New York State of Opportunity | Department of Environmental Conservation | Department of Health | Agriculture and Markets

HARMFUL ALGAL BLOOM ACTION PLAN LAKE CARMEL

Lake Carmel, 8/2/2016 (*Source:* NYSDEC)

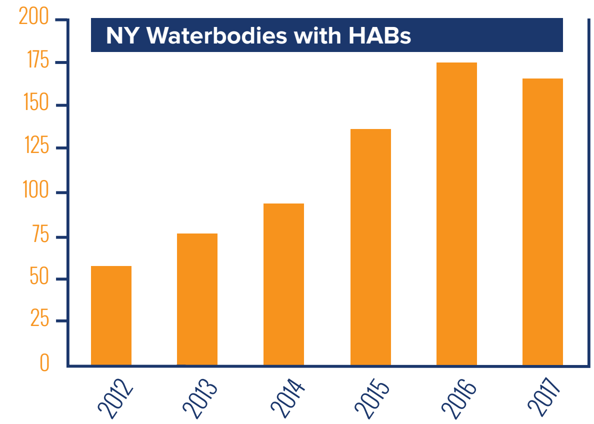
EXECUTIVE SUMMARY

SAFEGUARDING NEW YORK'S WATER

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

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

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



GOVERNOR CUOMO'S FOUR-POINT HARMFUL ALGAL BLOOM INITIATIVE

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

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

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

FOUR-POINT INITIATIVE

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

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

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

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

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

LAKE CARMEL

Putnam County

Lake Carmel, a 186-acre, manmade lake in Putnam County, is one of the 12 priority lakes impacted by HABs. The lake is used for swimming, fishing and boating. In addition, Lake Carmel is part of the Croton System, which supplies approximately 10 percent of New York City's clean, healthy drinking water.

Based on water quality monitoring conducted in 2016-17, Lake Carmel was designated as an "impaired waterbody" due to excessive nutrients (phosphorus), algae and poor water clarity, which could impact recreational uses in the lake. Total phosphorus concentrations in Lake Carmel are greater than average concentrations found in Hudson Valley lakes.

The significant sources of phosphorus loading in the lake are:

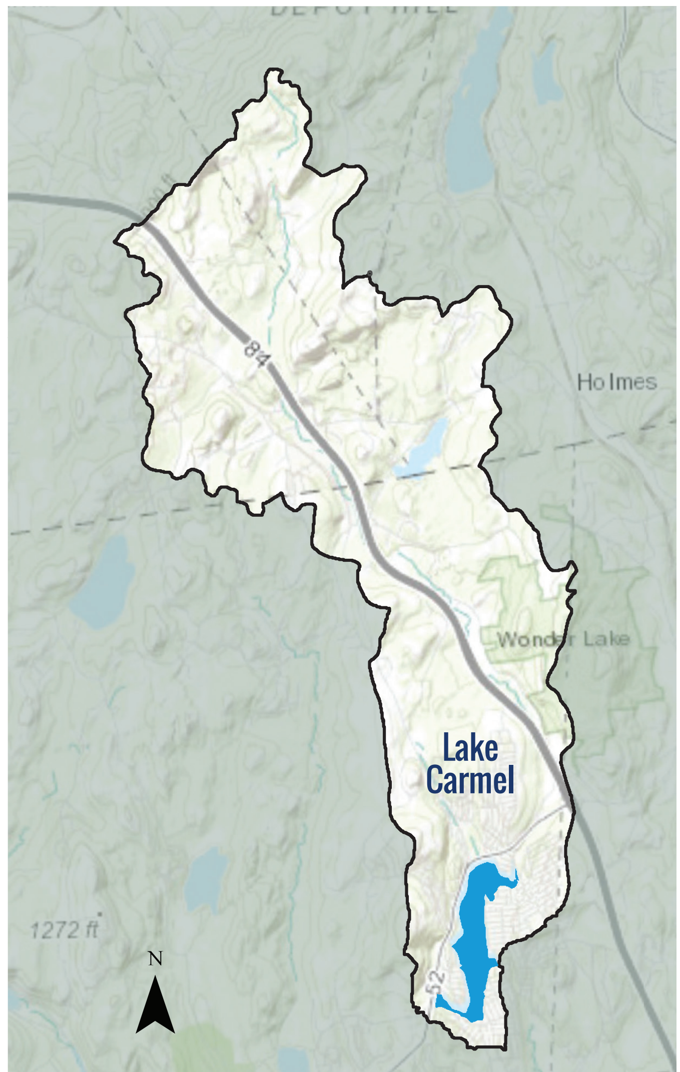
- Septic system discharges;
- Phosphorus being released from in-lake sediments; and
- Non-point source nutrient inputs from the contributing watershed.

There were 13 reported HABs occurrences in the lake from 2015 through 2017: including 7 confirmed occurrences, 2 that were "widespread/lakewide;" and 5 "suspicious" occurrences. These blooms caused beach closures at all four designated swimming beaches in mid-July 2015 and August 2016, and three of the four beaches in July 2017 (the other swimming beach remained open during July, but was closed for 20 days in August 2017).

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

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

- Construct a wastewater treatment plant (WWTP) and install infrastructure to connect 2,500 houses within the watershed to the WWTP;
- Stabilize and reinforce the banks of the Middle Branch of the Croton River and Stump Pond Stream;
- Create riparian buffers along streams to inhibit or restrict nutrient-enriched stormwater runoff and eroded soil from reaching the stream; and
- Implement multiple stormwater Best Management Practices (BMPs) to reduce sediment loading into Lake Carmel. This would include the purchase of a street sweeping vacuum truck to prevent sediment and organic debris from entering storm drains, ditches, tributaries and Lake Carmel.



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 CARMEL 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 Carmel 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 Carmel and interested members of the public are encouraged to submit comments and ideas to DOWInformation@dec.ny.gov to assist with HABs prevention and treatment moving forward.

NEW YORK STATE RESOURCES

Drinking Water Monitoring and Technical Assistance:

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

Public Outreach and Education:

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

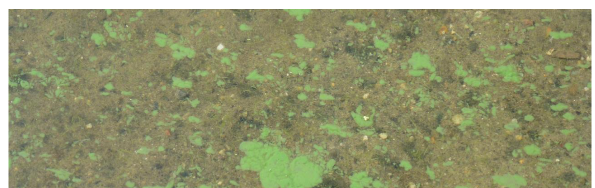
Research, Surveillance, and Monitoring:

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

Water Quality and Pollution Control:

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

Pea soup appearance



Floating dots or clumps

Spilled paint appearance

Streaks on the water's surface

CONTACT WITH HABs CAN CAUSE HEALTH EFFECTS

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

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1. Introduction

1.1 Purpose

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

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

This HABs Action Plan for Lake Carmel 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 contributing to HABs
- Provide specific recommendations to minimize the frequency, intensity, and duration of HABs to protect the health and livelihood of its residents and wildlife.

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

1.2 Scope, Jurisdiction and Audience

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

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

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

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 Carmel (e.g., Putnam County Soil and Water Conservation District (SWCD), Departments of Health (DOHs), New York City Department of Environmental Protection (NYCDEP), Lake Carmel Park District)
- Lake residents, managers, consultants, and others that are directly involved in the management of HABs in Lake Carmel.

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

1.3 Background

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

2. Lake Background

2.1 Geographic Location

Lake Carmel is a 186-acre man-made lake located in the Town of Kent, Putnam County, New York, approximately 60 miles north-northeast of New York City (**Figures 1 and 2**). It is north of the hamlet of Carmel and its watershed comprises much of the southeast corner of the Town of Kent.

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

2.2 Basin Location

Lake Carmel is located within the Lower Hudson River basin in southeastern New York, which encompasses most of Westchester, Putnam, Orange, Ulster, Columbia and Albany Counties, much of western and central Dutchess, eastern Greene, and southern Rensselaer Counties, and smaller parts of New York (Manhattan), Bronx, Rockland, Sullivan, Schoharie, and Schenectady Counties. Land use within the watershed is dominated by forest (65%) and developed lands (22%) (see **Section 10**). Land use immediately surrounding the lake consists primarily of developed land.

2.3 Morphology

The Lake Carmel watershed has a direct drainage of 8,150 acres, excluding its surface area (186 acres), and is 189 m (619 feet) above mean sea level (NYSDEC 2016). The Lake is oriented north to south (**Figure 1**), totaling approximately 2,134 m (7,000 feet) in length with a shoreline perimeter of approximately 7.2 km (4.5 miles). The width of the lake at its widest point is 691 m (2,266 feet). Lake Carmel has a maximum depth of 4.3 meters (14 feet) with an average depth of 2.4 meters (7.9 feet) (CSLAP 2016). The lake's surface area-to-depth ratio is approximately 24:1, a relatively low value. Lakes with smaller surface areas are generally less susceptible to turbulence caused by wind and wave actions, which makes them more likely to experience seasonal thermal stratification. In addition, shallow lakes generally experience significant temperature fluctuations, including elevated temperatures during summer months that can promote stratification and favorable conditions for HABs.

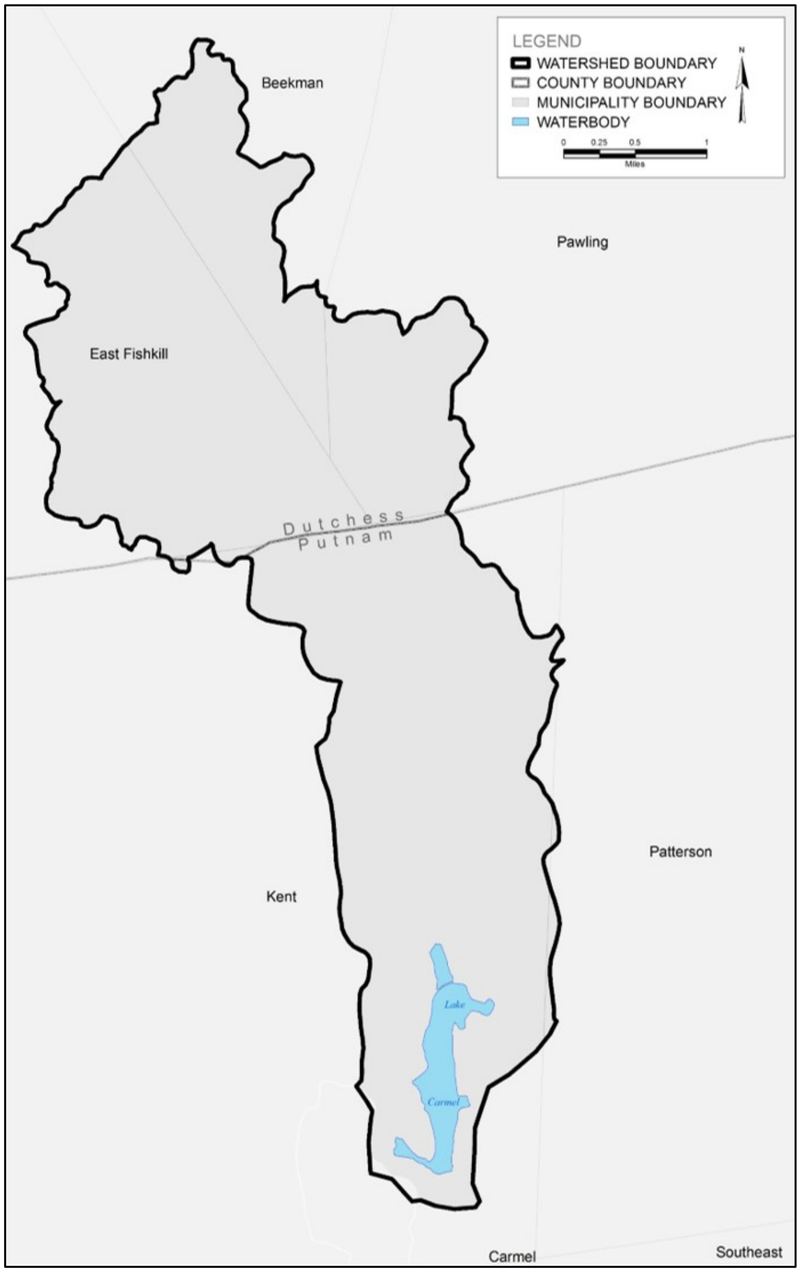


Figure 2. Political boundaries within the Lake Carmel watershed.

Lake Carmel has three prominent lobes extending off the main body of the lake. The northernmost lobe is bisected by NYS Route 311. Putnam County Route 46 bisects a smaller lobe in the northeastern portion of the lake in the north-south direction. A third lobe in the southern portion abuts NYS Route 52 to the west.

The wind rose in **Appendix A** indicates that a relatively strong prevailing wind direction influencing Lake Carmel from 2006 to 2017 during the months of June through

November were often from the southwest and south, as measured from the Danbury Municipal Airport. This predominant wind pattern results in a fetch length of 2,000 to 7,000 ft given the north-south orientation of Lake Carmel. Given these wind patterns during the growing season, buoyant cyanobacteria may accumulate in the eastern and northeastern portion of Lake Carmel potentially impacting bathing beaches and other recreational uses along the northeastern shoreline.

Typical of many reservoirs, Lake Carmel is part of a relatively large watershed (8,414 acres) compared to its lake area (192 acres). This higher watershed to lake area ratio (44:1) is often associated with lower water retention times, as well as relatively high sedimentation rates and land-based loading of phosphorus. Relatively high sediment and phosphorus loading to Lake Carmel during storm events may create conditions that increase the likelihood of a HAB event. Sedimentation rates and nutrient loads in reservoirs do not tend to be uniform throughout the water body and are often higher in deeper areas of the lake and areas of less water circulation. Sedimentation in the deeper areas of Lake Carmel contributes to internal releases of phosphorus during periods of stratification, ultimately leading to an increased likelihood of HABs.

2.4 Hydrology

Lake Carmel's hydraulic retention time, or the amount of time it takes water to pass through the lake, is estimated to be 0.1 years (CSLAP 2016). There are two main tributaries to the lake, including a section of the Middle Branch of the Croton River from topographically elevated marshlands approximately 0.5 miles to the north-northwest, and Stump Pond Stream which originates from a series of ponds and lakes to the north. A smaller unnamed tributary enters the lake from the southwest. Outflow from Lake Carmel is conveyed eastward to a southern section of the Middle Branch of the Croton River, which flows south and discharges downstream to the Middle Branch Reservoir. The outlet is located just south of the middle of the lake on the east shore. There are no inflow or outflow stream gauging stations to document flow in the tributaries of Lake Carmel.

