an estimated chlorophyll-a concentration (mg/L) above and below 10 mg/L and 25 mg/L in Lake George (2015 to 2017).

Date	% of surface area less than		% of surface area greater than or equal		% No data
	10 µg/L	25 µg/L	10 µg/L	25 µg/L	
2015-05-06	94	99	5	0	1
2015-06-07	0	0	0	0	100
2015-06-23	51	58	7	0	42
2015-07-25	1	1	0	0	99
2015-08-10	57	59	2	0	41
2015-08-26	86	90	5	0	10
2015-09-11	93	97	4	0	3
2015-09-27	95	99	4	0	1
2016-06-25	92	99	8	0	1
2016-07-11	69	77	8	0	23
2016-07-27	87	92	5	0	8
2016-08-28	77	81	5	0	19
2016-09-13	94	99	5	0	1
2016-09-29	85	89	4	0	11
2016-10-15	32	32	0	0	68
2017-05-11	76	82	6	0	18
2017-05-27	8	10	2	0	90
2017-06-12	85	93	9	0	7
2017-06-28	46	47	2	0	53
2017-07-30	93	99	6	0	1
2017-08-15	36	38	2	0	62
2017-08-31	46	47	1	0	53
2017-09-16	94	99	5	0	1
2017-10-02	89	92	3	0	8
2017-10-18	86	89	2	0	11

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).

8.1 WI/PWL Assessment

The current WI/PWL assessment for Lake George (**Appendix D**) reflects monitoring data from 2004 through 2017. Lake George is required to support its best uses of drinking water supply source, primary and secondary contact recreation use, and fishing use.

Lake George is assessed as an impaired waterbody due to secondary contact recreation use that is impaired due to silt/sediment from erosion and urban stormwater runoff. Lake George is classified with the highest water classification of Class AA-Special. As a protection measure, drinking water supply use is considered to be threatened in the Lake. Primary contact recreation (swimming) is assessed as threatened due to bacterial contamination in some locations (Million Dollar Beach Report 2017).

Lake George is included on the NYS Section 303(d) List of Impaired Waters Requiring a TMDL to address impairments due to silt/sediment. Lake George was first listed in 2002.

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 Lake George public drinking supply sources was completed. Although the information provides a historical perspective, the drinking water systems and/or land uses may have changed. Lake George public drinking supply sources need updated assessments to understand the current impacts to best protect water quality. NYSDEC and NYSDOH are working with stakeholders to build a sustainable statewide program to assist and encourage municipalities to develop and implement Source Water Protection Programs (SWPP) in their communities.

The 2004 SWAP assessment of Lake George found a moderate susceptibility to contamination, typical of water supplies that experience minimal impacts but are important water supply sources. Note that this information is over 10 years old.

The source water intake that supplies both the Village and Town of Lake George is located in Lake George approximately 1,300 feet offshore at a depth of 35 feet. A source water assessment of Lake George found a moderate susceptibility to contamination for this source of drinking water (NYSDEC 2009). This level of susceptibility is typical of many water supplies that experience no impacts to water supply use and reflects the need to protect the resource. The information contained in SWAP assessment reports assists in the oversight and protection of public water systems. It is important to note that SWAP reports estimate the potential for untreated drinking water sources to be impacted by contamination and do not address the quality of treated finished potable tap water (NYSDOH SWAP 2005, NYSDEC 2009).

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 Lake Scorecard

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

Lake George’s 2017 CSLAP scorecard is provided as **Figure 17** and indicates that algae levels are not threatening, stressing, or impacting the best uses of the lake.

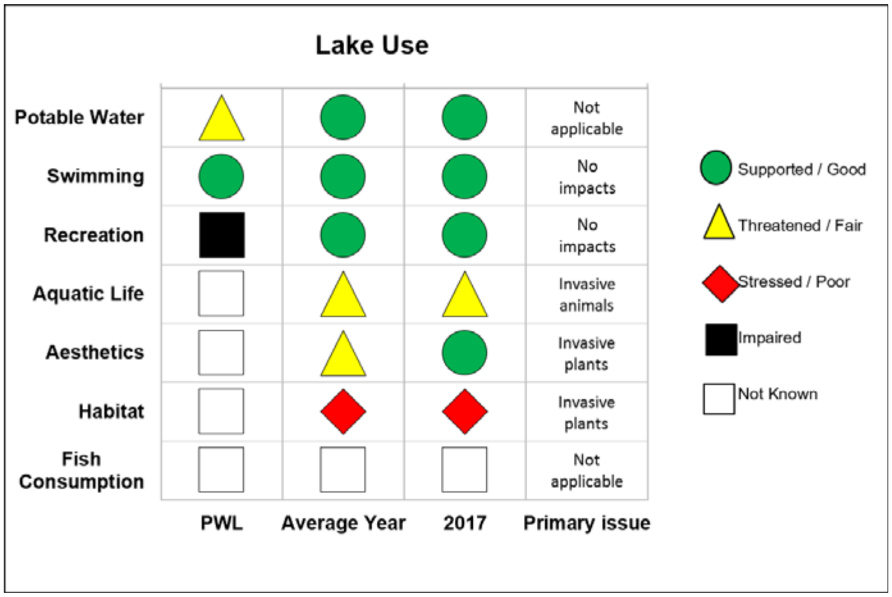


Figure 17. Lake George 2017 CSLAP scorecard.

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, the pattern by which an outcome (presence or absence of HABs) lags behind changes in the properties causing it (triggers) has been observed for ecological phenomena, including phytoplankton dynamics (Faassen et al. 2015). Further, unusual climatic events (*e.g.*, high TP input from spring runoff and hot calm weather in fall) may create unique conditions that contribute to a HAB despite implementation of management strategies to prevent them (Reichwaldt and Ghadouani 2012).

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

As described in **Section 6.3**, food web changes can result in conditions that are more suitable for HABs occurrence, even without changes in nutrient levels. Rainbow smelt became a self-sustaining population within Lake George by the mid-1970s resulting in an increase in phytoplankton and cyanobacteria through the mid-1980s (Siegfried 1987). The population dynamics of rainbow smelt and other species that alter the zooplankton-phytoplankton balance towards favoring cyanobacteria should be monitored so that pro-active management strategies, such as modification of harvest limits, can be implemented.

A dataset spanning 2012 to 2017 of 163 waterbodies in New York State has been compiled to help understand the potential triggers of HABs at the state-scale (CSLAP data). This dataset includes information on several factors that may be related to the occurrence of HABs, e.g., lake size and orientation (related to fetch length, or the horizontal distance influenced by wind); average total phosphorus and total nitrogen concentrations; average surface water temperatures; as well as the presence of invasive zebra and quagga mussels (i.e., dreissenid mussels) and Asian clams. This data set has been analyzed systematically, using a statistical approach known as logistic regression, to identify the minimum number of factors that best explain the occurrences of HABs in NYS. A minimum number of factors are evaluated to provide the simplest possible explanation of HABs occurrences (presence or absence) and to provide a basis for potential targets for management. One potential challenge to note with this data set is that lakes may have unequal effort regarding HABs observations which could confound understanding of underlying processes of HABs evaluated by the data analysis.

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

There is continuing interest in the possible role of nitrogen in the occurrence and toxicity of HABs (e.g., Conley et al. 2009), and preliminary analysis of this statewide data set suggests that elevated total N and total P concentrations are both statistically significant associates with the occurrence of toxic blooms. When total N and total P concentrations are not included in the statistical model, elevated inorganic nitrogen (NH4 and NOx) concentrations are also positively associated with toxic blooms. The significant association of inorganic N forms with toxic blooms may provide a more compelling association than total N, which may simply be a redundant measure of the biomass associated with toxins.

While dreissenid mussels have been documented in Lake George, their abundance has been controlled by early removal actions as well as chemical and biological conditions. This highlights the need for continued management of dreissenid mussels to maintain the low annual probability of a HAB. Because Lake George has not experienced a HAB event, lake-specific analyses to correlate water quality and meteorological variables (or “triggers”) were not conducted. Lake George may have a long enough fetch length to facilitate wind-blown accumulation of surface cyanobacterial scums, and the primary wind direction aligns with the orientation of the longest lake fetch (**Appendix A**). Therefore, although Lake George has not had a HAB, the long fetch makes the lake susceptible to blooms accumulated by sustained southwesterly winds. This finding underscores the need for robust controls on nutrients from the watershed and continuing efforts to keep dreissenid mussels out of the lake, although at present the lake is not conducive to colonization by these invasive mussels.

10. Sources of Pollutants

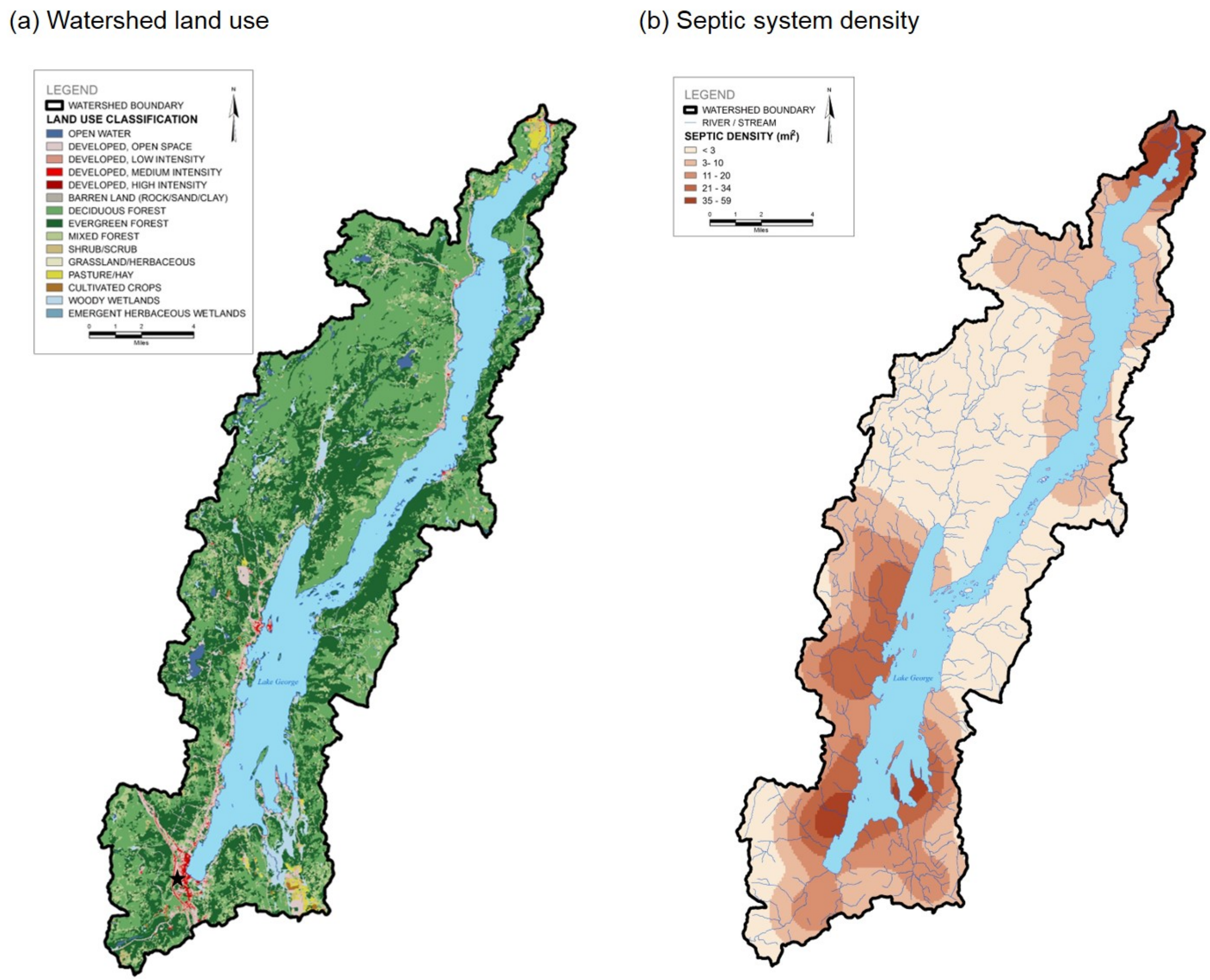
Existing data indicate that much of the nutrient loading (e.g., TP) to Lake George is from nonpoint sources. Nutrients enter the lake via overland flow, tributaries, and other sources, where they become available to planktonic algae and cyanobacteria, or are deposited in lakebed sediments. Local wastewater treatment plants (WWTP) do not discharge their effluent directly into the lake, but rather are groundwater discharges. Failing municipal collection systems are likely contributing some nutrient load to local groundwater which, in turn, interacts with Lake George surface water. The nutrient transport at this groundwater-surface water interface is not well understood, however, the load could be significant in the highly developed southern end of the lake. In general, phosphorus concentrations in Lake George tend to be greater in the southern portion of the lake and decrease towards the north (VTANR and NYSDEC 2002).

10.1 Land Uses

Lake George has a watershed area of approximately 149,300 acres, with a watershed to lake ratio of approximately 5.3. The watershed comprises the following land use types (**Figure 18a**):

- Natural areas = 74%
- Developed land = 5%
- Agriculture = 1%
- Open water = 20%

Natural areas include forests, shrublands, grasslands, and wetlands. If open water is excluded from the Lake George land use breakdown, approximately 92 percent of the Lake George watershed remains as natural areas, 46 percent of which is “forever wild” state-owned Forest Preserve. Six of Lake George’s 12 communities (Bolton, Hague, Lake George, Village of Lake George, Horicon, and Queensbury) have Adirondack Park Agency (APA)-approved land use plans.



★ = Location of point source discharge (approximate)

Figure 18. Lake George watershed land use and septic system density. Municipal wastewater districts are not shown on this figure.

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.

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

NYSDEC's LENS model indicates that annual phosphorus loading to Lake George occurs via nonpoint sources; point source discharges to groundwater within the Basin have not been quantified. Pollutant loads (on a gross basis) estimated using the LENS tool include (**Figure 19**):

- Septic Load = 18%

- Agricultural = 5%
- Natural areas = 58%
- Developed = 19%

While the majority of the phosphorus load to Lake George is from natural areas, it is generally in the form of particulate-bound phosphorus that is less biologically available than dissolved phosphorus associated with other sources such as septic system effluent. A significant portion (42%) is from anthropogenic sources which contribute disproportionate phosphorus loadings to Lake George on a unit area basis. The key anthropogenic sources of phosphorus to the Lake consist of: developed land (45% of anthropogenic sources), septic systems (43% of anthropogenic sources), and agricultural lands (12% of anthropogenic sources). An unknown within this analysis, and potentially unaccounted phosphorus load, is the potential impacts of deficiencies in the sewer collection systems that need repair. Similarly, it should be noted that LENS is an initial screening tool and these loading estimates are preliminary.

Additional nutrient loading evaluations have been historically performed for the Lake George Watershed. One study, from 1983 (Sutherland et al. 1983), was part of a national program and focused on the southern basins. Another study was performed in 2001 (Stearns & Wheler 2001), however, the underlying data are outdated. For example, land uses have changed and stormwater control projects have been implemented. It is recommended that a more detailed load assessment based on more recent land use, meteorological and water quality data be completed for Lake George.

Septic system density is highest (>35 per mi^2) along the southeastern shoreline and near the outlet (**Figure 18b**). Loading that is contributed from septic systems and developed land suggests that management strategies (e.g., septic system upgrades, stormwater management) aimed at reducing their loading should be prioritized since the scale at which management strategies could be targeted is much smaller and, perhaps, more easily targeted and implemented.

10.3 Internal Pollutant Sources

The history of Lake George having relatively low nutrient input from the contributing watershed, in addition to the lack of anoxic conditions, have limited the amount of nutrients within, and released from, the lake sediments. Therefore, internal loading from legacy phosphorus does not appear to contribute significantly to TP levels within the lake.

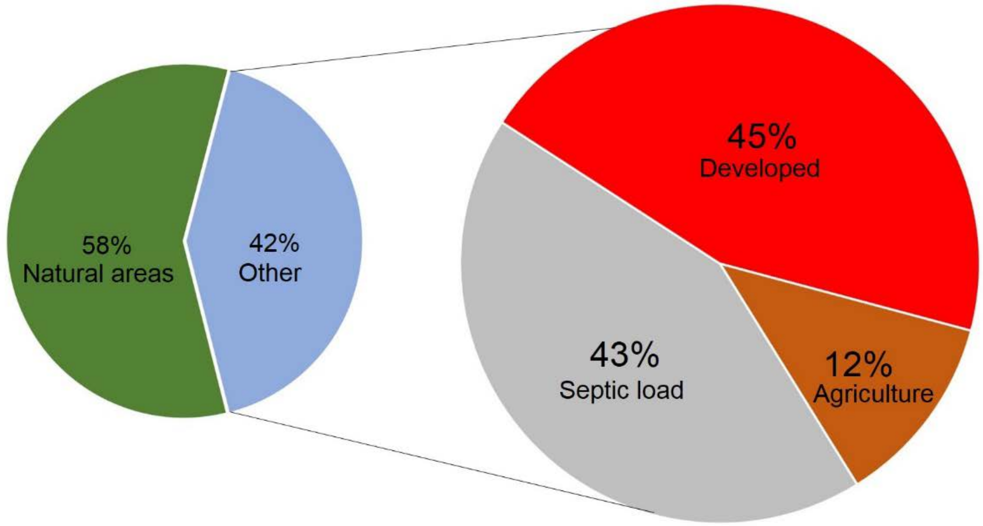


Figure 19. LENS phosphorus loading sources to Lake George. Natural areas include forests, shrublands, grasslands, and wetlands.

11. Lake Management / Water Quality Goals

The primary lake management/water quality goal for Lake George is to implement proactive management to minimize the potential for HABs occurring in the future. Based on an evaluation of the LENS model, significant reductions of P loading are possible by implementing strategies targeting anthropogenic sources from the watershed, such as:

- Minimizing septic loading
- Incorporating stormwater management facilities into developed land to minimize nutrient concentrations within runoff
- Repairing sewer collection systems

12. Summary of Management Actions to Date

12.1 Local Management Actions

1. The Lake Champlain – Lake George Regional Planning Board (LCLGRPB), in conjunction with the Champlain Watershed Improvement Coalition of New York, prepared the *Lake Champlain Non-Point Source Pollution Subwatershed Assessment and Management Plan* (2018) to assist local and regional resource managers in identifying projects and programs to improve and protect water quality. The goal of the Plan was to identify specific planning and implementation efforts that would reduce phosphorus loadings to surface waters from various

nonpoint sources. The Plan identified the following priority areas to direct management actions at:

- Urban stormwater runoff
- Aging public collection systems and private wastewater infrastructure
- Streambank and roadside erosion
- Agricultural operations

The impetus for preparing the Plan was the levels of phosphorus in Lake Champlain that still exceed the standards set forth in the TMDL documents and to maximize the effect of available implementation funds (LCLGRPB 2017).

2. The Lake George Park Commission (LGPC) is active in promoting both lake and watershed health through public education, invasive species prevention and management, stormwater management, and stream protection. The LGPC's local efforts include, but are not limited to:

    The LGPC is currently formulating new regulations on stream corridor management and watershed protection aimed at reducing nutrient and sediment loading to the lake. These regulations are anticipated to be promulgated in 2019. Elements of their proposal, currently under review include:

    - Apply APA shoreline cutting standards to NYSDEC-regulated streams within the watershed, as identified on the Environmental Resource Mapper:
        - No more than 30% of the trees > 6-inches DBH may be cut in any 10-year period within 35-feet of the mean high-water mark.
        - No more than 30% of any vegetation may be removed within 6-feet of the mean high-water mark.
        - No impervious area may be within 35-feet of the mean high-water mark.
    - Retrofits
    - Fertilizers
    - Logging
    - Stream corridor protections

    Lake George watershed communities (excluding Lake Luzerne, Horicon, and Warrensburg) are subject to the LGPC's stormwater regulatory program. With approval of the LGPC, communities may adopt and administer a local stormwater regulatory program as long as it conforms with the LGPC's model stormwater ordinance. Currently Bolton, the Town and Village of Lake George, and Queensbury have LGPC approved stormwater regulatory programs.