The location of the stream inflows and outflow may result in lower mixing and higher hydraulic residence time in the southern portion of Lake Carmel, which may increase sedimentation and nutrient concentrations in this portion of the lake. Potentially higher nutrient concentrations in the south branch of Lake Carmel may increase the likelihood of HABs in this area. HABs were observed at the beaches (**Figure 3**) located in proximity to the south branch of the lake in 2016 and 2017.

2.5 Lake Origin

Developers Arthur and Warren Smadbeck created Lake Carmel atop primarily farmland by damming the Middle Branch of the Croton River in 1928. At that time, the lake was primarily used for recreational purposes with cottages and small homes built along the shoreline. Lake Carmel takes its name from the nearby Carmel Hamlet.

3. Designated Uses

3.1 Water Quality Classification – Lake and Major Tributaries

Lake Carmel is designated as a Class B waterbody under the New York Codes, Rules, and Regulations (NYCRR). meaning it is best intended for contact recreation (i.e., swimming and bathing), non-contact recreation (i.e., boating and fishing), aesthetics, and support of aquatic life. The primary uses of Lake Carmel are described in the following sections, and the New York State classification system is provided in **Appendix B**.

Stump Pond Stream, an inflowing tributary to the northeast, is identified as a Class C water, indicating these waters are best used for fishing, fish propagation and survival. Class C waterbodies also are suitable for primary and secondary contact recreation, unless other factors limit the use for these purposes.

A section of the Middle Branch of the Croton River flows into Lake Carmel from the north. Another section of the Middle Branch of the Croton River east of the lake receives outflowing water. Both sections of the Middle Branch are identified as Class C waters. The reaches of the Middle Branch of the Croton River adjacent to Lake Carmel are also designated as trout spawning waters. The HABs conditions in Lake Carmel represent a potential threat to water quality within these downstream uses, particularly those associated with the resources that serve as potable water sources for the New York City Watershed. Additional discussion is provided in **Sections 3.2** and **3.7**.

3.2 Potable Water Uses

Lake Carmel is a part of the Croton System of New York City water supply reservoirs and is a tributary to the Middle Branch Reservoir. The Croton System supplies the City with approximately 10% of its drinking water (NYC Water 2013). An agreement between the New York City Department of Environmental Protection (NYCDEP) and the Croton Watershed communities is in place to provide programmatic guidance and funding for watershed protection (NYSDEC 2008). This connection between Lake Carmel and the New York City water supply reservoirs contributed to Lake Carmel's inclusion in the Governor's HABs initiative that led to the development of this HABs Action Plan.

The US 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 EPA 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 (mcg/L) for infants and children under the age of 6, and 1.6 mcg/L for older children and adults. (USEPA 2015). The 10-day health advisories are protective of exposures over a 10-day exposure period to microcystin in drinking water, and are set at levels that are 1000-fold lower than levels that caused health effects in laboratory animals. The USEPA's lower 10-day health advisory of 0.3 mcg/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 mcg/L as the basis for recommendations, and a do not drink recommendation will be issued upon confirmation that microcystin levels exceeds this level in the finished drinking water delivered to customers.

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

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

3.3 Public Bathing Uses

According to the Lake Carmel Park District Beach Rules and Regulations, there are four designated and regulated swimming beaches (#2, #3, #4, and #7) for Park District residents and their guests (**Figure 3**). Beaches #5 and #6 are designated as recreation only sites by the Park District, though, beach areas and life guard chairs are present at both locations.

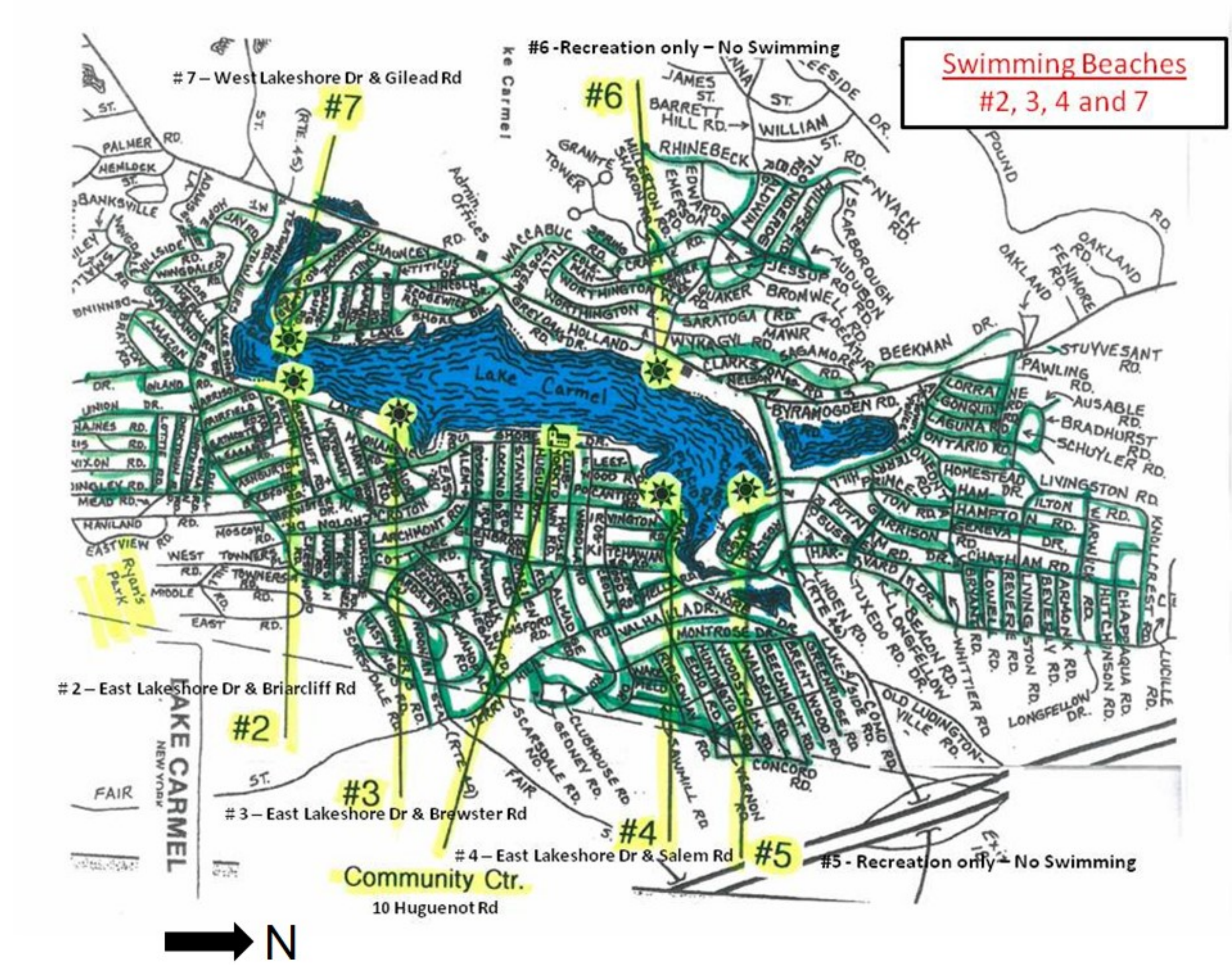


Figure 3. Lake Carmel Park District designated and regulated swimming beaches (Source: Town of Kent). Note that north is to the right on this figure.

As noted in **Section 2.3**, the prevailing wind patterns influencing Lake Carmel (**Appendix A**) indicate that cyanobacteria may accumulate along the eastern shoreline during HAB events, due to winds originating out of the west. Thus, swimming beaches such as #4 in the northeastern portion and #2 and #3, which are located in the southeastern portion of Lake Carmel, as well as the recreation only beach #5 may be priority locations to monitor for HABs to limit negative effects on public health (**Figure 3**).

3.4 Recreation Uses

The primary uses at the lake include swimming, boating, fishing, and aesthetics, as reported by watershed residents who attended a public meeting hosted by NYSDEC on July 29, 2014 (NYSDEC 2016). Lake Carmel has seven public access points, including the four designated swimming beaches, two non-regulated beaches (#5 and #6), and a community center access location along the eastern shoreline. Motorboats and boats greater than 20 feet in length are prohibited on Lake Carmel.

3.5 Fish Consumption/Fishing Uses

New York State fishing regulations are applicable in Lake Carmel for both regular fishing and ice fishing. Fish stocking is not known to occur. There are no fish consumption advisories specific to Lake Carmel (NYSDOH 2017), however, the lake is included in the Hudson Valley/Capital district region fish consumption advisory, where it is not recommended to consume more than 4 meals per month of fish.

3.6 Aquatic Life Uses

Lake Carmel, as a Class B waterbody, is suitable for the fish propagation and survival. The lake supports a typical assemblage of warmwater fish species, several of which are important recreationally and may be taken for consumption. These species include largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), yellow perch (*Perca flavescens*), black crappie (*Pomoxis nigromaculatus*), and common carp (*Cyprinus carpio*). The generally shallow depths and warm waters of the lake are not conducive to sustaining populations of coldwater fishes such as trout.

The Citizen Statewide Lake Assessment Program (CSLAP) is a cooperative volunteer monitoring effort between NYSDEC and the New York Federation of Lake Associations (FOLA). According to the CSLAP 2017 Lake Use Scorecard summary report for Lake Carmel, the aquatic life use is identified as “supported/good”, indicating the general absence of observable impacts to aquatic life despite habitat use being designated as “threatened/fair”. Notable, however, is that in the 2008 revised Waterbody Inventory/Priority Waterbodies List (WI/PWL) fact sheet for Lake Carmel, the aquatic life use was identified as “stressed” based on non-specific impacts (NYSDEC 2008).

While reliable data of the fish populations in Lake Carmel are not known to be available, the fish species reported coupled with the absence of observable impairment to the aquatic life use in the lake suggests that the fish assemblage and its potential cascading regulating effects on lower trophic levels is not a driver for HABs formations in Lake Carmel. However, the presence of common carp (*Cyprinus carpio*), an invasive cyprinid in the lake that forages preferentially on benthic macroinvertebrates in lakebed sediments, can increase sediment suspension and associated nutrients in the water column based on its feeding behavior. The increased suspended sediment liberated by the common carp's benthic foraging mode contains nutrients that may be utilized by blue green algae, potentially leading to HABs.

4. User and Stakeholder Groups

Access to Lake Carmel for recreational activities such as fishing, boating, and swimming is restricted to homeowners with access rights and to guests. Portions of the Lake Carmel shoreline not under private ownership are owned by the Town of Kent.

The Lake Carmel Park District is responsible for the adoption and administrative enforcement of the rules, regulations, and provisions governing parks, playgrounds, athletic fields, tennis courts, swimming pools, beaches, boardwalks, piers, docks, and other recreational areas, open places, roadways, roads, paths, walks, and waters owned or to be acquired by the Town of Kent. These rules and regulations cover specific lake-related activities including access, permitting and registration, feeding of waterfowl, fishing restrictions, and smoking in beach areas (Town of Kent 2018a).

The Kent Lake Association is local volunteer group concerned with the quality of nine lakes, including Lake Carmel, in the Town of Kent. The goal of this association is to engage in and discuss their collective knowledge and individual expertise of lake conditions to identify and resolve common issues (Town of Kent 2018b).

As mentioned above, there is no public access to Lake Carmel, limiting the involvement of non-governmental organizations (NGOs), sportsman groups, other organizations, and other members of the public.

5. Monitoring Efforts

5.1 Lake Monitoring Activities

Sampling of Lake Carmel has been conducted as part of CSLAP from 1986-1990 and then again in 2016 and 2017. Section 6 details the physical, chemical, and biological condition of Lake Carmel based on data collected through the CSLAP program. HABs monitoring has been conducted through CSLAP since 2013.

Lake Carmel was sampled in 2013 by the NYSDEC as part of the Lake Classification and Inventory (LCI) Monitoring Program, conducted to support NYSDEC water quality assessments and management activities. The LCI data set for Lake Carmel includes monthly water quality samples collected between June and September, and depth profiles (0 to 2 meters) of temperature, pH, conductivity, and dissolved oxygen.

5.2 Tributary Monitoring Activities

No known programs are in place for monitoring Stump Pond Stream, one of the two tributaries entering the lake from the north. The United States Geological Survey (USGS) has provided an identifier number and name ("Stump Pond Stream at Mouth at Kent Corners, NY") for a stream monitoring site on Stump Pond Stream located just upstream of its entry to Lake Carmel; however, on-line water quality data for this stream site are not available (USGS 2018).

The section of the Middle Branch of the Croton River that discharges to Lake Carmel from the north is monitored by the NYCDEP as part of its efforts to maintain water quality protection of New York City's water supply system. These monitoring efforts include recording current conditions and providing a long-term record for trend analysis, with a sample collection program focusing on TP, dissolved oxygen, turbidity, and pathogens (as measured by fecal coliform levels). NYCDEP maintains one water quality sampling station on the Stump Pond Stream between Lake Carmel and Stump Pond, an 18-acre pond located approximately 2.5 miles upstream of Lake Carmel (NYSDEC 2008).

6. Water Quality Conditions

Trends in water quality conditions were assessed using data from 1986 to 1990 and 2016- 2017 collected by CSLAP as well as the 2013 NYSDEC LCI data. Trend analysis is challenging due to the large time gap in the available water quality data; however, trends were evaluated using a nonparametric correlations coefficient (Kendall's tau, τ) to determine if time trends were significant (p-values less than 0.05). Water quality data used in this analysis were limited to those that were collected under a State-approved Quality Assurance Project Plan (QAPP), and analyzed at an Environmental Laboratory Accredited Program (ELAP) certified laboratory. Note that long-term trends presented below are intended to provide an overview of water quality conditions, and that continued sampling will better inform trend analyses over time.

Table 1 provides a regional summary of surface total phosphorus (TP) concentrations from Lake Carmel 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 the form of phosphorus is an important consideration when evaluating management alternatives (**Section 13**).

Table 1. Regional summary of surface total phosphorus (TP) concentrations (mg/L, ± standard error) for New York State lakes (2012-2017, CSLAP and LCI), and the average TP concentration (± standard error) in Lake Carmel (2016-2017).			
Region	**Number of Lakes**	**Average TP (mg/L)**	**Average TP Lake Carmel (mg/L) 2016 and 2017**
NYS	521	0.034 (± 0.003)	-
NYC-LI	27	0.123 (± 0.033)	-
Lower Hudson	49	0.040 (± 0.005	0.047 (± 0.005)
Mid-Hudson	53	0.033 (± 0.008)	-
Mohawk	29	0.040 (± 0.009)	-
Eastern Adirondack	112	0.010 (± 0.0004)	-
Western Adirondack	88	0.012 (± 0.001)	-
Central NY	60	0.024 (± 0.005)	-
Finger Lakes region	45	0.077 (± 0.022)	-
Finger Lakes	11	0.015 (± 0.003)	-
Western NY	47	0.045 (± 0.008)	-

Regionally, the data provided in **Table 1** indicate that the average TP concentration in Lake Carmel is greater than the average concentration found throughout the Lower Hudson region. Further, the average TP concentration is more than two times greater than the New York State water quality guidance value of 0.02 mg/L, which suggests that future management actions to protect water quality should likely focus on reducing TP concentrations. Excessive inputs of phosphorus and nitrogen may result in the formation of HABs when environmental conditions are suitable (see **Section 9**).