3. The FUND for Lake George is a not-for-profit, privately funded organization dedicated to the protection of Lake George. Formed in 1980, the FUND applies a science-guided approach to protection focused on Lake George water quality and the overall health of the Lake George watershed. The FUND works collaboratively with partners throughout the watershed to promote lake protection activities. These include, but are not limited to:
    a. Promote implementation of Low Impact Development in collaboration with the Lake George Waterkeeper;
    b. Implement a matching grant program for septic system replacements in the watershed;
    c. Develop the Low Impact Development (LID) Certification System to promote the implementation and incentivization for LID practices.
4. The West Brook Conservation Initiative is a collaborative effort between the FUND for Lake George, the Lake George Land Conservancy, the Lake George Association (LGA), the NYSDOT, and others to conserve and restore portions of the West Brook watershed, an important tributary to Lake George. This initiative has leveraged funds to purchase, conserve, and restore portions of the watershed to create an environmental park that showcases the importance of environmental stewardship while hosting a variety of public events. The objective is to significantly reduce nutrient and sediment loads that enter Lake George via stormwater runoff (FUND, LGLC and LGA June 2009).
5. In addition to their involvement with the West Brook Conservation Initiative, the LGA is involved in a number of local actions to educate and act to improve Lake quality including the following:
    - Educational programs with local schools and community groups.
    - CSLAP: Volunteers assist in lake water quality monitoring
    - Water Assessments by Volunteer Evaluators (WAVE): The NYSDEC works with the LGA to train citizen scientists to collect water quality data.
    - Invaders Watch: The Adirondack Park Invasive Plant Program (APIPP) works with citizen scientists from the LGA to alert APIPP to potential new aquatic invasive species.
6. The Lake George Land Conservancy is a land trust that works with landowners, government officials, conservation partners, volunteers, and supporters to protect water quality of Lake George through land conservation.
7. Local SWCDs in the region play an important management role. The Warren County SWCD has been engaged in projects targeting stormwater reductions (*e.g.*, roadside ditch work, streambank stabilization, and stormwater retrofits),

and has developed stormwater management and watershed assessment plans and reports at the subwatershed level for several of the major tributaries to Lake George.

8. In 2017, the Town of Lake George facilitated an inspection of the Caldwell Sewer District's (CSD) infrastructure along Lake George's shorelines and adjacent areas in response to a Notice of Violation (NOV) issued by the NYSDEC. A portion of the required sewer main lines, pump stations, and sanitary manholes were assessed and rated based on damage severity and failure potential. For budgetary reasons, the remaining infrastructure will be inspected in 2018. (Chazen 2017).

12.2 Agricultural Environmental Management Program

The New York State Agricultural Environmental Management (AEM) Program that was created by the New York State Department of Agriculture and Markets as a voluntary, incentive-based program that helps farmers make common-sense, cost-effective, and science-based decisions to meet business objectives while protecting and conserving New York State's natural resources. Soil and Water Conservation Districts in agricultural counties lead the local AEM effort, including Warren County within the Lake George watershed. Four AEM projects (two Tier 1; two Tier 2) have been undertaken in the Lake George watershed between 2011 and 2017.

The Warren County SWCD developed an *Agricultural Environmental Management (AEM) Program Strategic Plan 2015-2020* (Warren County SWCD 2015) to promote land stewardship to increase the quality of natural resources and production on agricultural lands within the County. One of the primary recommendations of the AEM Plan is to manage pastures, soils, manure, and stream and floodplain impacts to minimize nutrient and soil loading to adjacent waterbodies. Specific BMPs recommended by the New York state Soil and Water Conservation Committee (NYSSWCC 2016) that are promoted within their conservation plans include:

- Implementation of rotational grazing
- Proper timing of manure spreading and storage
- Proper pesticide and fertilizer use and storage
- Maintenance of stream buffers
- Management of stormwater drainage from barns and other structures are available
- Use of erosion and sediment control measures on skid trails and other access roads during silvicultural practices
- Proper use and storage of chemicals in any of the agricultural practices including Christmas trees, nursery, greenhouse, and field crops

12.3 Funded Projects

Local projects within Lake George and its watershed focus on BMPs such as those recommended by the NYSSWCC listed in **Section 12.2**. The LGA provides project descriptions ranging from stormwater management to erosion control (LGA 2018f).

The *Lake Champlain Non-Point Source Pollution Subwatershed Assessment and Management Plan* is a collaborative effort funded by a NYSDOS Local Waterfront Revitalization Grant, and identifies projects and programs that would reduce phosphorus loadings to surface waters from various nonpoint sources (LCLGRPB 2017). **Section 12.1** provides additional details on specific priority areas.

The Lake Champlain Watershed Water Quality Management Planning project was one of eleven projects in New York State that was funded through the Federal Government's American Recovery and Reinvestment Act initiative. The project was completed through a partnership between the LCLGRPB, the Champlain Watershed Improvement Coalition of New York (CWICNY) and the five County SWCD's. The goal of this project was to identify eroding roadside banks that contribute significant sediment loads to streams throughout the Champlain Watershed. Data, photographs, and maps identifying erosion sites were produced for each county and township within the study area. For each site, a prioritization ranking matrix was used to determine the level of erosion; High, Moderate or Low, and potential remediation strategies and cost estimates were identified. Proposed remediation strategies included:

- Hydroseeding with tackifier and bonded fiber matrixes
- Stabilizing ditches with rock and gravel
- Installing erosion control blankets
- Constructing check dams and sediment traps
- Stabilizing bank toes and re-grading slopes and roads.

Several educational training sessions were also completed to educate local engineers and municipal staff on floodplain management, cold climate best management practices and performance, low impact development, advanced mechanisms and designs for phosphorus treatment, green roofs and pervious asphalt. County SWCDs also performed Erosion and Sediment Control trainings for local contractors.

12.4 NYSDEC Issued Permits

Article 17 of New York’s Environmental Conservation Law (ECL) entitled “Water Pollution Control" was enacted to protect and maintain the state’s surface water and groundwater resources. Under Article 17, the State Pollutant Discharge Elimination System (SPDES) program was authorized to maintain reasonable standards of purity for state waters. NYSDEC issues Multi-Sector General Permits (MSGPs) under the SPDES Program for stormwater discharges related to certain industrial activities. MSGPs have been issued for numerous active facilities in Washington, Warren, and Essex counties (NYSDEC 2018). A few of these facilities are within the Lake George watershed, and may influence water quality conditions in Lake George if not operated as per their permit guidelines.

CAFO permits, issued under the SPDES Program, are required for animal feed programs that meet animal size (number of animal) thresholds. CAFO permits have been issued to five currently active facilities in Washington County, two of which are located in the Town of Fort Ann (NYSDEC 2018e). However, there are no CAFO farms located within the Lake George watershed.

For more information about NYSDEC's SPDES program and to view permits issued in the Lake George watershed visit http://www.dec.ny.gov/permits/6054.html.

12.5 Research Activities

The Jefferson Project at Lake George is a partnership of the Fund for Lake George, IBM, and RPI that includes a team of over 100 researchers and students who are building an advanced environmental monitoring system that includes a sensor network that collects chemical and physical measurements annually, computer models depicting the flow of water, nutrients, and contaminants through the watershed, and surveys of aquatic organisms in the lake and streams. In addition, monitoring includes experiments testing the impacts of human activities on the Lake George ecosystem including road salt, invasive species, and excess nutrients.

DFWI's field station, located at Bolton Landing, NY along the western shore of Lake George, is the only research laboratory on the lake, and includes several housing, teaching, and research facilities equipped with a wide variety of scientific equipment. The field station is the laboratory base camp for the Jefferson Project, where researchers launch expeditions, gather samples, and deploy and maintain sensors around the lake.

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

Lake George and its tributaries were first listed on Part 1 of the NYS Section 303(d) List of Impaired Waters requiring the development of a TMDL or other strategy to address impairments due to silt/sediment in 2002. A draft TMDL for impacted tributaries identified the need to dredge sediment deltas to fully restore recreational uses, but was not considered by the USEPA to meet the requirements of a TMDL.

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).

13.2 Priority Project Development and Funding Opportunities

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

Steering committee members:

- Terry Martino, Adirondack Park Agency
- Chris Garrow, Essex County Department of Public Works
- Anna Reynolds, Essex County Office of Community Resources
- Dave Reckahn, Essex County Soil and Water Conservation District (SWCD)
- Eric Siy, The FUND for Lake George
- Beth Gilles, Lake Champlain - Lake George Regional Planning Board
- Eric Howe, Lake Champlain Basin Program
- Walt Lender, Lake George Association
- Dave Wick, Lake George Park Commission
- Sarah Trumbull, Natural Resources Conservation Service

- Thomas Bielli, Natural Resources Conservation Service
- Brian Steinmuller, NYSDAM
- Don Tuxill, NYSDEC
- Fred Dunlap, NYSDEC
- Rob Streeter, NYSDEC
- Anita Gabalski, NYSDOH
- George Laundrie, NYSDOT
- Ian Miller, NYSDOT
- Mike Arthur, NYSDOT
- Sandra Nierzwicki-Bauer, RPI Darrin Freshwater Institute
- Jeffery Tennyson, Warren County Department of Public Works
- Wayne LaMothe, Warren County Planning Department
- Jim Lieberum, Warren County SWCD
- Steven Haskins, Washington County Department of Public Works
- Chris DeBolt, Washington County Planning Department
- Corrina Aldrich, Washington County SWCD

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

As described throughout this HABs Action Plan, the primary water quality factors that should be addressed in Lake George include:

- Nutrient loadings associated with WWTP discharge
- Stormwater runoff from developed areas as well as stormwater and collection system infrastructure and on-site septic systems
- Nonpoint source sediment and nutrient inputs from the contributing watershed (e.g., ditches)

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 implement projects to address nonpoint source pollution:

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

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

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

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

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

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

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

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

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

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

Readers of this Action Plan that are interested in submitting funding applications are encouraged to reference this Action Plan and complementary planning documents (i.e., TMDLs or 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).

13.3 Lake George Priority Projects

13.3.1 Priority 1 Projects

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

Short-term (3 years)

1. Implement, along with any needed predesign and design, a woodchip bioreactor demonstration project at the Bolton Landing Wastewater Treatment Plant to evaluate the effectiveness of woodchip-filled trenches to extract nitrogen and phosphorus.
2. Evaluate the treatment efficiency at the Bolton Landing Wastewater Treatment Plant to remove additional nutrients from WWTP effluent.
3. Upgrade the Town of Lake George Caldwell Sewer District wastewater collection system, including slip lining pipes, replacing manholes, and repairing pump stations.
4. Complete upgrades to the Town of Hague Wastewater Treatment.
5. Implement an inspection and maintenance program for near-shore septic systems, including:
    - Inspection and pump-out of all septic systems located within 200-feet of the lakeshore.
    - Replace failing systems with a 50% cost-share with individual property owners.

Mid-term (3 to 5 years)

1. Upgrade WWTP for the Village of Lake George.
2. Extend sanitary sewer infrastructure along Route 9N to the Tahoe Resort and add service to existing commercial properties.

Long-term (5 to 10 years)

1. Reduce Inflow and Infiltration (I&I) of wastewater within the Towns of Lake George and Bolton and Village of Lake George by slip lining the conveyance pipes.