Water clarity (based on Secchi depth, m), TP (mg/L), and chlorophyll-a (µg/L) concentrations are used to assess trophic state using New York State criteria (**Table 2**). Based on water quality sampling in Lake Carmel in 2016 and 2017, these indicators reflected eutrophic (high productivity) conditions.

Table 2. New York State criteria for trophic classifications (NYSFOLA 2009) compared to average Lake Carmel values in 2016 and 2017 (CSLAP, ± standard error).				
Parameter	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Lake Carmel (2016-2017)**
Transparency (m)	>5	2-5	<2	1.6 (± 0.18)
TP (mg/L)	<0.010	0.010-0.020	>0.020	0.047 (± 0.005)
Chlorophyll a (µg/L)	<2	2-8	>8	22.4 (± 3.5)

6.1 Physical Conditions

Water clarity can be related to the amount of suspended material in the water column including sediment, algae, and cyanobacteria. Lake Carmel has lower water clarity and higher nutrient and algae concentrations than other lakes in the Lower Hudson region (CSLAP 2016). Specific factors that appear to have contributed to this condition are provided in the following sections.

Appendix A includes estimated wave heights in Lake Carmel from 2006 to 2017 during the months of June through November, wave heights and direction were modeled using wind speed and directions from the Danbiry Municipal Airport. The modeled wave heights indicated that the height of waves was generally greater in the northern and southern portions of the lake. Note that most estimated wave heights in Lake Carmel over this time period were less than or equal to 0.2 meters. Based on these estimates, an evaluation of the potential of re-suspension of lakebed sediments by waves indicated that for water depths greater than 1.2 meters (4 feet), re-suspension is unlikely to occur in an average year. Thus, most of the lake bed is generally not susceptible to re-suspension by waves.

Water clarity, as represented by Secchi depth, has generally increased ($\tau = 0.286$) over time (**Figure 4**) although this trend was not statistically significant ($p = 0.322$). **Figure 4b** shows a pattern of increased clarity from 2013 to 2016-2017. Early season (e.g., June) water clarity in Lake Carmel were greater than 2 m in 2016 and 2017 and then decreased to less than 2 m) throughout the remainder of the sampling months (**Figure 4b**). This seasonal trend in water clarity was observed in 2013, but water clarity remained less than 2 m throughout the growing season. Secchi disk transparency readings occasionally exceeded the 1.2-meter (4 feet) New York State Sanitary Code requirements for siting new bathing beaches (NYSDOH 2018). Such trophic indicators should continue to be monitored for any changes.

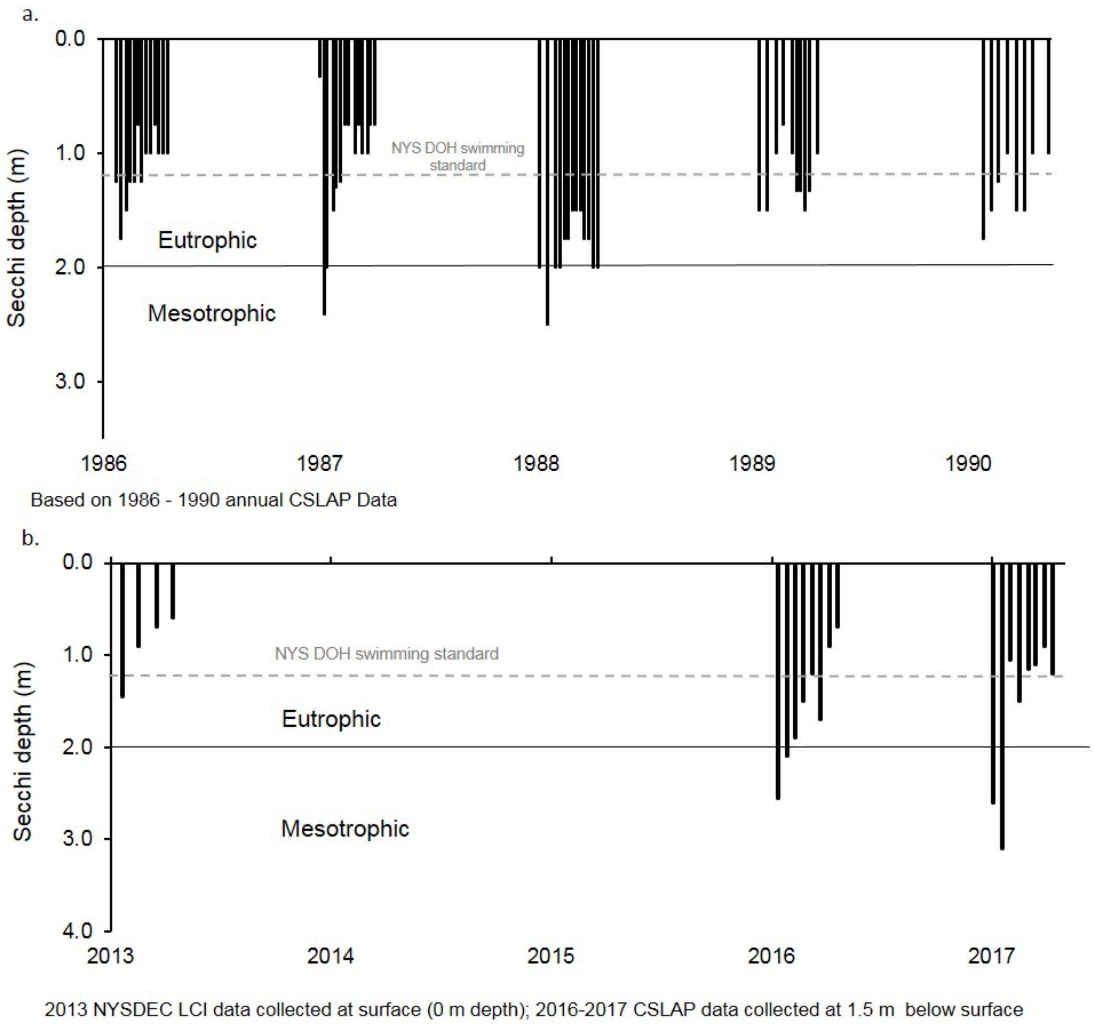


Figure 4. (a) Historic (1986-1990) and (b) recent (2013, 2016, 2017) Secchi depth (m) measurements at Lake Carmel.

Maximum water temperatures in Lake Carmel were between 25°C (77°F) and 30°C (86°F) in all years sampled except for the 2017 sampling period where maximum water temperatures were observed to be 24°C (75°F). No long-term trends in water temperature were observed ($p > 0.05$). Typical seasonal variations in temperature are shown for all sampling seasons (**Figure 5**). Temperature depth profiles conducted during the LCI sampling in 2013 indicate that Lake Carmel was weakly stratified during the months of June, July, and September (**Figure 6**). The absence of thermal stratification in August indicates mixing in Lake Carmel during the growing season. Additional temperature profiles collected in Lake Carmel will provide further understanding into temperature-driven stratification and the overall mixing regime of the lake. These temperature profiles could be compared to the patterns observed in 2013, and be used to document and refine estimates of internal loading in Lake Carmel (when coupled with dissolved oxygen profiles, see **Section 6.2**). Understanding temperature changes within a waterbody seasonally, as well as annually, is important in understanding HABs. Most cyanobacteria taxa grow better at higher temperatures than other phytoplankton which give them a competitive advantage at higher temperatures (typically above 25°C) (Paerl and Huisman 2008).

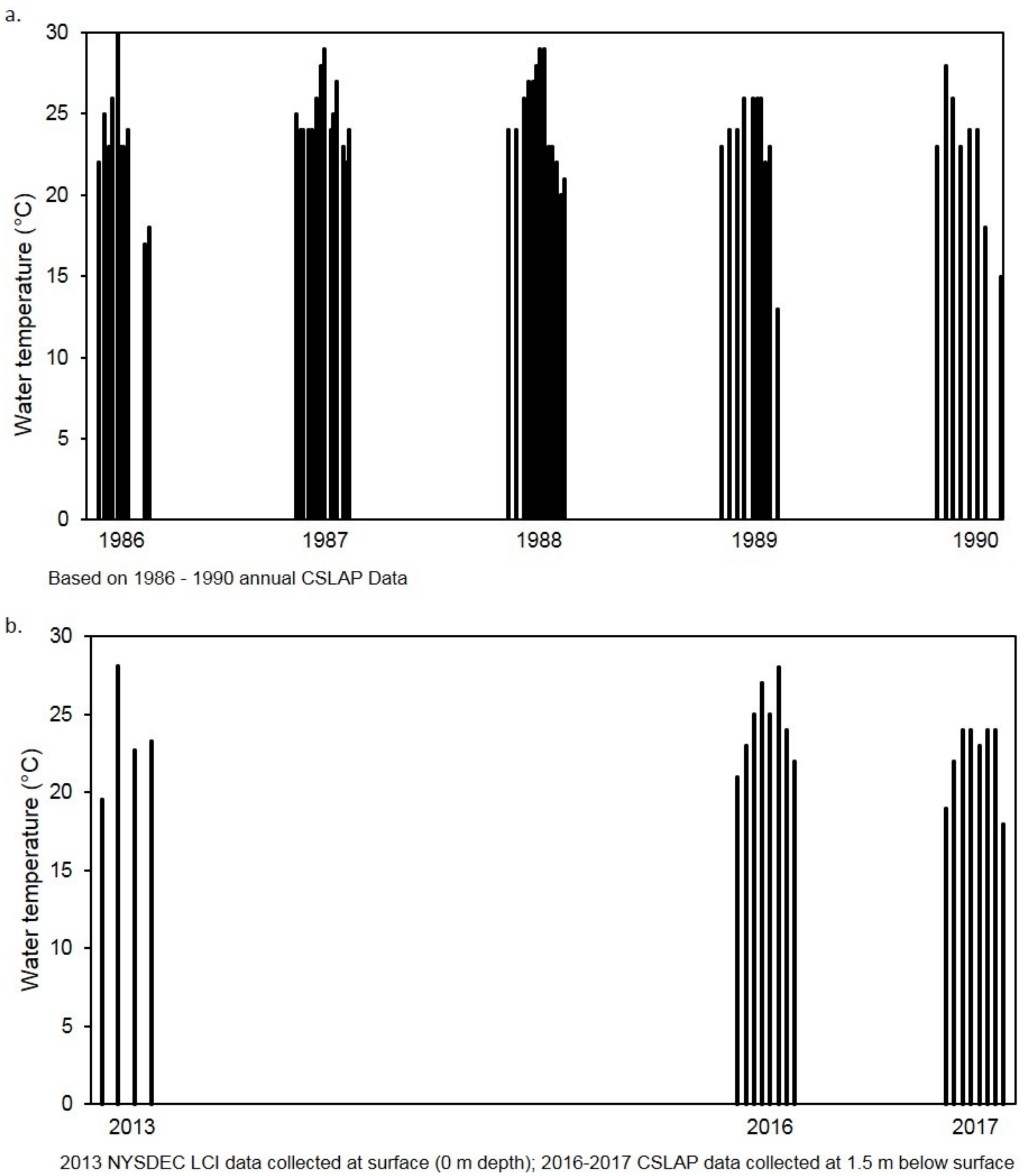


Figure 5. (a) Historic (1986-1990) and (b) recent (2013, 2016, 2017) surface water temperature (°C) at Lake Carmel.

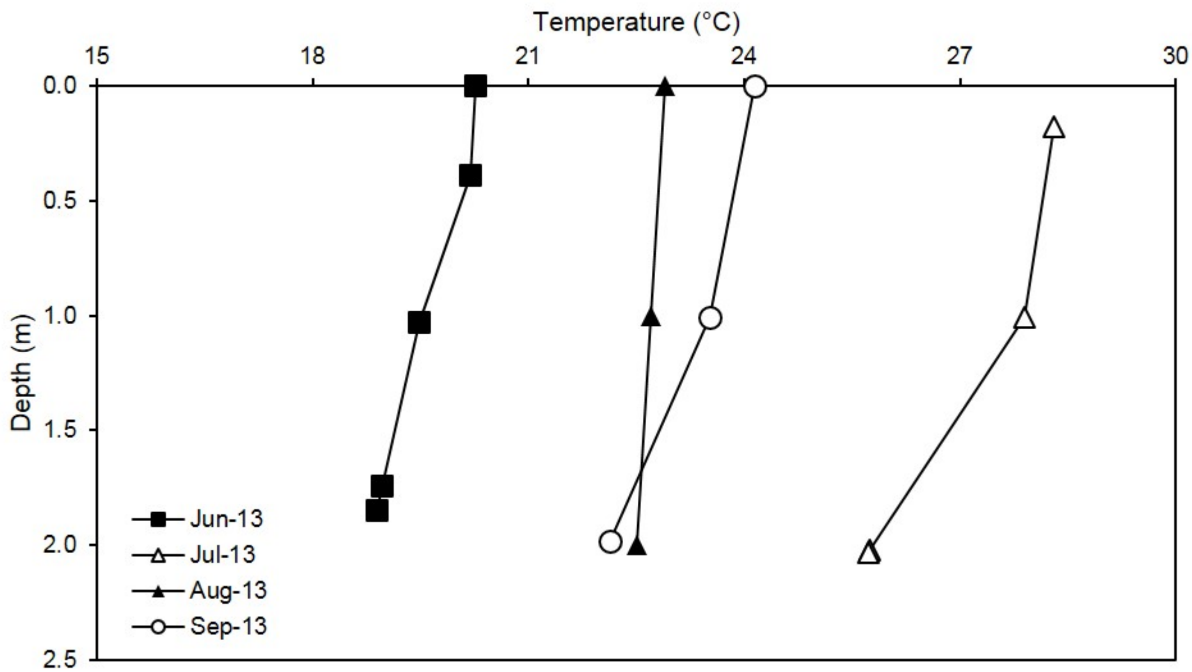


Figure 6. Temperature (°C) depth (m) profiles in Lake Carmel from June to September in 2013 (LCI).

6.2 Chemical Conditions

Dissolved oxygen (DO) profiles also indicate thermal stratification during summer, with notable DO depletion observed at 2 meters depth and anoxic conditions (e.g., no oxygen) measured in July 2013 (**Figure 7**). Thermal stratification during summer effectively isolates the deeper water layers from atmospheric inputs of oxygen, creating a finite pool of DO. Loading of organic matter to the deep layers and sediments of productive lakes increases the consumption of the DO pool, resulting in a progressive reduction in DO concentrations during summer stratification (Wetzel 2001).

The increase in DO at 2 meters depth and the corresponding decrease at the surface in August 2013 (**Figure 7**) indicates a mixing event and breakdown of thermal stratification. This is supported by the lack of a vertical gradient in the corresponding August temperature profile (**Figure 6**). These temperature and dissolved oxygen profiles suggest that summer thermal stratification is generally weak and temporary in Lake Carmel. When mixing occurs, phosphorus accumulated in the bottom water layers during periods of anoxia becomes available to support algal growth and potentially HABs. Further data collection of the temperature and dissolved oxygen profiles in Lake Carmel will provide insight into internal nutrient loading dynamics over time, and indicate if this pattern observed in 2013 is typical.

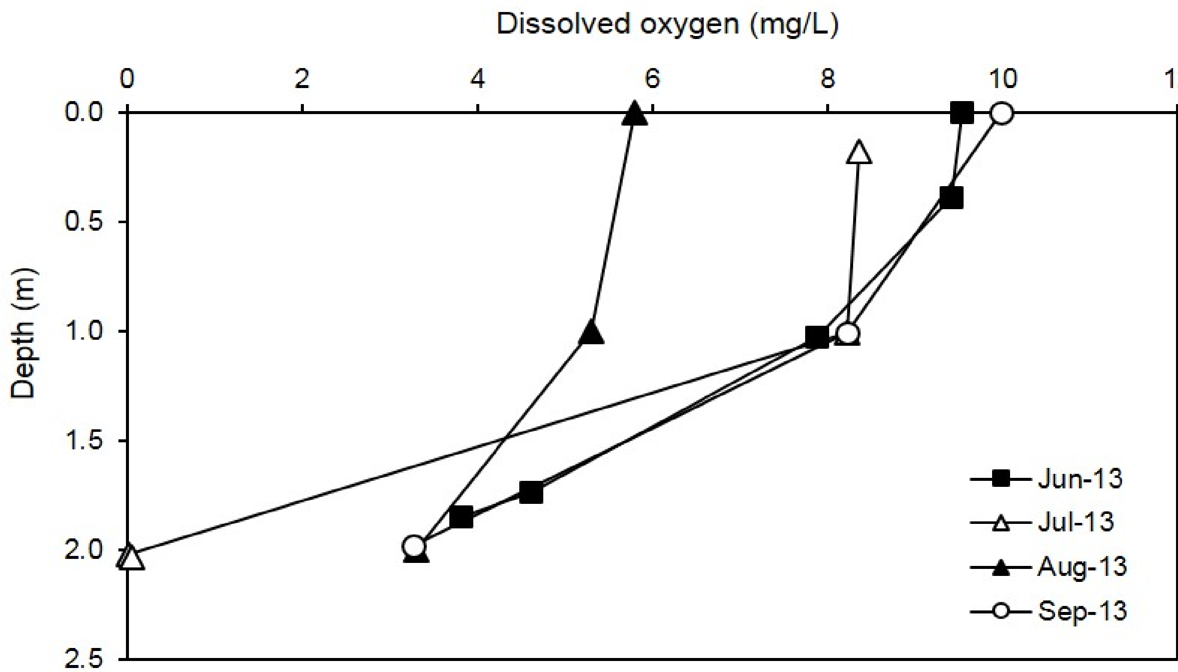
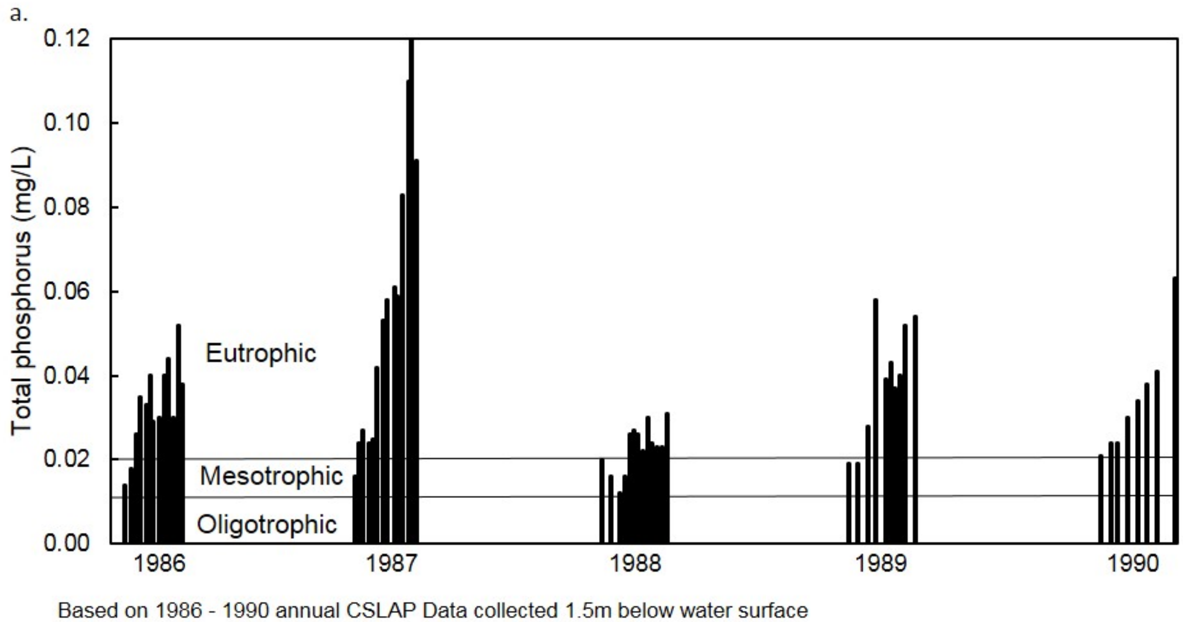


Figure 7. Depth (m) profile of dissolved oxygen (DO) concentrations (mg/L) in Lake Carmel from June to September 2013 (LCI).

Average summer total phosphorus (TP) concentrations in Lake Carmel are indicative of eutrophic conditions (concentrations >0.02 mg/L) (**Figure 8**). Trends in annual average TP concentrations suggest a non-significant increase (p = 0.322, τ = 0.286) over time, although, unusually high concentrations in 1987 may reduce the general increasing trend in TP. For example, average TP concentrations in 2017 (0.045 mg/L) were 2-times greater than in 1988 (0.023 mg/L). Seasonal trends in TP concentrations were observed, with the lowest concentrations observed earlier in the growing season (June) and maximum concentrations near the end of the growing season (August and September). Large increases in TP concentrations in August and September of 2013 may be associated with lake mixing in August (as suggested by the temperature and DO data). TP at the beginning of the growing season (June) approaches concentrations of 0.01 mg/L. Maximum annual TP concentrations from 2013-2017 were between 0.08-0.1 mg/L in all years sampled. Periods of increased TP concentrations in Lake Carmel increase the likelihood of the occurrence of HABs (see **Section 9**).

Trends in total nitrogen (**Figure 9a**), based on average annual values, were not able to be calculated due to limited data availability. Previous nitrogen concentrations indicate eutrophic conditions (> 0.6 mg/L, Canfield et al. 1983). The sum of nitrate (NO_3^-) and nitrite (NO_2^-) was greater in 2013 compared to 2016 (**Figure 9b**) and average ammonia concentrations increased from 2016 (0.046 mg/L ± 0.01) to 2017 (0.11 mg/L ± 0.13).



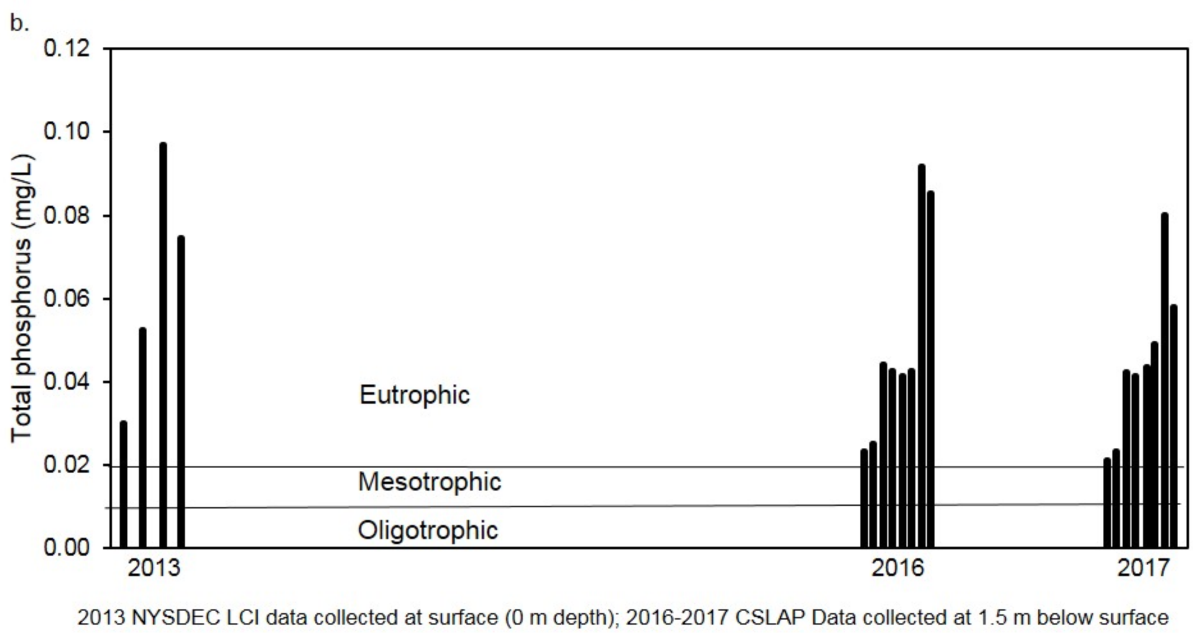


Figure 8. (a) Historic (1986-1990) and (b) recent (2013, 2016, 2017) total phosphorus (TP) concentrations (mg/L) in Lake Carmel.

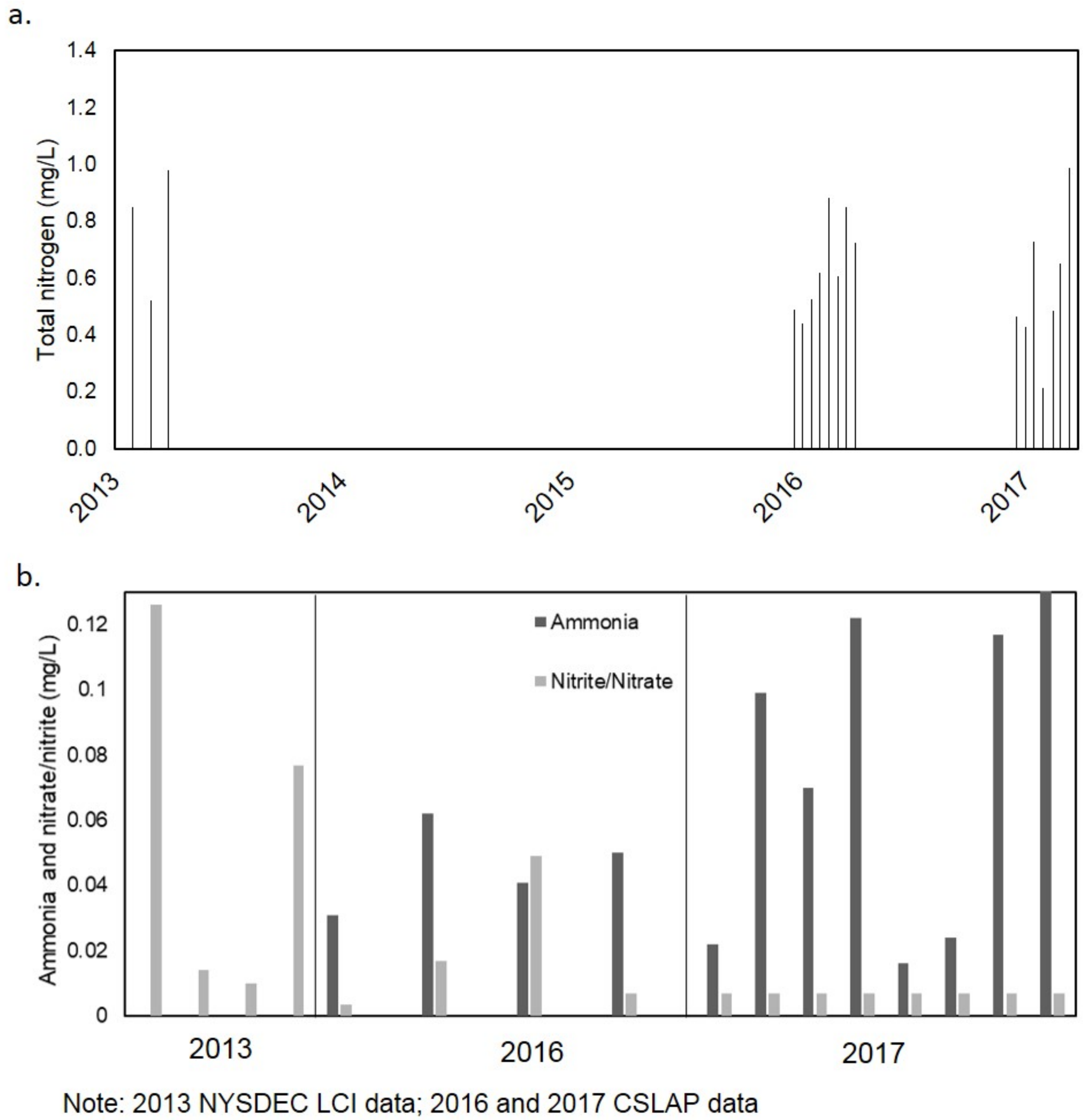


Figure 9. (a) Total nitrogen (TN) and (b) ammonia and nitrite/nitrate concentrations (mg/L) in Lake Carmel from 2013 (LCI), and 2016 to 2017 (CSLAP).