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. Continue to address roadside erosion issues throughout the watershed on local, County, and State roads through systematic roadside hydroseeding and erosion control.
2. Implement the North Queensbury Wastewater Management District Matching Grant Program.

Mid-term (3 to 5 years)

1. Create a Rockhurst Wastewater District and design a collection system and treatment plant in the Town of Queensbury.

13.3.3 Priority 3 Projects

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

Short-term (3 years)

1. Implement a matching grant program in the Town of Lake George for OWTS Replacement.
2. Install transportable sensor units in Jefferson Project buoys to determine nutrient reduction benefits.

Long-term (5 to 10 years)

1. Implement a Save the Rain Program in the Village of Lake George that mimics Onondaga County's Program and includes stormwater retrofits.
2. Enhance stormwater swales adjacent to I87 that discharge to West Brook and East Brook. Techniques include installation of infiltration systems and check dams and reduction in paved swales.
3. Implement a systematic roadway stormwater pre-treatment and infiltration program in the Town and Village of Lake George.
4. Implement a systematic roadway stormwater pre-treatment and infiltration program in the Town of Bolton.
5. Upgrade NYS Route 9, 9N, and 9L stormwater conveyance systems to incorporate stormwater capture and infiltration facilities.
6. Implement stormwater reduction projects in Gull Bay.
7. Implement stormwater runoff controls on Baldwin Road, Blackpoint Road, and the surrounding area.

8. Install stormwater capture and infiltration systems at the Town and Village of Lake George Municipal Centers and access road.
9. Implement a stormwater reduction and infiltration program in Assembly Point.
10. Install green infrastructure retrofits at Lake George Elementary and High Schools, including green roof, cisterns, rain gardens, and pervious pavement.
11. Install stormwater infiltration systems at Rogers Park and the Dula Street public parking areas with porous asphalt.
12. Install stormwater infiltration and retention facilities at Steamboat Landing.

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. Identify forests in locations where significant soil erosion and nutrient loading occurs and take actions to maintain or improve forest health within the watershed. These actions should include:
    - Evaluate the presence of forest pests that affect hemlock (*Tsuga spp.*), ash (*Fraxinus spp.*), spruce (*Picea spp.*), and other tree species that are currently integral to watershed stabilization and implement pro-active pest prevention and/or management to reduce the impacts of the pests. Recommended strategies include:
        - Work with Cornell Cooperative Extension on establishing hemlock hedges within biological control field stations
        - Use systemic insecticides (imidacloprid and dinotefuran) and introduce natural enemies such as the predatory beetle *Laricobius nigrinus* that controls hemlock wooly adelgid (HWA) in areas dominated by hemlock.
    - Providing outreach and training on best management practices for landowners with forested lands.

13.5 In-Lake Management Actions

Estimates indicate that internal loading does not contribute significantly to decreased water quality in Lake George. Thus, in-lake management actions are not currently recommended but should be considered if future data suggests that it is warranted.

13.6 Monitoring Actions

To help determine the stresses that could lead to HABs in Lake George in the future and to assess improvements associated with management actions, the following monitoring actions are recommended:

Short-term

1. Supplement the understanding of the cyanobacteria taxa that are prevalent in Lake George. Additionally, a greater temporal resolution of algal density in Lake George could help to identify seasonal trends and inform management strategies.

2. Maintain and enhance community and/or volunteer monitoring efforts of water quality conditions in the lake, particularly during the growing season. This would include collaboration among stakeholder groups, including government agencies, the Lake George Association and other advocacy groups, and lakefront residents. Align in-lake water quality data collection efforts with overpasses of NASA's Landsat 8 satellite (**Table 6**), to the extent possible. This alignment will allow for the effective use of satellite imagery when characterizing lake conditions based on corresponding field data. In addition, the remote sensing approach presented here may be improved by collecting chlorophyll-a field samples over the depth of light transmissions (e.g., twice the Secchi depth to the water surface).

Table 6. Landsat 8 overpasses of Lake George for May through October 2018.

Month	Dates	
May	May 14	May 30
June	June 15	NA
July	July 1	July 17
August	August 2	August 18
September	September 3	September 19
October	October 5	October 21

3. Collect additional DO data and develop depth profiles for each sub-basin within Lake George.

13.7 Research Actions

The NYSDEC should continue to coordinate with the Jefferson Project (see **Section 12.4**) and other organizations to maximize the efficacy of research efforts with the shared goal of maintaining the high water quality in Lake George. Proposed research initiatives with a clear connection to HABs should be supported.

Short-term

1. Maintain financial and programmatic support for monitoring activities in Lake George.

2. Conduct water quality sampling in tributaries and/or in discharge points in the lake during or following heavy rainfall events, as permissible, to document nutrient inputs that may contribute to localized HABs facilitated by storm events. Priority for such sampling efforts should be given to sub-watersheds with larger catchment areas and where land use is predominantly developed land.

Mid-term

1. Evaluate benthic blooms for their potential production of cyanotoxins and impact to recreational users, including pets. This research should include development of visual assessment protocols to distinguish *Cladophora* and other nuisance blooms from harmful cyanobacteria blooms.
2. Evaluate the potential influence of rainbow smelt on phytoplankton community dynamics.
3. Investigate possible drivers of the observed decreased abundance of *Nitella*, and evaluate implications for the phytoplankton assemblage resulting from decreased biomass of aquatic plants.
4. 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.
5. 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.
6. The NYSDEC should support research to investigate the role of climate change on lake metabolism, primary production, nutrient cycling, and carbon chemistry.
7. 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, erosion and sediment controls, prescribed grazing, conservation skills, etc.) to municipal decision makers, SWCDs, and personnel in order to underscore the importance of water quality protection as well as associated tools and strategies.

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 Lake George watershed.
3. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.
4. Coordinate with and support Departments of Health 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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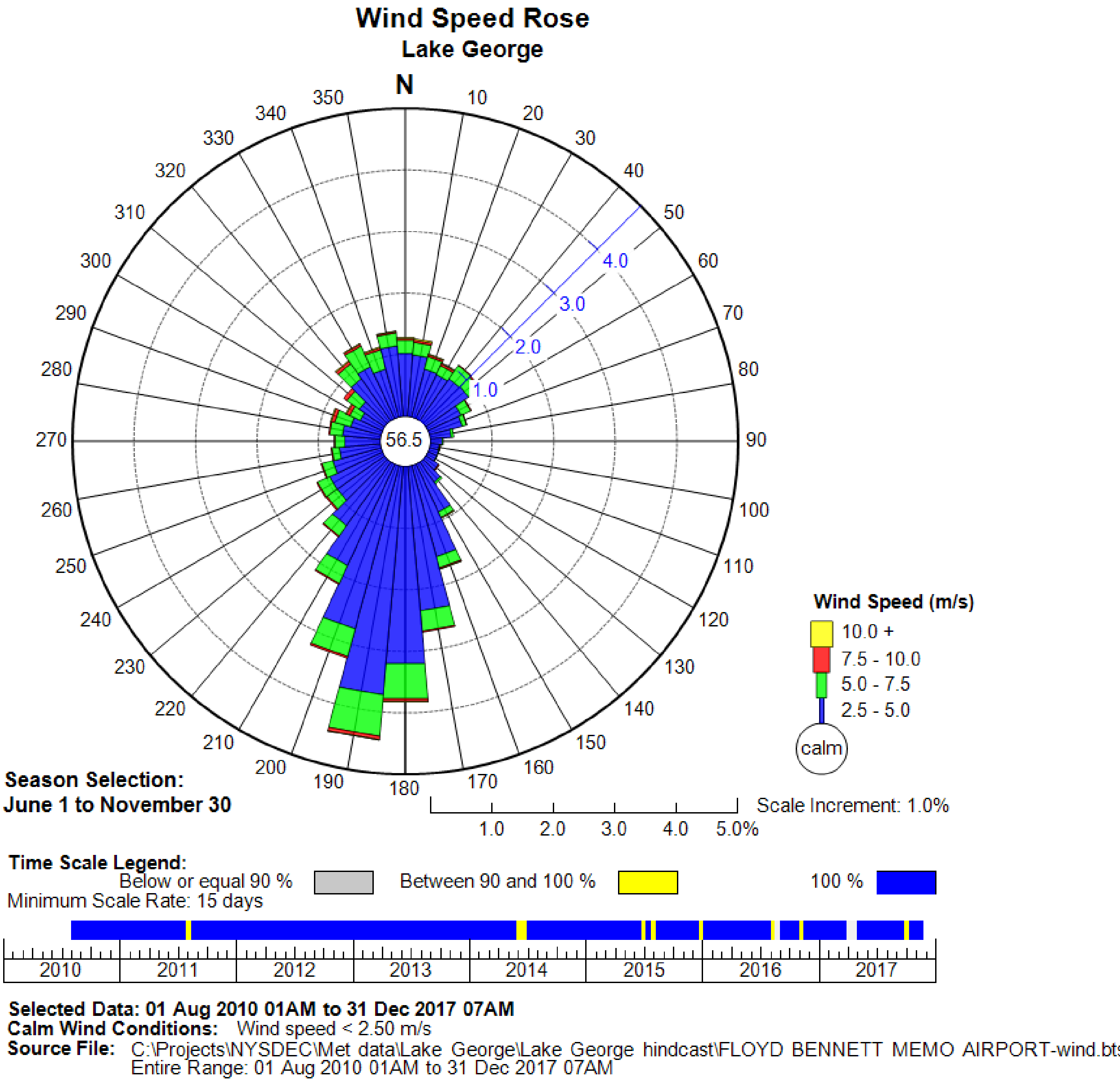
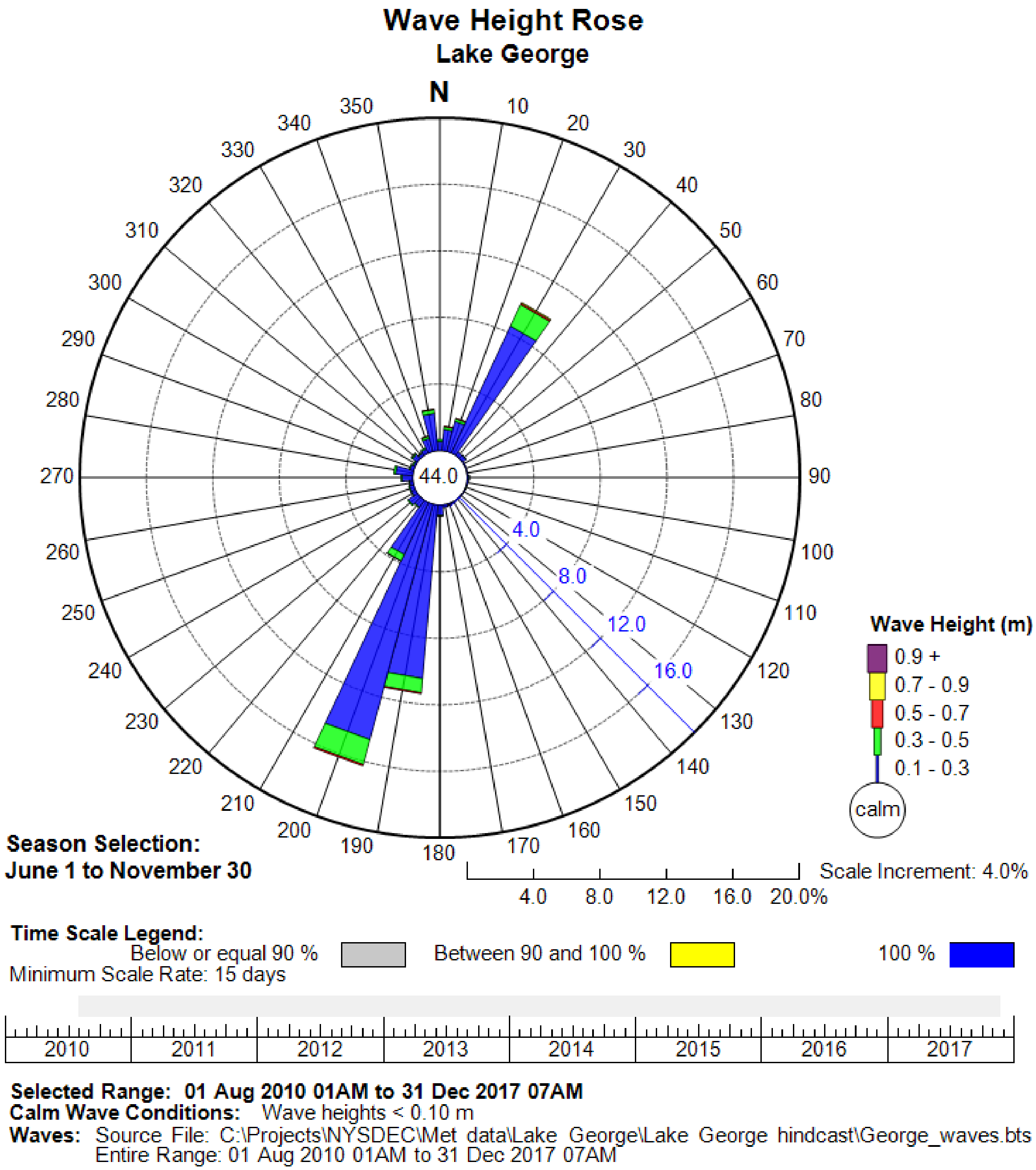
Appendix A. Wind and Wave Patterns



Wind speeds in Lake George from 2010 to 2017, during the months of June through November, indicate that stronger winds were generally from the south-southwest.



Wave height patterns from 2010 to 2017, during the months of June through November, indicate wave heights were greater in the southwestern and northeastern portions of Lake George.

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:	Best usage is for primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival
Class C:	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:	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 dimensions 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 study[1]. 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.

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

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 Error! Reference source not found..

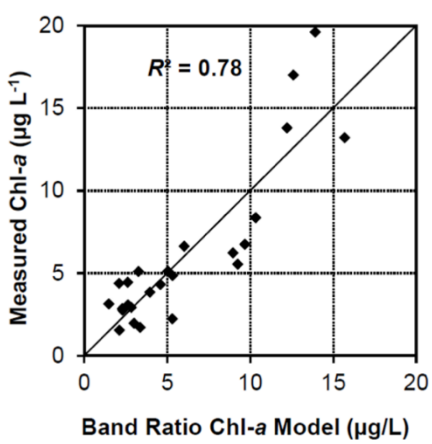


Figure C1. Measured and modeled chlorophyll-a concentrations for Lake Champlain, from Trescott 2012.

[1] 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 coverage[2]. 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 lighted 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.

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

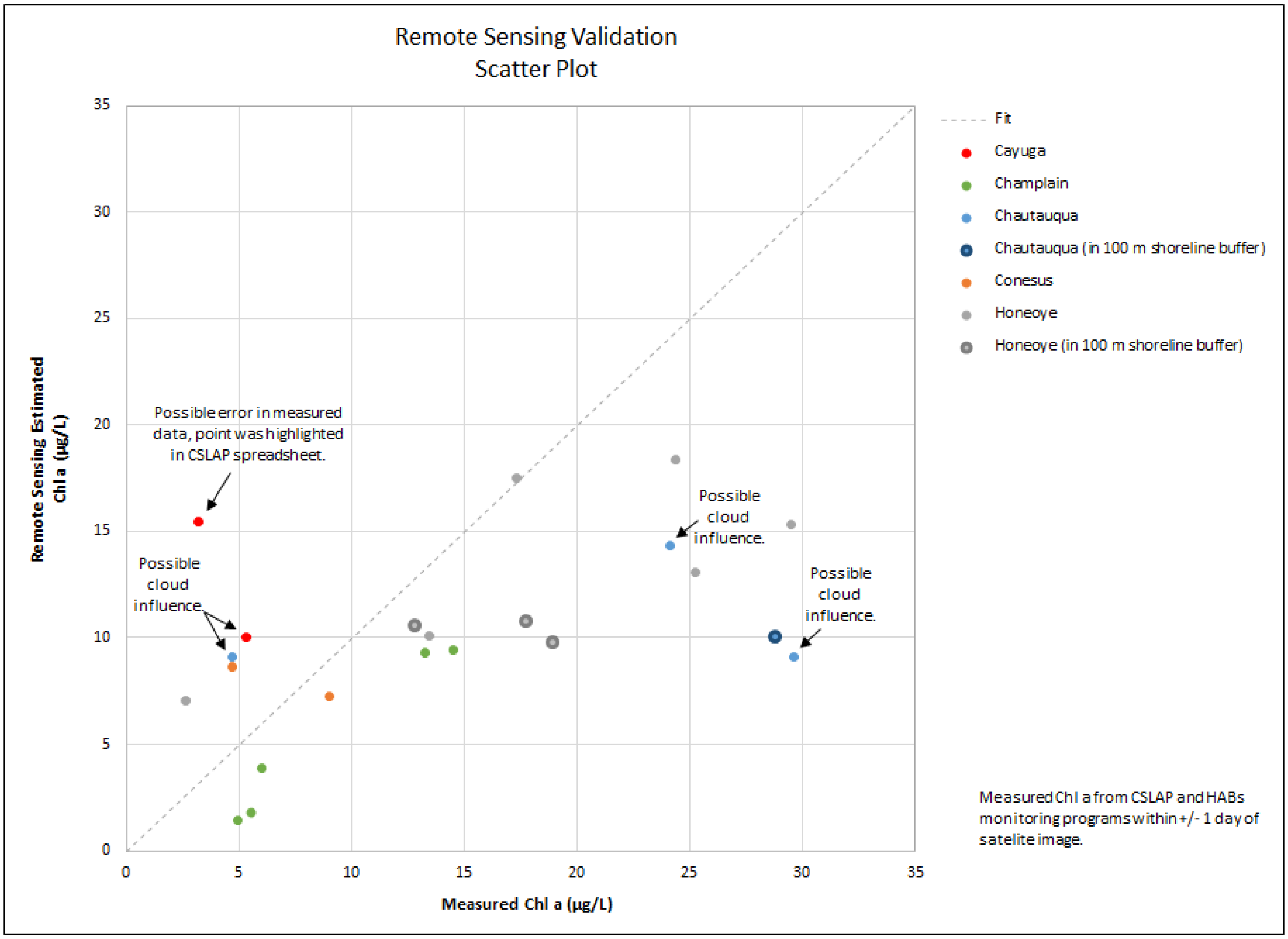


Figure C2. Measured and modeled chlorophyll-a concentrations for Cayuga Lake, Lake Champlain, Chautauqua Lake, Conesus Lake, and Honeoye Lake (2016-2017 data).