The relative concentrations of nutrients other than phosphorus may contribute to cyanobacteria growth. Ratios of total nitrogen (TN) to total phosphorus (TP) in lakes can be used as a suitable index to determine if algae growth is limited by the availability of nitrogen or phosphorus (Lv et al. 2011). Cyanobacteria blooms are typically rare in lakes where mass based TN:TP ratios are greater than 29:1 (Filstrup et al. 2016, Smith 1983). This is thought to occur because cyanobacteria can take up and use nitrogen more efficiently than algae and thus be more competitive when nitrogen becomes limiting. This ratio is higher than the ratio when nitrogen is the limiting nutrient (TN:TP <10) because phosphorus and other micronutrients are required by cyanobacteria to perform nitrogen fixation (nitrogenase, the N-fixing enzyme requires relatively high concentrations of P to operate) (Mantzouki et al. 2016). Ratios (by mass) of TN to TP in Lake Carmel from 2013 to 2017 ranged between 5 and 20 and indicate that algal biomass (including cyanobacteria) may be limited by nitrogen (TN:TP < 10) for short periods during the growing season (**Figure 10**). Cyanobacteria present during confirmed HABs blooms in 2017 after decreases in the TN:TP ratios consisted primarily of genera known to be nitrogen-fixers (see **Section 7**). However, for much of the growing season, TN to TP ratios suggest that algal productivity is predominately limited by phosphorus. Trend analyses of TN:TP ratios were not able to be calculated due to limited total nitrogen concentration data.

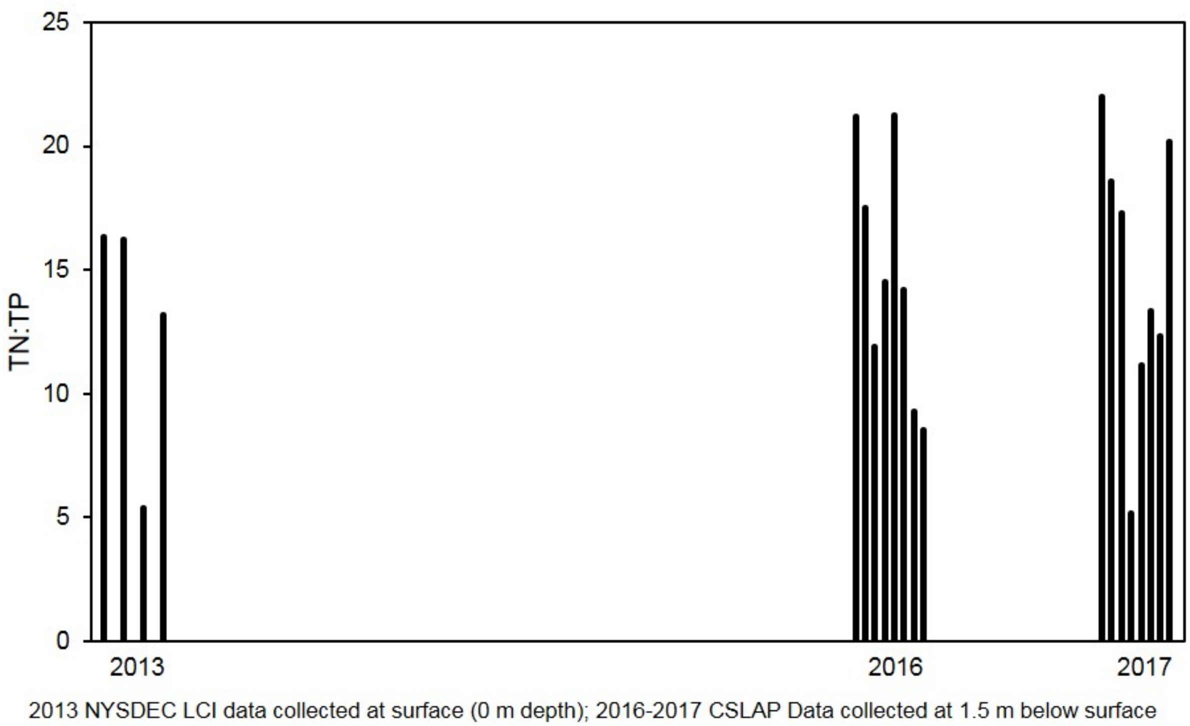


Figure 10. Ratios of total nitrogen (TN) to total phosphorus (TP), by mass, in Lake Carmel water samples from 2013 (LCI), and 2016 to 2017 (CSLAP).

6.3 Biological Conditions

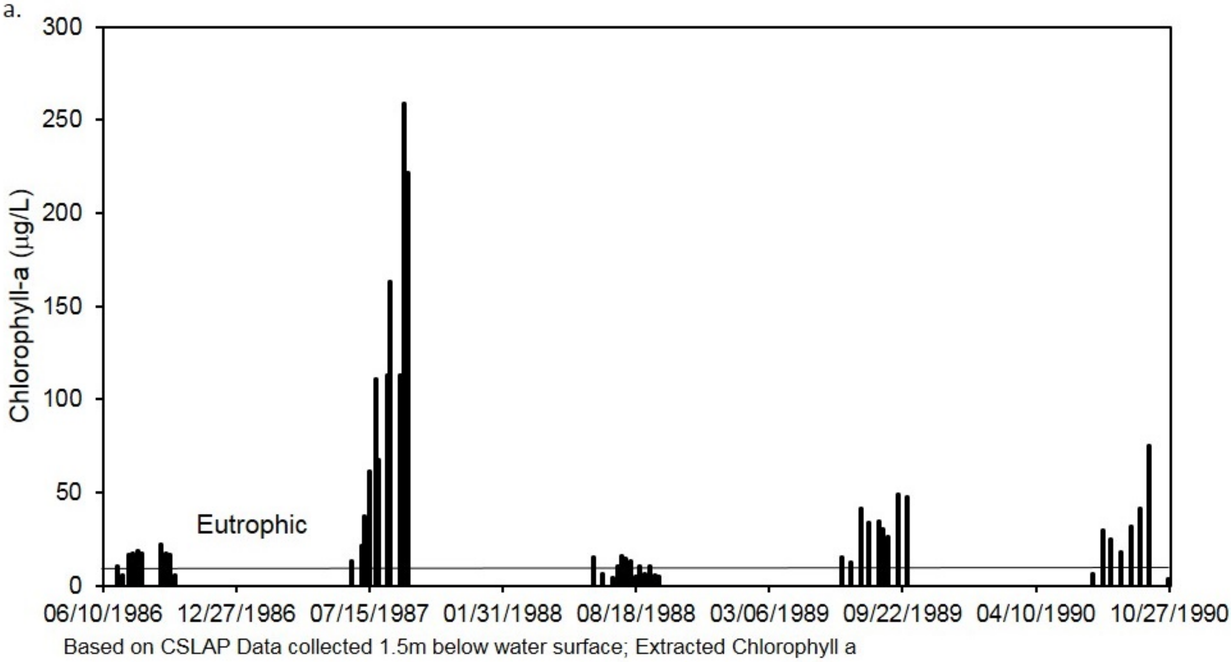
Lake Carmel's aquatic plant coverage is slightly lower than in many other lakes within the Lower Hudson River region (CSLAP 2016). A review of past assessments suggest a slight decrease in the density of aquatic plants, and Lake Carmel historically had "very dense" plant growth. Algae levels are higher in Lake Carmel than other lakes within the region (CSLAP 2016). Increased algae levels and reduced water clarity are likely causing the slight decreases in aquatic plant coverage by reducing light availability and shrinking the photosynthetic zone (the water depth at which plants can grow) in Lake Carmel.

Two aquatic invasive plants, Eurasian watermilfoil (*Myriophyllum spicatum*) and brittle naiad (*Najas minor*), have been reported in Lake Carmel. Both invasive plants are of major concern because they often grow in large dense beds and are known to outcompete and crowd out native aquatic vegetation. These dense beds are often less suitable habitat for fish and other aquatic species and can impede recreational activities such as boating, fishing and swimming. These aquatic macrophytes also act as a nutrient pump, by bringing nutrients up from the sediment and back into the water column as plant biomass during the growing season (Smith and Adams 1986). Some of these nutrients are then released into the water column during respiration and decay of plant material. While several studies from the scientific literature discuss the role of milfoil as a potential nutrient pump, lake specific conditions can alter these dynamics including, local anoxic patches, trophic state, plant density, and plant decomposition rates (Carpenter 1983, Carpenter and Lodge 1986); further research is warranted to assess the variables on Lake Carmel.

Two native plants, coontail (*Ceratophyllum demersum*) and duckweed (Lemnoideae) are considered nuisance plants in Lake Carmel. Coontail, like the invasive aquatic plants mentioned above, form dense beds that decrease plant diversity by crowding out other native plants, may limit habitat suitability for aquatic life, and can impede recreation. Duckweed can also proliferate to nuisance levels in eutrophic conditions and cause impediments to recreational activities such as swimming and fishing. Although considered a nuisance under certain environmental conditions, these native plants are more desirable than invasive aquatic plants. Duckweed, specifically, is a small floating aquatic plant and may compete with cyanobacteria for light and available nutrients.

Average summer concentrations of the photosynthetic pigment chlorophyll-a, both historically (1986-1990, **Figure 11a**) and more recently (**Figure 11b**), indicate that Lake Carmel is eutrophic (highly productive). Chlorophyll-a concentrations in Lake Carmel were observed to follow a similar seasonal pattern as phosphorus concentrations. In the early growing season (e.g., June) chlorophyll-a concentrations were lower with concentrations below 8 $\mu g/L$. Chlorophyll-a concentrations increased throughout the season, with maximum concentrations observed near August and September, potentially related to deep water phosphorus inputs from mixing events as observed in 2013. High chlorophyll-a concentrations are consistent with reports of algae levels that have been reported to impact aesthetic and recreation uses (CSLAP 2016). Trend analyses did not identify a trend in average chlorophyll-a concentrations between 1986 to 2017 ($p > 0.05$). It should be noted that algae levels are affected by the use of algaecides- the lake was treated with copper sulfate or Cutrine (a chelated copper algaecide) on several occasions in 2016 and 2017, and perhaps in other previous CSLAP sampling seasons.

a.



b.

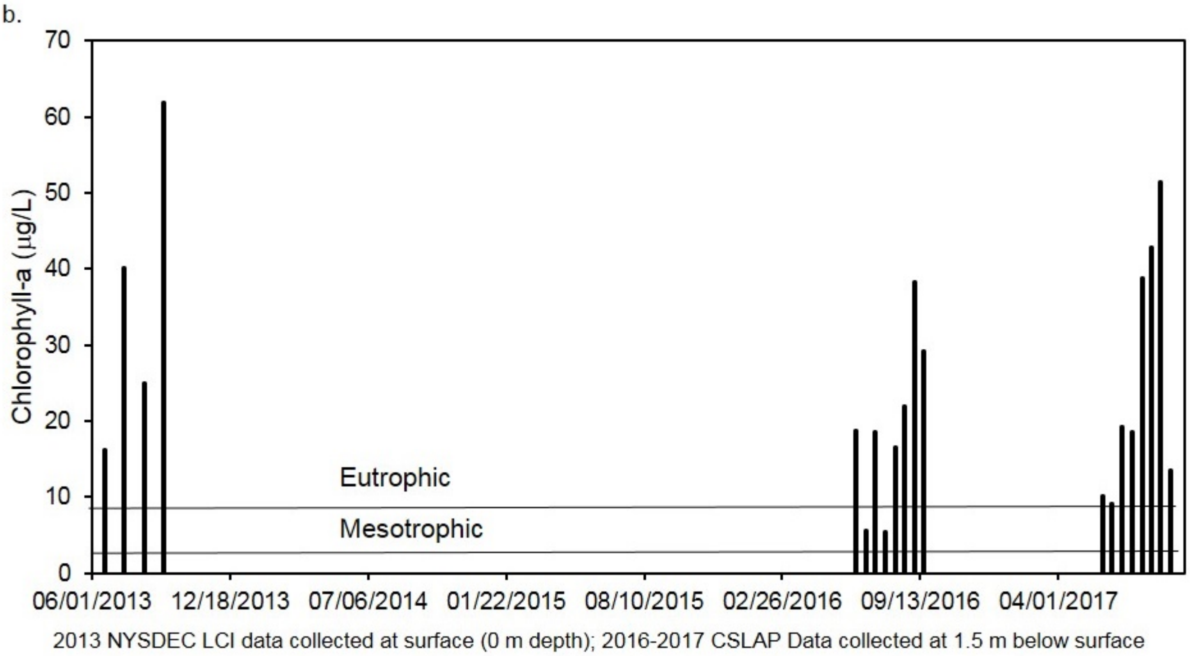


Figure 11. (a) Historic and (b) current chlorophyll-a concentrations (μg/L) in Lake Carmel.

6.4 Other Conditions

Additional aquatic invasive plants species have been found in Putnam County, including water chestnut (*Trapa natans*) and curly-leaf pondweed (*Potamogeton crispus*). Eutrophic conditions in Lake Carmel increase its vulnerability to colonization of additional invasive plants.

In 2000, an assessment of macroinvertebrates of the West Branch Croton River downstream of Lake Carmel (at Route 57) indicated non-impacted water quality conditions. The diverse macroinvertebrate fauna included several taxa such as mayflies, stoneflies, and caddisflies that are indicative of good water quality. Minor effects of nonpoint source nutrient enrichment were noted.

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

Information and data on suspected and/or confirmed occurrences of HABs in Lake Carmel were reported by several sources, including the Putnam County Department of Health, CSLAP, observations made by the general public, and “other” sources. When lake observations of potential HABs are collected, they are compiled and assigned a status, per NYSDEC’s *Harmful Algal Blooms Program Guide* (NYSDEC 2017) and as described above.

A total of 13 occurrences of HABs have been documented in Lake Carmel by the above information sources based on HABs data collected during the months of July and August in 2015, 2016, and 2017. NYSDEC also reported closure of several Lake Carmel beaches due to an abundance of cyanobacteria in 2014 (NYSDOH 2017). Of the 13 reported HABs between 2015-2017, seven (54%) were documented as “confirmed”, five (42%) were of “suspicious” status, and one was documented as “no bloom”. The spatial extents of five of the confirmed blooms were qualitatively reported by CSLAP; three of which were described as “small/localized” and two were reported as “widespread/lakewide” (**Table 3**). Of the seven confirmed HABs, three occurred in 2017 and four occurred in 2016. Suspicious status blooms were reported in all three years (2015-2017). Beaches were reported to be closed during six of the 13 reported HABs occurrences. It is likely that blooms were also present but undocumented at other times or in other locations in the lake over the last several years.

Table 3. Lake Carmel HABs history as documented by CSLAP.					
Date	**July 7, 2016**	**August 20, 2016**	**July 1, 2017**	**July 31, 2017**	**August 26, 2017**
Bloom extent	Small localized	Widespread/ lakewide	Small localized	Small localized	Widespread/ lakewide
Bloom status	Confirmed	Confirmed	Confirmed	Confirmed	Confirmed
Bloom location	Shoreline	Lakewide	Shoreline	Shoreline	Lakewide
Chl-a (µg/L, Fluoroprobe)	89.0	3705.0	5002.3	347.3	33.6
Daily avg. air temp (°C)	25	21.5	23.7	21	17.2
Water temp (°C)	Not available	28	24	23	24
Daily rainfall (mm)	7.1	0	9.2	0	0
10-day total rainfall (mm)	32.1	30.7	18.9	15.7	11.2
Max daily wind speed (m/s)	5.1	6.7	5.7	3.6	4.6
Water quality data	Not available	Available	Available	Available	Available

Table 4 presents a summary of the taxa identified during the five confirmed blooms in 2016 and 2017. Cyanobacteria are denoted in **bold** font. *Microcystis* and *Dolichospermum* were the most prevalent, dominant cyanobacteria documented in Lake Carmel (each identified as a dominant taxon during 60% of documented dates). The identification of dominant cyanobacteria (i.e., those that are most often present) in Lake Carmel can help to determine management actions that target key functional traits to limit their ability to become abundant (see **Section 13**).

Sphaerocystis, *Pediastrum*, and *Staurastrum* are green algae that may present a nuisance, but generally are not harmful. *Fragilaria* is a large genus of diatoms that typically form irregular colonies, the growth of which typically does not produce adverse effects. Dinoflagellates such as *Ceratium* may form blooms that result in oxygen-depleted conditions.

Table 4. Dominant algal taxa present during confirmed or archive bloom events in Lake Carmel, 2016 and 2017.		
Date	**HABs Status**	**Dominant Taxa**
07/07/2016	Confirmed	***Microcystis, Dolichospermum*** **(**formerly ***Anabaena), Woronichinia, Oscillatoria***
08/20/2016	Confirmed	***Aphanizomenon***, ***Microcystis,*** *Pediastrum, Fragilaria*
07/01/2017	Confirmed	Dense ***Dolichospermum,*** moderate ***Microcystis,*** Dinoflagellates
07/31/2017	Confirmed	Dense ***Woronichinia,*** moderate ***Aphanizomenon, Dolichospermum***, trace *Ceratium*
08/26/2017	Confirmed	Trace *Sphaerocystis,* Dinoflagellates, ***Dolichospermum,*** *Pediastrum,* ***Radiocystis,*** *Straurastrum*
Notes: Cyanobacteria genera are denoted in **bold font**		

Based on the limited algal composition/density analysis summarized above, cyanobacteria may have been more dominant than other algae in early-mid summer (July). In late-summer (late August), a more pronounced presence of green algae was documented.

7.2 Drinking Water and Swimming Beach HABs History

Drinking water

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

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

As discussed previously, Lake Carmel is not itself a direct source of public drinking water, but is within the watershed that supplies the New York City area with a portion of its drinking water. The NYSDOH recommends never drinking untreated surface water, bloom or no bloom. Untreated surface water might contain blue-green algae and their toxins. It can also contain other bacteria, parasites or viruses that can cause symptoms such as diarrhea, nausea and vomiting. Drinking water in the area is derived from three bedrock wells drilled at two local pump houses, and is chlorinated prior to distribution. Thus, HABs do not pose a direct threat to Lake Carmel residents through regulated drinking water sources.

Swimming

Bathing beaches are regulated by NYSDOH District Offices, County Health Departments and the New York City Department of Health and Mental Hygiene in accordance with the State Sanitary Code (SSC). The SSC contains qualitative water quality requirements for protection from HABs. NYSDOH developed an interactive intranet tool that provides guidance to County, City and State District DOH staff to standardize the process for identifying blooms, closing beaches, sampling, reopening beaches and reporting activities. The protocol uses a visual assessment to initiate beach closures as it affords a more rapid response than sampling and analysis. Beaches are reopened when a bloom dissipates (visually) and samples collected the following day confirm the bloom has dissipated and show toxin levels are below the latest guidance value for microcystins. Sample analysis is performed by local health departments, the Wadsworth Laboratory in Albany or academic institutions. **Table 5** provides a summary of the guidance criteria that the NYSDEC and NYSDOH use to advise local beach operators.

Table 5. HABs guidance criteria.			
NYSDEC Bloom Categories			
Confirmed	**Confirmed w/ high toxins**		**Suspicious**
	Open water	**Shoreline**	
[BGA chlorophyll a] >25 µg/L	[Microcystin] > 10 µg/L	[Microcystin] > 20 µg/L	Visual evidence w/out sampling results
NYSDOH Guidelines			
Closure		**Re-open**	
Visual evidence (sampling results not needed).		Bloom has dissipated (based on visual evidence); confirmatory samples 1 day after dissipation w/ microcystin < 10 µg/l or < 4 µg/l (USEPA 2016) starting in 2017.	

A historical summary of the observations and impacts of HABs on bathing beach recreational use at Lake Carmel is presented below (**Figure 12**). Bathing beaches are under the regulatory jurisdiction of the NYSDOH and directly regulated by DOH District Offices, County health departments, the New York City Department of Health and Mental Hygiene, and the New York State Office of Parks, Recreation and Historic Preservation. These agencies report information on HAB related beach closures to NYSDOH. This policy was established in 2011 and the enhancements have been made to the information to better assess the impact of HABs at public beaches.

- August 2014 – Beaches #3 and #7 were closed in mid- to late-August

- 2015 – four designated swimming beaches (#2, #3, #4, and #7) were closed in mid-July resulting from observations of suspected blooms lakewide.
- August 2016 - All four designated swimming beaches were closed resulting from observations of suspected blooms at Beaches #2 and #7.
- 2017 - Beaches #2, #4, and #7 were “self-closed” due to a suspicious bloom appearing to be cyanobacteria in July. Beach #3 reportedly remained open as the bloom did not impact this area. However, Beach #3 was closed for 20 days in August 2017.

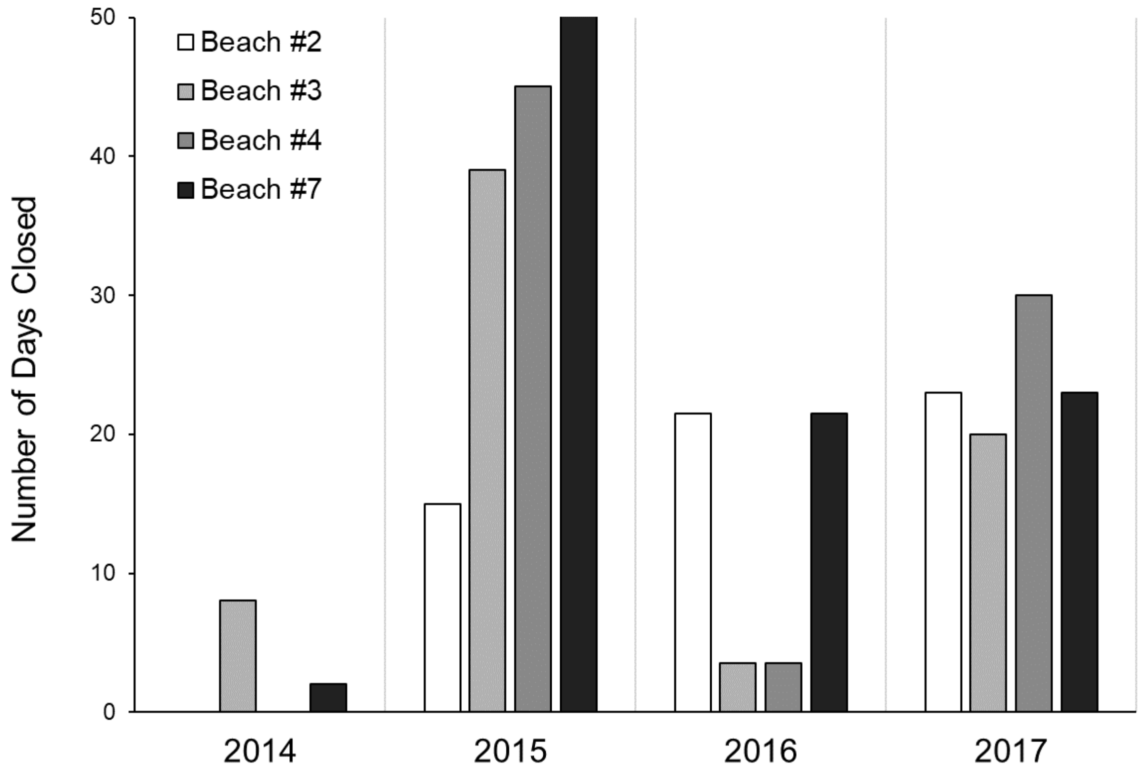


Figure 12. Number of days of beach closures on Lake Carmel due to the presence of HABs, 2014 to 2017 (NYSDOH).

7.3 Other Bloom Documentation

Cyanobacteria Chlorophyll-a

Cyanobacteria cell counts and/or BGA chlorophyll-a concentrations can be used to trigger HABs alert and advisory systems. BGA chlorophyll-a concentrations were quantified with a Fluoroprobe (bbe Moldaenke) during the five confirmed blooms. Confirmed bloom BGA concentrations ranged from 30.6 µg/L to 5,002 µg/L. Note that BGA chlorophyll-a was 0.16 µg/L during the no bloom sample (collected from an open, mid-lake location). As noted earlier, cyanobacteria levels in the lake have also been artificially altered by the use of copper-based algaecides, applied to the lake on multiple occasions in 2016 and 2017, and perhaps in other previous years.

Cyanotoxins

Some cyanobacteria taxa also produce toxins (cyanotoxins) that are harmful to people and pets. As a result, several different toxins are monitored during blooms. Microcystin is the most commonly detected cyanotoxin in New York State (NYSDEC 2017). The 20 µg/L microcystin "high toxin" threshold for shoreline blooms was, like the BGA chlorophyll-a standard, established based on WHO criteria. For four of the five confirmed blooms, microcystin was not detected by laboratory analysis. During the July 2017 shoreline HAB sample when BGA chlorophyll-a was at its highest concentration (5,002 µg/L), microcystin was detected at a concentration of 0.36 µg/L, substantially below the DEC 20 µg/L high toxin threshold. This detectable microcystin concentration also does not exceed USEPA's 2016 draft human health recreational swimming advisory threshold of 4 µg/L (USEPA 2016). Sample results below this threshold value are consistent with what is currently prescribed by NYSDOH guidance to allow a regulated bathing beach to reopen. The NYSDEC and NYSDOH believe that all cyanobacteria blooms should be avoided, even if measured microcystin levels are less than the recommended threshold level. Other toxins may be present, and illness is possible even in the absence of toxins.

7.4 Use Impacts

Swimming use in Lake Carmel was determined to be impaired in 2016 due to the presence of algal blooms, as described in the CSLAP report. Recreational use was classified as impaired in 2016 due to water quality conditions described as "high algae levels". As a result of blooms and excessive algae, temporary closures of bathing beaches at the lake were enacted each year between 2014 and 2017. Algal blooms are also identified as the primary factor for the "stressed/poor" classification assigned to the aesthetics use.

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 DEC 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 Carmel reflects monitoring data collected from 2016 through 2017. Lake Carmel is required to support primary and secondary contact recreation uses and fishing uses.

Lake Carmel is assessed as an impaired waterbody due to primary and secondary contact recreation uses that are impaired due to excessive nutrients (phosphorus) and algae, and poor water clarity. These uses are also impaired due to public beach closures for swimming as a result of the occurrence of harmful algal blooms.

The Total Maximum Daily Load (TMDL) characterizes all sources of phosphorus to the lake. The primary sources of phosphorus are internal loading, failing septic systems, and streambank erosion.

Lake Carmel is included on the NYS Section 303(d) List of Impaired Water Requiring a TDML for phosphorus. The TMDL for phosphorus was approved by USEPA in 2016 and will be categorized as an IR Category 4a waterbody – TMDL completed – on the 2018 Section 303(d) List.

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 is not available for Lake Carmel since it is not a source of drinking water.

8.3 CSLAP Scorecard

Results from CSLAP activities are forwarded to the New York State Federation of Lake Associations (NYSFOLA) and NYSDEC and are combined into a scorecard detailing potential lake use impact levels and stresses. The scorecards represent a preliminary assessment of one source of data, in this case CSLAP. The WI/PWL updates include the evaluation of multiple data sources, including the CSLAP scorecard preliminary evaluations. The scorecard for Lake Carmel suggests that 2017 swimming and recreation are impacted, aesthetic conditions are stressed/poor and habitat is threatened/fair (**Figure 13**). Algal blooms are the primary issue associated with swimming, recreation, and aesthetics in the lake. Habitat is primarily impacted by invasive plants.

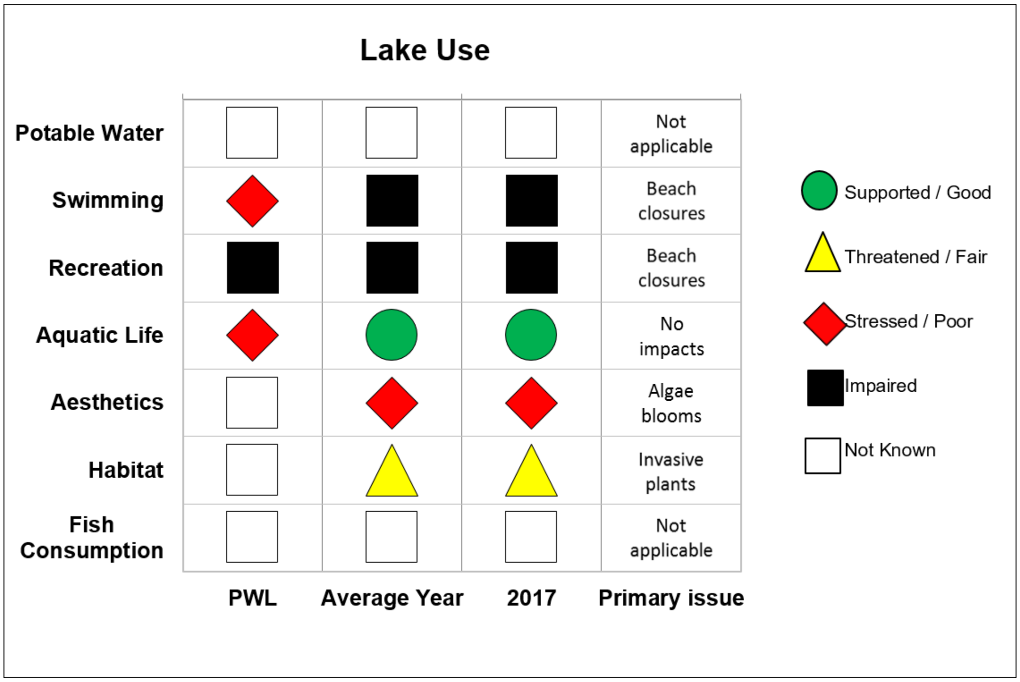


Figure 13. Lake Carmel 2017 CSLAP scorecard.