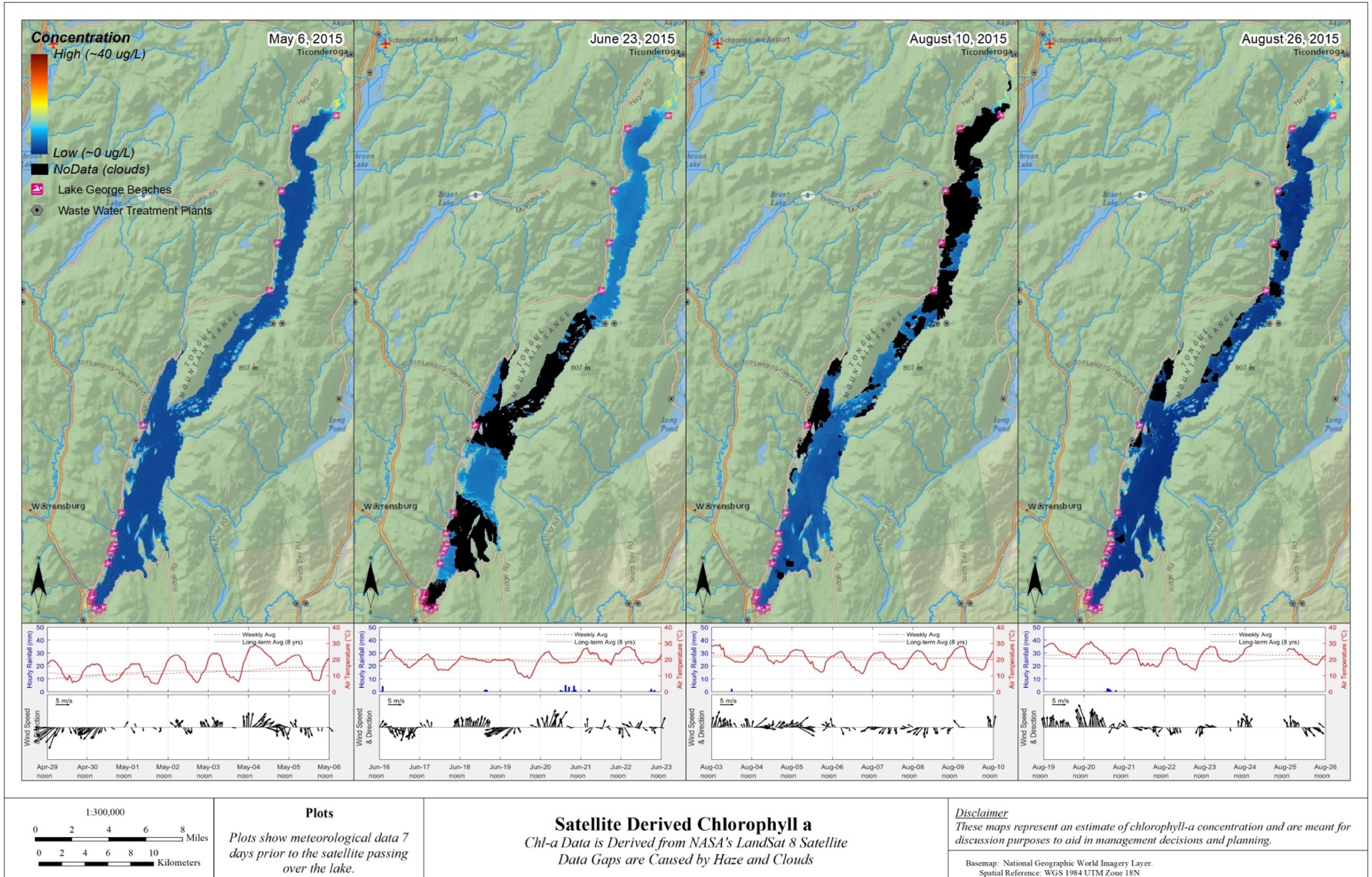
Limitations of the Method

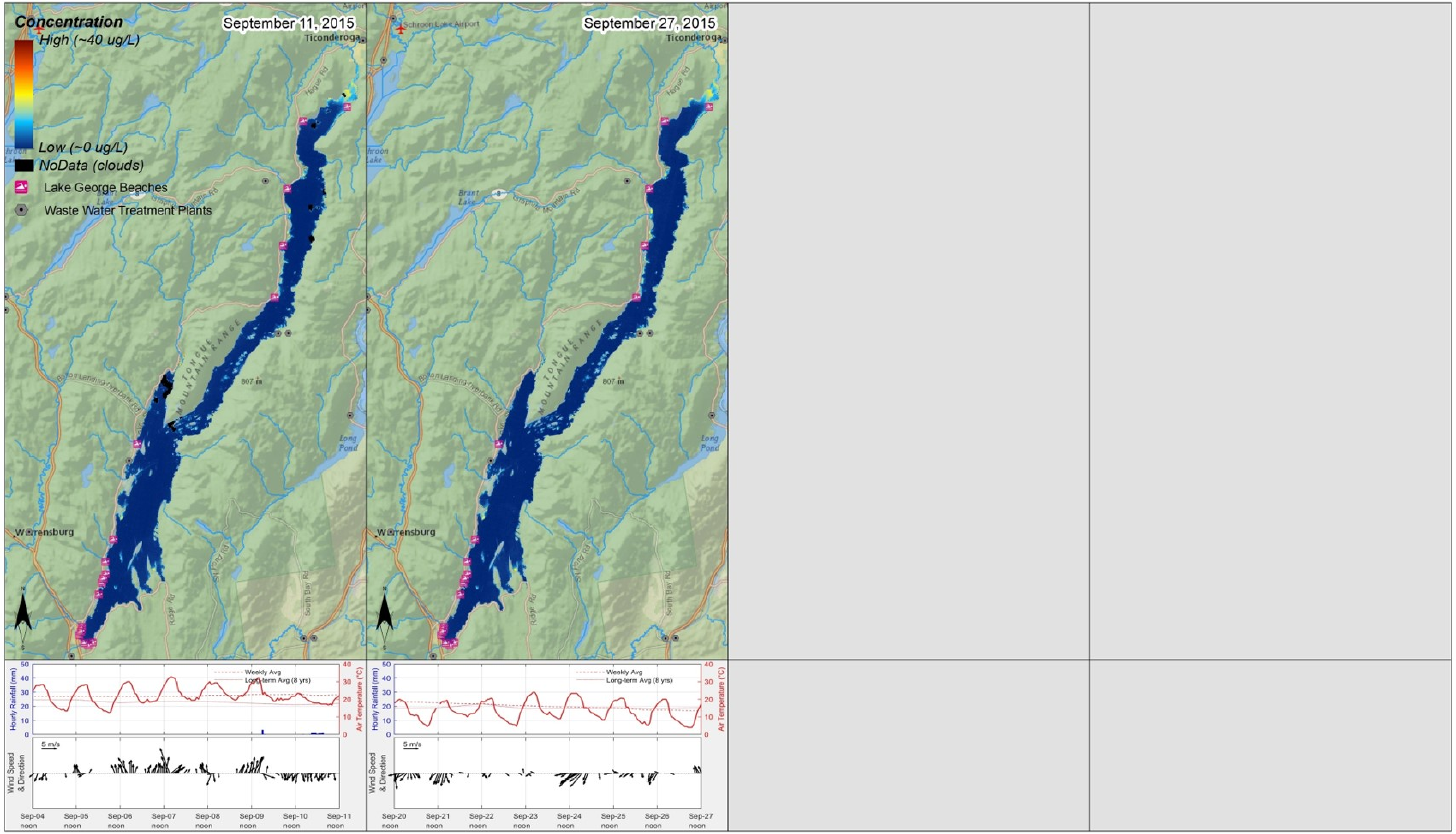
The remote sensing chlorophyll-a model was developed for Lake Champlain using four years of coincident in-situ chlorophyll-a measurements and Landsat 7 imagery. The model was calibrated and cross-validated using samples that were collected within one day of the satellite overpasses and imagery that was 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 (Error! Reference source not found.) 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.


Concentration
High (~40 ug/L)
Low (~0 ug/L)
NoData (clouds)
Lake George Beaches
Waste Water Treatment Plants
May 6, 2015
June 23, 2015
August 10, 2015
August 26, 2015
Ticonderoga
Schroon Lake Airport
Warrensburg
Brant Lake
Long Pond
TONGUE MOUNTAIN RANGE
Weekly Avg
Long-term Avg (8 yrs)
Hourly Rainfall (mm)
Air Temperature (°C)
Wind Speed & Direction
5 m/s
Apr-29 noon
Apr-30 noon
May-01 noon
May-02 noon
May-03 noon
May-04 noon
May-05 noon
May-06 noon
Jun-16 noon
Jun-17 noon
Jun-18 noon
Jun-19 noon
Jun-20 noon
Jun-21 noon
Jun-22 noon
Jun-23 noon
Aug-03 noon
Aug-04 noon
Aug-05 noon
Aug-06 noon
Aug-07 noon
Aug-08 noon
Aug-09 noon
Aug-10 noon
Aug-19 noon
Aug-20 noon
Aug-21 noon
Aug-22 noon
Aug-23 noon
Aug-24 noon
Aug-25 noon
Aug-26 noon
1:300,000
0 2 4 6 8 Miles
0 2 4 6 8 10 Kilometers
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