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.

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 (e.g., dreissenid mussels). This data set has been analyzed systematically, using a statistical approach known as logistic regression, to identify the minimum number of factors that best explain the occurrences of HABs in NYS. A minimum number of factors are evaluated to provide the simplest possible explanation of HABs occurrences (presence or absence) and to provide a basis for potential targets for management. One potential challenge to note with this data set is that lakes may have unequal effort regarding HABs observations which could confound understanding of underlying processes of HABs evaluated by the data analysis.

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

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

The annual frequency of HABs on Lake Carmel is higher than what is expected from other lakes in the Hudson Valley region considering total phosphorus and its absence of dreissenid mussels, and despite the persistent use of copper-based algaecides. However, it may be that Lake Carmel is relatively susceptible to HABs because of its large contributing watershed relative to its surface area, and potentially, greater predominance of soluble phosphorus due to the prevalence of septic inputs described in **Section 10**. As additional data become available for Lake Carmel, statistical analysis may be performed to better identify possible triggers of HABs on this lake.

9.1 Pollutant Assessment

A TMDL for phosphorus was developed by NYSDEC in July 2016 to address the impairment of recreational uses (including swimming) in Lake Carmel due to algal and aquatic plant growth stemming from excessive nutrient concentrations, specifically phosphorus. In 2004, Lake Carmel was added to the NYSDEC's 303(d) list of impaired waterbodies based on phosphorus concentrations repeatedly exceeding New York's water quality guidance value for phosphorus.

As described in **Section** 9, excessive inputs of phosphorus and nitrogen may result in the formation of HABs during periods when environmental conditions such as elevated water temperature and still winds predominate. Several potential sources of phosphorus are contributing to the reduced water quality in Lake Carmel, including stormwater runoff, streambank erosion across, lakefront and near-lake residential septic systems, and internal loading from sediments. These and other external nutrient sources are described in more detail in **Sections 10.2** and **12.5**. Nutrients enter the lake directly from the surrounding watershed via its two tributaries, overland flow, and groundwater seepage, where they can be used by cyanobacteria and aquatic plants, or be deposited and stored in lakebed sediments.

Total phosphorus concentrations in LCI and CSLAP lake water samples collected between June and September in 2013, 2016, and 2017 ranged from 0.02 to 0.1 mg/L, all of which either met or exceeded the New York State epilimnetic[1] summer average

[1] Refers to the layer of water between the water surface and the thermocline. The epilimnion is typically characterized by warm uniform temperature waters. The thermocline is the thin zone of water where temperature decreases rapidly with increasing depth.

guidance value of 0.02 mg/L and indicative of re-occurring eutrophic (nutrient-rich) conditions. The average TP concentration based on available data is 0.04 mg/L, more than twice the NYSDEC summer average guidance value. Time-series plots of TP both historically (1986-1990) and in recent years (2013-2017) depict eutrophic conditions in the lake during the summer and early fall seasons.

According to CSLAP data, confirmed blooms only occurred in Lake Carmel at TP concentrations greater than 0.04 mg/L (**Figure 8**). No clear relationship between TN and the occurrence of algae blooms was observed (**Figure 9**). These results, albeit based on a limited data set (years 2016 and 2017), suggest that the occurrence of HABs in Lake Carmel is phosphorus-driven, with potential contributing influences by physical factors such as water temperature and quiescent conditions, discussed below.

9.2 Other Contributing Factors

In addition to phosphorus, other potential contributing influences may facilitate the formation of HABs or exacerbate the range and/or intensity of HABs. One physical parameter that often strongly aligns with HABs is elevated water temperature. Other factors include poor water circulation, low dissolved oxygen concentrations, strong rainfall events, reduced/minimal wind intensity and duration, and low zooplankton abundance.

As expected, the presence of cyanobacteria blooms coincides with the warmer months of the year, specifically between July 1 and August 30. Accordingly, confirmed HABs occurred on Lake Carmel during periods of warmer temperatures of at least 23°C or higher. As discussed in **Section 6.2**, the water column features dissolved oxygen depletion with hypoxic/anoxic conditions at a depth of approximately 2 m. The hypoxic (oxygen-depleted) dissolved conditions in the lake in July 2013 coincided with highly elevated water temperatures (>28°C) (**Figure 6**). The dissolved oxygen depletion and hypoxic conditions in deeper water provide suitable conditions for the liberation of legacy phosphorus from lakebed sediments. The soluble phosphorus yielded under such conditions is readily available to cyanobacteria.

10. Sources of Pollutants triggering HABs

10.1 Land Uses

The Lake Carmel watershed is composed of the following land use types (**Figure 14**), with developed land highly concentrated around the perimeter of Lake Carmel (**Figure 15a**):

- Developed land = 22%
- Forest = 65%
- Agricultural = 3%
- Open Water = 7%
- Wetlands = 3%

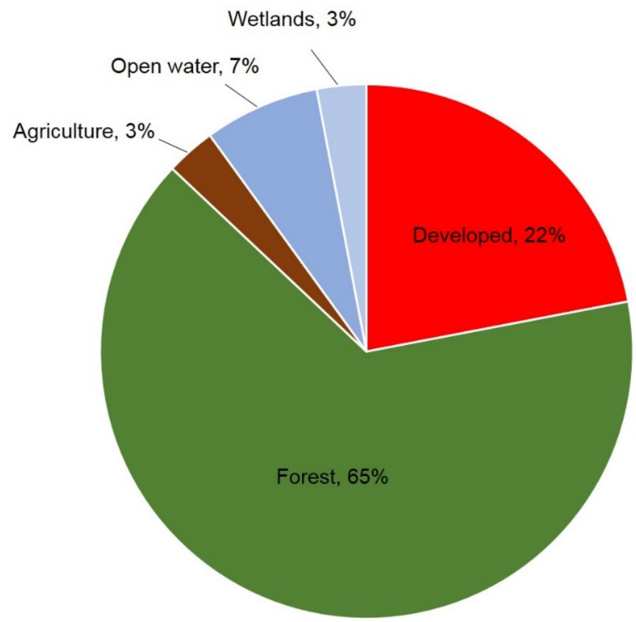


Figure 14. Land uses and percentages in the Lake Carmel watershed.

The most dominant land use within the watershed is forest, consisting of wooded, shrub, and grass land. Developed land was the second dominant land use in the watershed, which is considered intensely developed. The primary development associated with the watershed are small residential parcels that are served by private septic systems (NYSDEC 2016). The highest density of developed land and septic systems are located immediately surrounding the lake (**Figure 15**).

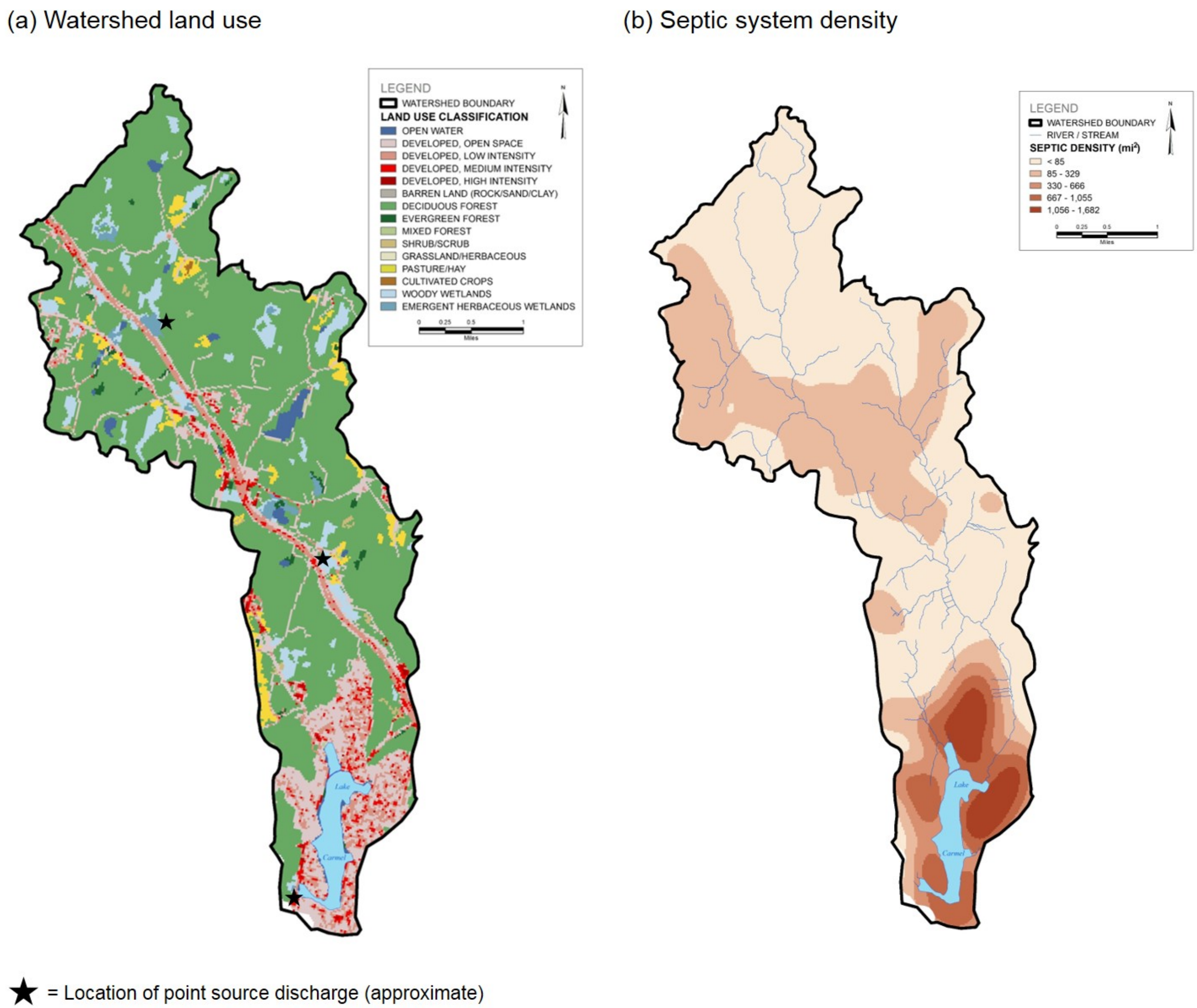


Figure 15. (a) Watershed land use and (b) septic system density for Lake Carmel.

10.2 External Pollutant Loadings

The MapShed watershed model was used during the 2016 TMDL assessment to estimate long term (1986-2013) mean annual phosphorus loading for the growing season of Lake Carmel and estimates the contribution of available external sources of phosphorus. The MapShed watershed model uses local weather and land cover data as well as curve number from U.S. Soil Conservation Service hydrologic studies, soil types from the Natural Resource Conservation Service and estimated septic failure rate derived from the 2010 U.S. census and real parcel data to determine mean annual phosphorus loading. Although sufficient data were available to develop the MapShed watershed model, water quality variability was higher for observed data than the model predicts. External phosphorus loading to Lake Carmel was composed of the following estimated sources:

- Developed land = 4%
- Septic systems = 23%
- Forest = 4%
- Streambank = 33%
- Groundwater = 15%
- Wastewater treatment facilities = 3%

Mean growing season phosphorus load was estimated to be 2,711 lbs. The primary sources of phosphorus were attributed to streambank erosion (886 lbs/yr) and septic systems (614 lbs/yr) (NYSDEC 2016). Although septic systems were not the dominant source of phosphorus loading, the impacts can be much greater due to the phosphorus being in a soluble form. In comparison to its particulate form, which is often dominant in streambank erosion, soluble phosphorus is immediately available for use by plants and algae. The faster uptake of soluble phosphorus from septic systems by plants and algae results in a significantly greater fertilization effect compared to an equal amount of particulate phosphorus often associated with streambank erosion. High phosphorus loading associated with septic systems results from aging septic systems and the proximity of residential properties to Lake Carmel (**Figure 15b**). Groundwater tables close to waterbodies are typically too shallow to allow for the effective function of septic systems.

Streambank erosion is an important source of phosphorus and sediment to Lake Carmel. The MapShed watershed model uses an average watershed specific lateral erosion rate calculated using regional specific estimates of watershed slope, soil type and land use. Streambank erosion is then calculated by multiplying the lateral erosion rate by stream length, stream bank height, and bulk soil density (NYSDEC 2016). Lake bank erosion is not considered in the TMDL analyses and is likely a minimal loading source to Lake Carmel.

Groundwater seepage (404 lbs/yr) was also estimated to be a dominant source of phosphorus loading to Lake Carmel. Model-estimated groundwater phosphorus concentration was 0.01 mg/L and is estimated to be made of 60% natural phosphorus from forest land use and 40% phosphorus from developed areas (NYSDEC 2016).

Within the Lake Carmel watershed, there are three wastewater treatment facilities (WWTFs) that have a combined design flow of 26,260 gallons per day. These three WWTFs were not a primary source of phosphorus and contribute 70 lbs/yr of phosphorus (NYSDEC 2016).

The loading percentages are based upon data collected as part of the TMDL analysis, but does not take into consideration existing BMPs and other nutrient reduction measures implemented by the agricultural community and other potential contributors of nutrients to the lake. Consequently, the land use percentages and loading estimates presented above for Lake Carmel should be interpreted with caution.

10.3 Internal Pollutant Loadings

Internal loading of phosphorus in Lake Carmel was estimated using the BATHTUB lake model to be 511 lbs/yr, approximately 19% of the TP loading to the lake. Excessive algal growth contributes to periods of low dissolved oxygen concentrations in the bottom layers of the lake and the large internal loading of Lake Carmel. Low dissolved oxygen concentrations or anoxic conditions, such as those observed in July 2013 at a depth of 2 meters, favor releases of soluble phosphorus from sediments (NYSDEC 2016).

Lake Carmel was also noted as being a source of nutrient loading to downstream reservoirs in the Middle Branch Croton River. Although median TP concentrations recorded at a NYCDEP monitoring station on the Middle Branch Croton River (lower section) were below the USEPA recommended criterion of 0.05 mg/L (for streams entering lakes), concentrations were found to be higher in the river downstream of Lake Carmel than in the river upstream of the lake indicating that Lake Carmel is a source of TP to the Middle Branch Croton River. Middle Branch Reservoir concentrations of TP have been reported by the NYCDEP to routinely exceed 0.02 mg/L (NYSDEC 2008). This agency maintains water quality sampling stations throughout the Croton System of New York City water supply reservoirs, in which the Middle Branch Croton River is a tributary.