1:300,000

0 2 4 6 8 Miles

0 2 4 6 8 10 Kilometers

Plots

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

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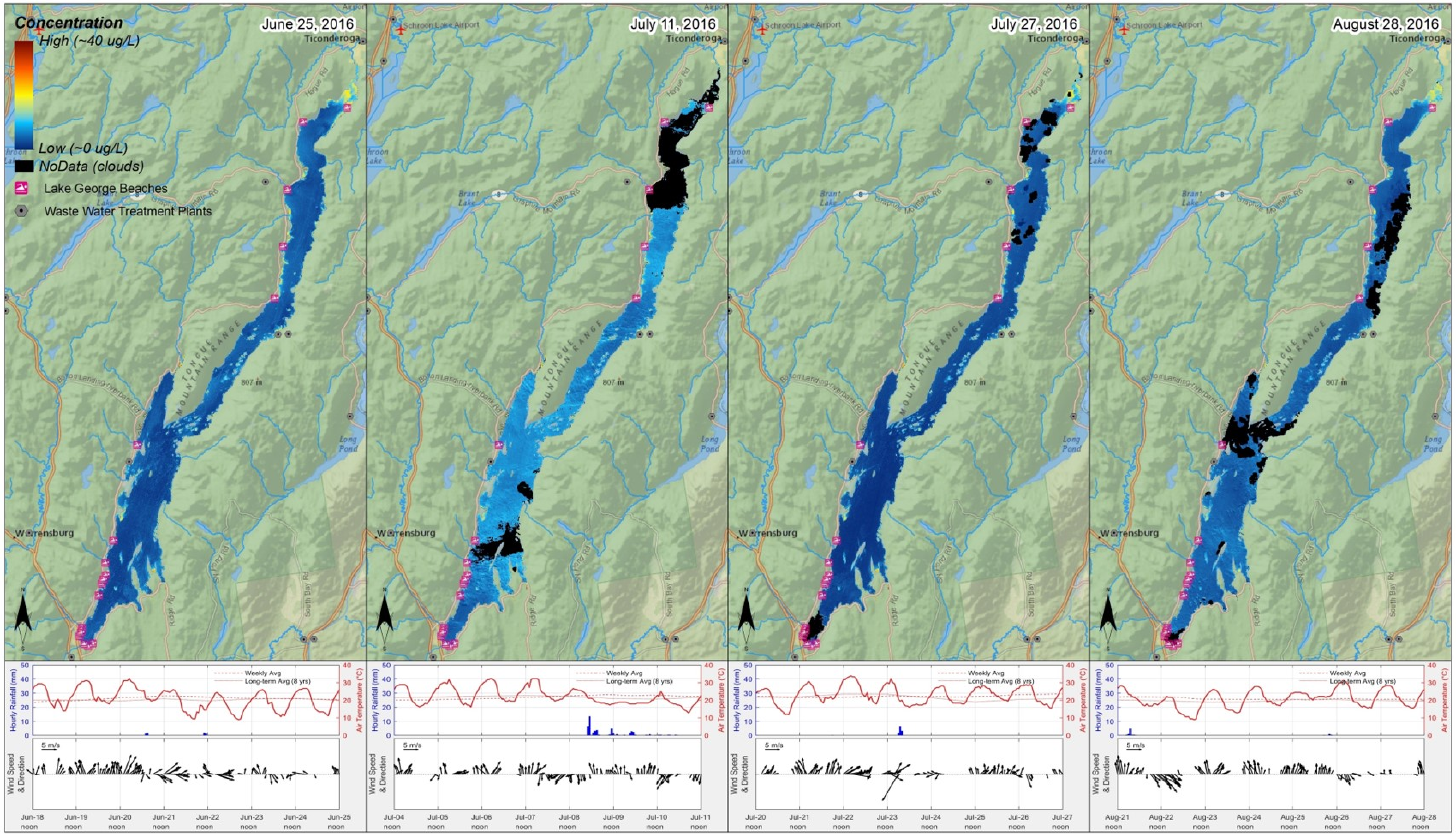
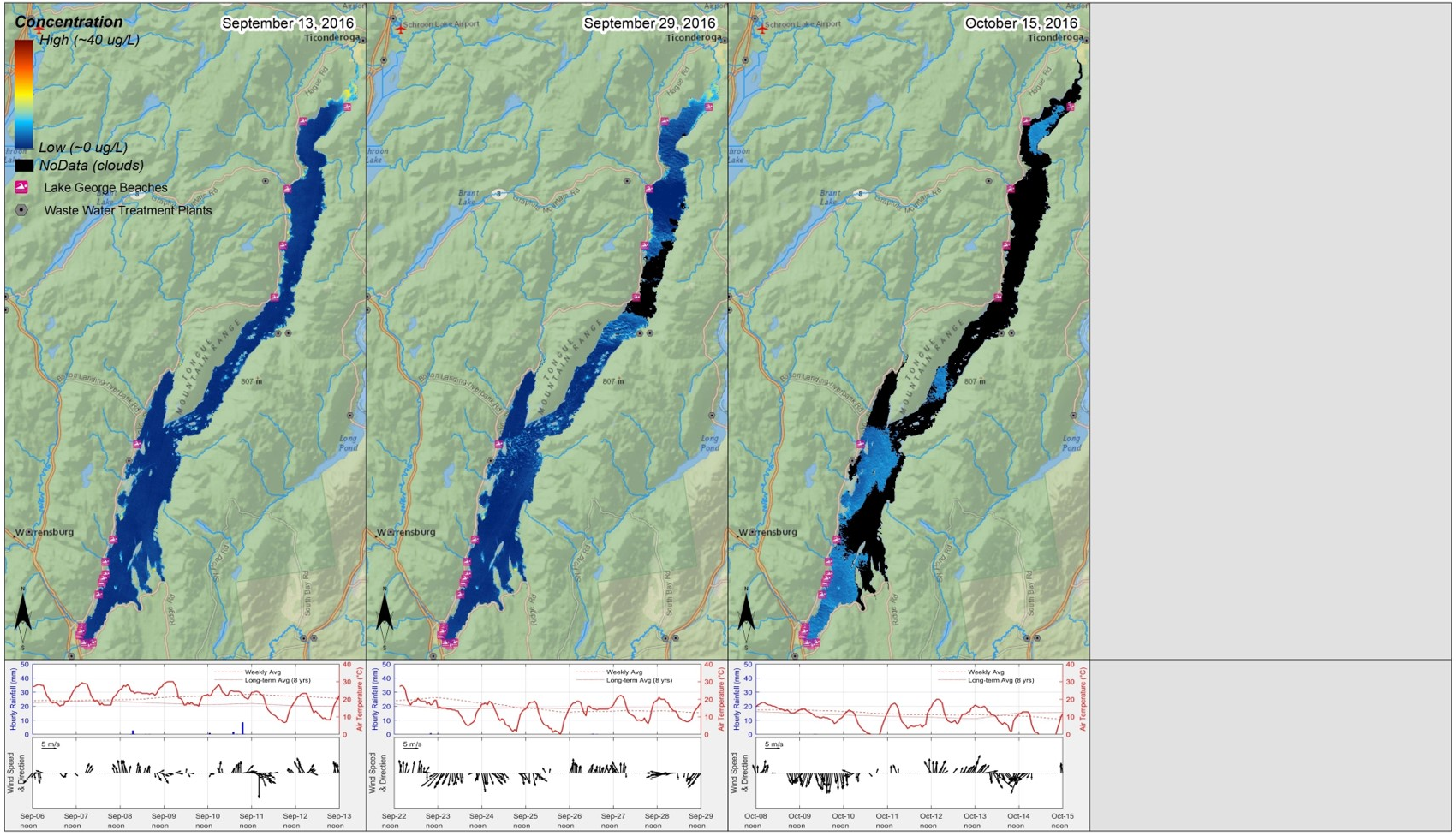
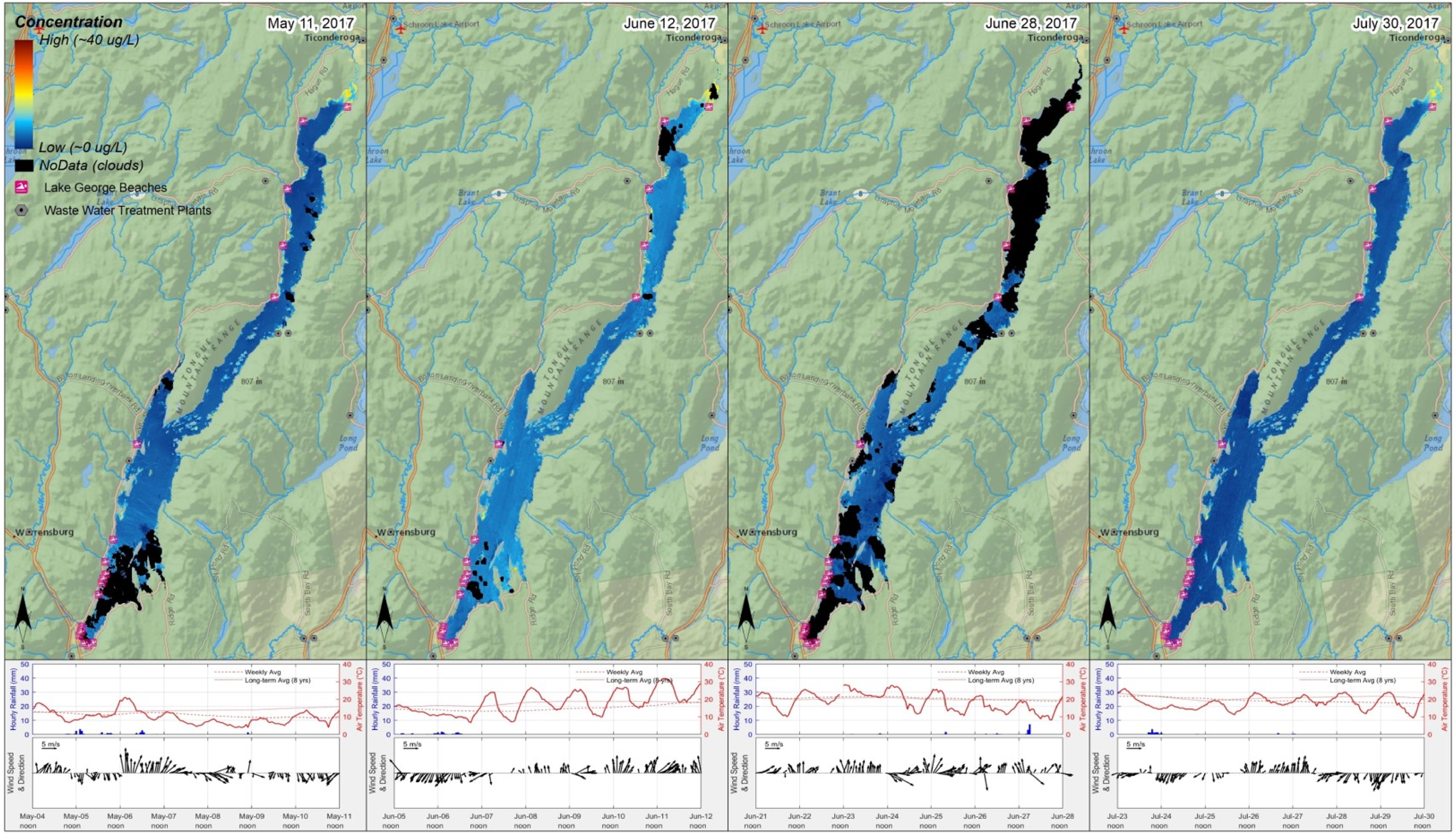


1:300,000	Plots	Satellite Derived Chlorophyll a	Disclaimer
0 2 4 6 8 Miles 0 2 4 6 8 10 Kilometers	*Plots show meteorological data 7 days prior to the satellite passing over the lake.*	*Chl-a Data is Derived from NASA's LandSat 8 Satellite* *Data Gaps are Caused by Haze and Clouds*	*These maps represent 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



1:300,000	Plots	Satellite Derived Chlorophyll a	Disclaimer
0 2 4 6 8 Miles 0 2 4 6 8 10 Kilometers	*Plots show meteorological data 7 days prior to the satellite passing over the lake.*	*Chl-a Data is Derived from NASA's LandSat 8 Satellite* *Data Gaps are Caused by Haze and Clouds*	*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



1:300,000

0 2 4 6 8 Miles

0 2 4 6 8 10 Kilometers

Plots

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

Satellite Derived Chlorophyll a

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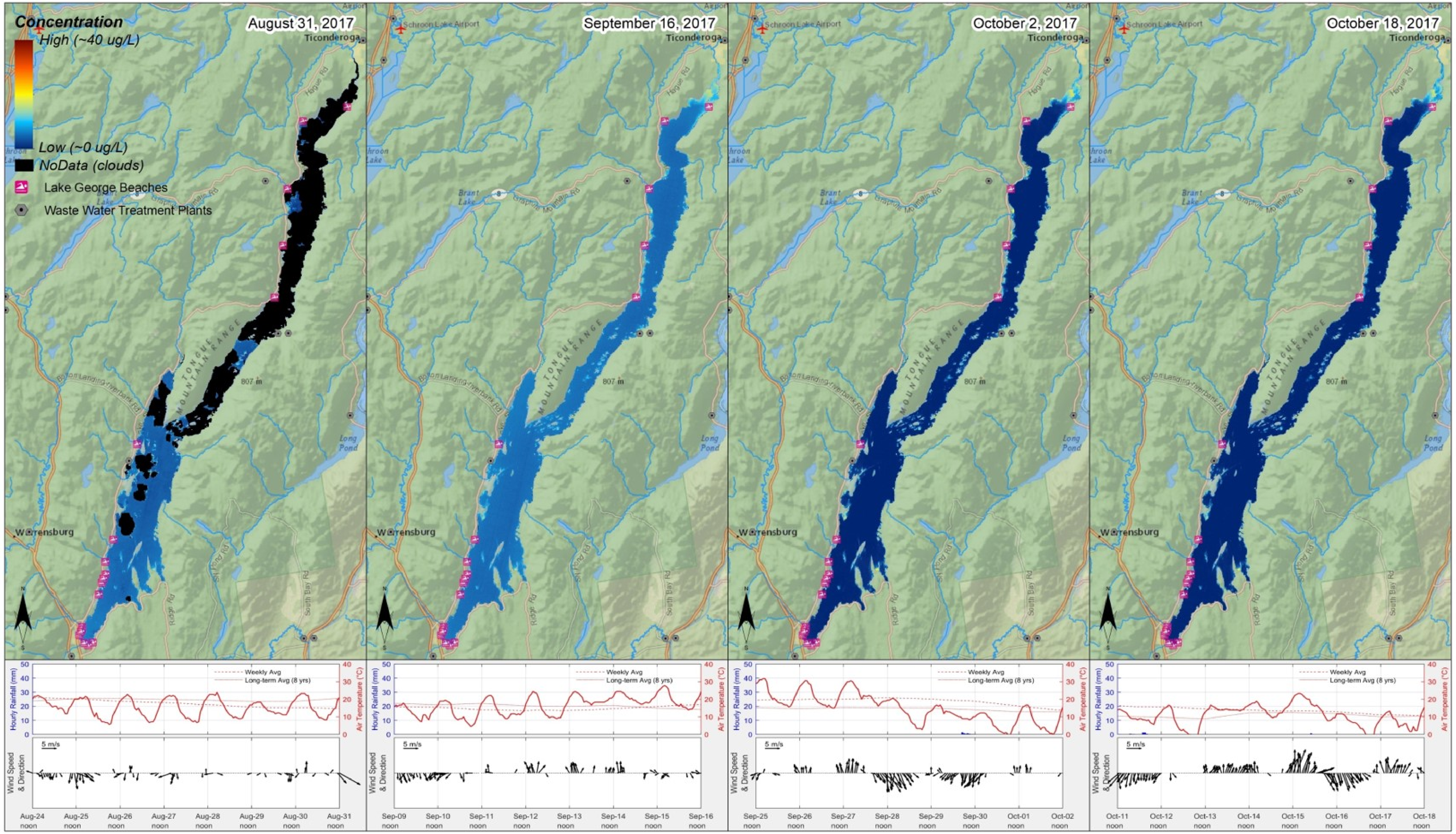

1:300,000

0 2 4 6 8 Miles

0 2 4 6 8 10 Kilometers

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

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Basemap: National Geographic World Imagery Layer.
Spatial Reference: WGS 1984 UTM Zone 18N

Appendix D. WI/PWL Summary

Lake George (1006-0016) Impaired

Waterbody Location Information

Revised: 5/1/2018

Water Index No:	C-101-P367	**Water Class:**	AA-spcl
Hydro Unit Code:	Lake George-La Chute (0415040802)	**Drainage Basin:**	Lake Champlain
Water Type/Size:	Lake/Reservoir 28523.1 Acres	**Reg/County:**	5/Warren (57)
Description:	entire lake		

Water Quality Problem/Issue Information

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

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

Known: SILT/SEDIMENT
Suspected: Restricted Passage
Unconfirmed: Aquatic Invasive Species, Pathogens

Source(s) of Pollutant(s)

Known: EROSION, URBAN/STORM RUNOFF
Suspected: Deicing (Stor/Appl), Municipal Discharges, On-site Septic Syst
Unconfirmed: ---

Management Information

Management Status: Strategy Implementation Scheduled or Underway
Lead Agency/Office: DOW/Reg5
IR/305(b) Code: Impaired Water Requiring a TMDL (IR Category 5)

Further Details

Overview
Lake George is assessed as an impaired waterbody due to secondary contact recreation uses that are impaired due to silt/sediment from erosion and urban stormwater runoff.

Use Assessment
Lake George is a Class AA–special waterbody required to support and protect the best usage as a water supply source for drinking, culinary, or food processing purposes, primary and secondary contact recreation, and fishing. The Class AA–special designation also means there shall be no discharge or disposal of sewage, industrial wastes, or other wastes

into these waters. As a result of this designation, the lake is considered a highly valued resource and is subject to special protections.

The evaluation of water supply source focuses on the lake water prior to treatment, and does not necessarily reflect the quality distributed for use after treatment. Monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. Water supply use in Lake George is considered to be threatened as a protective measure, although some land use changes in the lake watershed may ultimately threaten this use as noted below (NYSDOH, September, 2017; DEC/DOW, BWAM, April 2018).
A source water assessment of Lake George found a moderate susceptibility to contamination for this source of drinking water. This level of susceptibility is typical of many water supplies that experience no impacts to water supply use and reflects the need to protect the resource. This assessment was conducted through the NYSDOH Source Waters Assessment Program (SWAP) which compiles, organizes, and evaluates information regarding possible and actual threats to the quality of public water supply (PWS) sources. The information contained in SWAP assessment reports assists in the oversight and protection of public water systems. It is important to note that SWAP reports estimate the potential for untreated drinking water sources to be impacted by contamination and do not address the quality of treated finished potable tap water. This water supply source provides water multiple users. (NYSDOH, Source Water Assessment Program, 2005)

Primary and secondary contact recreation may be threatened due to bacterial contamination in some locations (NYSDEC Preliminary Pollution Source Investigation, April 2017), and recreation is impaired due to silt and sediment loading resulting in deltas at the mouth of several tributaries. Secondary contact recreation use (boating, fishing) may be affected by the presence of invasive plant growth (Eurasian watermilfoil, curly leafed pondweed). Fishing use is believed to be fully supported based investigations by NYSDEC Region 5 fisheries staff. Several invasive animals are found in the lake, including Asian clam, spiny water flea, virile crayfish, and zebra mussels. These organisms may threatened aquatic life (DEC/DOW, BWAM, April 2018).

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

Water Quality Information
Lake George has been sampled (at multiple locations) as part of the NYSDEC Citizen Statewide Lake Assessment Program (CSLAP) beginning in 2004 and continuing through 2014, and again in 2017. An Interpretive Summary report of the findings of this sampling was published in each year of CSLAP sampling, including 2017. 2017 sampling was conducted near Diamond Island, Basin Bay, and Gull Bay; while previous CSLAP sampling in the last few years also included sites near Crown Island, Harris Bay, and Huletts Landing These data indicate that the lake continues to be best characterized as oligotrophic, or unproductive. Lake productivity appears to increase from south to north. Phosphorus levels in the lake are typically below the state guidance values indicating impacted/stressed recreational uses. Corresponding transparency measurements easily exceed the recommended minimum for swimming beaches. Measurements of pH typically fall within the state water quality range of 6.5 to 8.5. The lake water is slightly colored, but color does not limit water transparency. (DEC/DOW, BWAM/CSLAP, April 2007)

Source Assessment
Sediment loadings to the lake from streambank erosion, winter road sanding and construction activities in the lake watershed also affect uses. Areas of roadbank erosion have been inventoried through the Warren County Critical Area Treatment Seeding Program. Significant sedimentation deltas have formed at the mouths of many tributary segments, the largest of these being Hague, Indian, Finkle, English, West and Foster Brooks, and to lesser extent East and Prospect Mountain Brooks (Bathymetric Mapping of Selected Delta Areas of Lake George, Eichler etal, Darrin Freshwater Institute, 1999). These deltas impede recreational boat navigation and present opportunities for the establishment of non–native aquatic vegetation. Local efforts to reduce sediment loads to the lake are underway for several tribs. See also various Lake George Tributary segments. (Warren County WQSC, June 2000)

While the lake fishery is considered to be fully supported, fishery habitat in the lake is affected by sediment as well.

Sand applied to roads during the winter and sediment from erosion runs off into tributary streams (and eventually the lake) during spring snowmelt and other high flow events. Once in the streams and lake, sand and silt fills in gravel spawning beds, decreasing salmonid spawning success, limiting macroinvertebrate production and increasing winter mortality of fish and invertebrates due to loss of escape cover from the effects of anchor ice. Percent embeddedness has been determined to show a reliable correlation to restriction of trout/salmon spawning habitat. Additionally, fish migration and spawning is known to be restricted by the sediment deltas at the mouths of numerous lake tribs. The DEC Region 5 Fisheries Unit plans continued field investigations of the lake and tribs to monitor the extent of propagation impairment. (DEC/DFWMR, Region 5, April 2000)

In other parts of the lake inadequate and/or failing on–site septic systems serving homes along the lake shore are thought to be contributing nutrient and pathogen contamination to the lake. Numerous summer cottages as well as year–round residences coupled with poor site conditions (small lots, inadequate soils) and poorly designed systems are problematic.

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. Lake George was identified for inclusion in this initiative as it is vulnerable to HABs and is a drinking water source.

There are a number of citizen advocacy groups focused on the protection of the water resources of Lake George. The Lake George Association (LGA) is comprised of year–round and seasonal residents, members of the business community and local government representatives. Its stated mission is one of advocacy, education and broad–based community involvement. The LGA advocates a reasoned approach to management of the Lake George watershed to ensure long–term stability of water quality and of the watershed's environmental and economic viability. (http://www.lakegeorgeassociation.org)

The Fund for Lake George pursues its mission through support for long–term scientific research on the lake, advocacy for new protections, and partnerships with other organizations and local governments. The Fund supports long–term scientific research on the water quality of Lake George through a partnership with the RPI Darrin Freshwater Institute. This results in a science–based approach to the protection of Lake George water quality and the overall health of the Lake George watershed. (http://www.fundforlakegeorge.org)

A number of water quality studies have been conducted on Lake George; many of which have focused on urban runoff. These include an extensive USEPA National Urban Runoff Program (Lake George Urban Runoff Study, Sutherland et al, 1983 NYS Park Management and Research Institute and NYSDEC (Feasibility of Reducing the Impacts of Runoff in Developed Areas of Lake George Park, Hyatt et al, 1995), various RPI Freshwater Institute studies, Darrin Freshwater Institute studies and investigations sponsored by the Warren County Office of Lake George Affairs.

Section 303(d) Listing

Lake George is included on the NYS 2008 Section 303(d) List of Impaired Waters. The lake is included on Part 1 of the List as a waterbody segment requiring the development of a TMDL or other strategy to address impairments due to silt/sediment. This waterbody was first listed on the 2002 Section 303(d) List.

Segment Description

This segment includes the total area of Lake George (P367).

Appendix E. NYSDEC Water Quality Monitoring Programs

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

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 Lake George 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.