10.4 Summary of Priority Land Uses and Land Areas

As discussed in **Sections 10.2** and **10.3**, external loadings from streambank erosion (33%) and septic systems (23%), and internal loading from sediment contributions (19%) are estimated to be the leading contributors of phosphorus to the system.

11. Lake Management / Water Quality Goals

A primary lake management/water quality goal for Lake Carmel is to achieve and maintain the summer average total phosphorus concentration below 0.02 mg/L (20 μg/L), consistent with New York State guidelines for maintaining aesthetic quality.

However, even lower phosphorus concentrations may be required to safeguard from potential events stemming from acute loadings of phosphorus (e.g., runoff events) and from the potential exacerbating effects from other contributory sources of HABs (e.g., elevated water temperatures). The statewide dataset of HABs discussed in **Section 9** includes many examples of waterbodies with total phosphorus levels < 0.01 mg/L that still had HABs.

The Lake Carmel TMDL reports that a 59% reduction in phosphorus loads from all sources is required to meet the TMDL target of 0.02 mg/L. Streambank (recommended 46% reduction) and developed land (recommended 10% reduction) phosphorus loads (and acute loading events associated with runoff events) should be minimized to the extent practicable through the application of streambank, floodplain, and wetland restoration techniques at strategic watershed locations. The TMDL also recommends a 100% reduction of internal and septic system phosphorus loading.

12. Summary of Management Actions to Date

12.1 Local Management Actions

Algaecide treatment of Lake Carmel had been conducted since 2015 in an effort to reduce the amount of algae in the lake (CSLAP 2016; Town of Kent 2017). Cutrine Ultra was used in response to confirmed blooms in 2016 and 2017. Applications were conducted on 7/21 and 8/20 in 2016 and on 7/5 and 8/2 in 2017. Permits to use copper sulfide (2015 and 2016) and Cutrine Ultra (2016 and 2017) in Lake Carmel have been given under the name Lake Carmel. After a review of CSLAP water clarity and beach closure data, the effectiveness of the treatments was considered to be relatively short. Only one treatment (7/21/2016) showed a decline in chlorophyll-a, an indicator of algae biomass, post application. Algaecide treatment in Lake Carmel are likely ineffective for long term control of HABs because of the short (0.1 years) hydrological residence time and large watershed to lake area ratio (44:1). Meteorological data indicated rain events occurred 2 to 5 days after each treatment. Although the rain events were not substantial (0.7 to 1.3 inches), the events may have been enough to flush out the system due to the lakes relatively large watershed.

The 2016 TMDL for Lake Carmel (discussed in detail in **Section 12.5** below) presents a number of recommended management actions for control of phosphorus inputs to the lake. Effective implementation of these management actions for reducing phosphorus loading and, accordingly, the potential for HABs, requires broad participation of both lake watershed residents and local governments, preferably in collaboration. Citizen involvement is key to implementing effective management actions, and can range from traditional conservation practices for mitigating erosion and stormwater runoff to more comprehensive programs that focus on water storage enhancements and/or increased control of point source discharges.

The Town of Kent has installed stormwater filtration systems designed to trap sediment prior to its discharge to the lake. Some Croton watershed towns, including the Town of Kent, have installed stormwater retrofits designed to intercept sediment from reaching the lake, resulting in reduced sedimentation and phosphorus loading. Town of Kent ordinances are in place governing sewage disposal systems, on-site sanitary systems, stormwater management, and wetlands protection, all of which are designed to promote enhanced water quality in the lake and its tributaries (Town of Kent 2018c). Collectively, these efforts are expected to result in a lower probability of HABs occurrences. In addition, several storm water retention pond have been built around Lake Carmel to reduce sediment loading during storm events (Town of Kent 2018a).

12.2 Funded Projects

Limited information exists on projects funded to improve water quality in Lake Carmel or its watershed (see **Section 5** an overview of previous monitoring actions).

The State's Agricultural Environmental Management (AEM) and Agricultural Nonpoint Source Abatement and Control (ANSACP) programs provides resources for the planning and implementation of best management practices on farms to protect water quality. There are twenty-three farms in Putnam County that have implemented nearly forty types of best management practice associated with agricultural operations, however, none of these farms are within the boundaries of the Lake Carmel watershed.

12.3 DEC 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 through the issuing of permits for discharges to waterbodies.

NYSDEC provides on-line information for the SPDES Permit Program for all nine regions in the state. Based on the SPDES Individual Permit records available for Putnam County, NYSDEC has issued a total of 22 SPDES Individual Permits within the Town of Kent. Of the 22 permits, three are available for viewing, none of which were determined to be associated with direct discharges of waters or materials to Lake Carmel (NYSDEC 2018).

NYSDEC also issues Multi-Sector General Permits (MSGPs) under the SPDES Program for stormwater discharges related to certain industrial activities. MSGPs have been issued for 12 active facilities in Putnam County (NYSDEC 2018). None of these facilities are within the Town of Kent, and therefore are not likely to strongly influence water quality conditions in Lake Carmel. It should be noted however that, in addition to Kent, the towns of Patterson, East Fishkill, Pawling, and Beekman fall within the Lake Carmel watershed, and each of these towns contain municipal separate stormwater systems (MS4s) that potentially contribute phosphorus to Lake Carmel through collection and subsequent contribution of stormwater from roadways and other impervious surfaces that discharge to tributaries and then to the lake.

Permits to use copper sulfide (2015 and 2016) and Cutrine Ultra (2016 and 2017) were issued to the name “Lake Carmel” for use to control algae blooms in Lake Carmel. Algaecide treatment fall under the aquatic pesticide permits under Article 15, “Protection of Waters Program” of New York’s ECL and Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York (NYCRR).

For more information about NYSDEC’s SPDES program and to view Individual SPDES permits visit http://www.dec.ny.gov/permits/6054.html.

12.4 Research Activities

No information exists on current research activities that focus on water quality conditions in Lake Carmel.

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

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

- A TMDL calculates the maximum amount of a single pollutant that a waterbody can receive and still meet water quality standards. TMDLs are developed by determining the amount that each source of a pollutant can discharge into the waterbody and the reductions from those sources needed to meet water quality standards. A TMDL is initiated by NYSDEC for waterbodies that are on the 303d impaired waters list with a known pollutant.

- 9E Watershed Plans are consistent with the USEPA's framework to develop watershed-based plans. USEPA's framework consists of nine key elements that are intended to identify the contributing causes and sources of nonpoint source pollution, involve key stakeholders in the planning process, and identify restoration and protection strategies that will address the water quality concerns. The nine minimum elements to be included in these plans include:

  A. Identify and quantify sources of pollution in watershed.
  B. Identify water quality target or goal and pollutant reductions needed to achieve goal.
  C. Identify the best management practices (BMPs) that will help to achieve reductions needed to meet water quality goal/target.
  D. Describe the financial and technical assistance needed to implement BMPs identified in Element C.
  E. Describe the outreach to stakeholders and how their input was incorporated and the role of stakeholders to implement the plan.

F. Estimate a schedule to implement BMPs identified in plan.
G. Describe the milestones and estimated time frames for the implementation of BMPs.
H. Identify the criteria that will be used to assess water quality improvement as the plan is implemented.
I. Describe the monitoring plan that will collect water quality data need to measure water quality improvement (criteria identified in Element H).

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

Section 303(d) of the Federal Clean Water Act required that USEPA and the states develop total maximum daily loads (TMDLs) for the pollutants violating applicable water quality standards/criteria and for which are responsible for impairment of the water body and its capacity to meet its designated uses. As discussed in **Section 8.1**, Lake Carmel was listed on the Lower Hudson River Basin WI/PWL based on impairment to water quality that adversely impacted the recreational and aesthetic lake uses. In 2004, NYSDEC added Lake Carmel to the Section 303(d) list of impaired waters based on impairment to recreation stemming from high phosphorus concentrations and associated excessive algal/weed growth (NYSDEC 2016).

In July 2016, NYSDEC issued a TMDL for Lake Carmel to address the recreational use impairment attributable to phosphorus-induced eutrophication. As discussed in **Section 9.1**, NYSDEC's summer average guidance value for surface (i.e., epilimnetic) waters in ponds, lakes, and reservoirs is 0.02 mg/L. This guidance value was applied as the TMDL target for Lake Carmel.

As described in **Sections 10.2** and **10.3**, the quantitative models MapShed and BATHTUB were used to estimate external and internal phosphorus contributions to Lake Carmel and subsequently support development of the TMDL. The MapShed model estimated mean annual and seasonal phosphorus loadings to the lake for the years 1990 through 2013. The BATHTUB model was used to define the proportion of the phosphorus load to be reduced in order to meet the 0.02 mg/L water quality target, permitting informed decisions to be made regarding the extent of management strategies and measures to mitigate phosphorus loading to the lake.

Per **Section 10.2**, TMDL modeling indicated that the principal sources of phosphorus loading to the lake watershed were streambank erosion-induced sedimentation, lakeside residential septic systems, and stormwater runoff.

13. Proposed Harmful Algal Blooms (HABs) Actions

13.1 Overarching Considerations

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

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

13.1.1 Phosphorus Forms

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

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

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

13.1.2 Climate Change

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

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

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

For more information about climate change visit 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 reducing HABs in Lake Carmel.

Steering committee members:

- Kathleen Weathers, Cary Institute of Ecosystem Studies
- Tanya Clark, Dutchess County Department of Health
- Brian Scoralick, Dutchess County Soil and Water Conservation District (SWCD)
- Erin Sommerville, Dutchess County SWCD

- Patricia Madigan, Lake Carmel Park District
- Lori Emery, NYCDEP
- Jennifer Clifford, NYSDAM
- Shohreh Karimipour, NYSDEC
- Bob Capowski, NYSDEC
- Tom Snow, NYSDEC
- Lauri Taylor, Putnam County SWCD
- William Wegner, Riverkeeper
- Rick Croniser, Town of East Fishkill
- Bruce Barber, Town of Kent
- Maureen Fleming, Town of Kent
- Paul Heisig, United States Geological Survey (USGS)
- Gibson Dunford, Watershed Agricultural Council (East of Hudson)

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

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

As described throughout this HABs Action Plan, the primary factors that contribute to HABs in Carmel Lake include:

- Phosphorus inputs associated with septic system discharge.
- Internal loading of legacy phosphorus from in-lake sediments.
- Nonpoint source nutrient inputs from the contributing watershed.

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

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

Funding Programs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13.3 Lake Carmel Priority Projects

13.3.1 Priority 1 Projects

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

Short-term (3 years)

1. Stabilize and reinforce the banks of the Middle Branch of the Croton River and Stump Pond Stream, by local SWCDs and other partners, through one or more of the following techniques. A landscape analysis to identify priority locations needs to be completed prior to implementation.
    a. Implement streambank armoring with wood or stone revetment.
    b. Implement live staking and other soil bioengineering techniques.
    c. Install streambed stabilization structures such as rock or log vanes.
2. Purchase a street sweeping vacuum truck to prevent sediment and organic debris from entering storm drains, ditches, tributaries, and Lake Carmel. A joint application request by multiple municipalities is recommended so equipment can be used through a shared services agreement.

Mid-term (3 to 5 years)

1. Construct a wastewater treatment plant (WWTP) and install infrastructure required to connect to 2,500 houses within the watershed, thereby removing 500,000 gallons/day of sanitary effluent from Lake Carmel.
    a. Prior to implementation, the following will need to be completed:
        i. Prepare an Engineering Report (expected in June 2018).
        ii. Receive project approval from the Town of Kent and/or approval of a referendum for long-term funding.
        iii. Apply for and receive regulatory approvals from the NYCDEP, NYSDEC, and other agencies.

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. Create riparian buffers along streams to inhibit or restrict nutrient-enriched stormwater runoff and eroded soil from reaching the stream through implementation of one or more of the following. A landscape analysis to identify priority locations, as identified by local SWCDs and municipalities or other relevant stakeholders, needs to be completed prior to implementation.
    a. Establish conservation easements.

b. Establish vegetated riparian buffers to inhibit or restrict nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams.

c. Rehabilitate degraded buffers to improve riparian habitat function.

Mid-term (3 to 5 years)

1. Stabilize the Lake Carmel shoreline through one or more of the following techniques to reduce shoreline erosion in problematic areas, as identified by local SWCDs and other relevant stakeholders:

    a. Implement live staking and other soil bioengineering techniques.

    b. Rehabilitate degraded buffers to improve riparian habitat function.

    c. Install wood and rock facilities (e.g., crib walls, revetments).

Long-term (5 to 10 years)

1. Implement multiple stormwater BMPs to reduce sediment loading into Lake Carmel.

    a. Acquire land and/or establish conservation easements on lands within the watershed.

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

    c. Implement roadside ditch improvement projects that are likely to contribute the greatest reduction in erosion. Best management practices could include:

        i. Timing of cleanout to minimize vegetative loss.

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

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

    d. Install stormwater management basins or wetlands, or enhance existing wetlands at Lake inlets or along the tributaries, if streams within the Lake Carmel watershed are contributing to high nutrient loads.

    e. Install infrastructure retrofits to replace existing stormwater management facilities that were installed prior to the promulgation of Article 17, Titles 7 and8, and Article 70 of the New York State Environmental Conservation Law. Approaches may include green roofs, permeable pavement, rain gardens, vegetated riparian buffers, sediment traps, water and sediment control basins (WASCoBs), and urban treescapes in developed areas.

13.3.3 Priority 3 Projects

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

Long-term (5 to 10 years)

1. Implement an educational outreach program to inform landowners of stewardship actions that could improve Lake quality. Topics could include how the use of fertilizers and the discharge from septic systems influences water quality. Demonstration projects should be completed to illustrate actions that homeowners can duplicate on their property (e.g. raingardens).

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. Review phosphorus discharge concentration limits for the Putnam Nursing and Rehabilitation and Girl Scouts of Hudson WWTP.
2. Mandate strict adherence to the requirements of MS4 permit requirements by the five towns within the lake. Requirements for the towns include a 10% reduction in phosphorus loading in MS4 developed land (NYSDEC). Management actions to comply with MS4 requirements include public education to promote sensible lawn care, cleanup of pet waste, and limiting large flocks of waterfowl that could contribute nutrients to watershed lakes and streams.
3. Implement stormwater control measures during construction projects that are consistent with the stormwater management procedures and erosion control measures that the Town of Kent has incorporated into its by-laws.
4. Evaluate locations where animal wastes are concentrated (e.g., pet stores and animal care/boarding facilities) for illicit connections and exposure to stormwater, and provide them with tailored education and outreach materials.
5. Evaluate locations where yard or food wastes are stored (e.g., “dumpsters” serving restaurants and grocery stores, yard waste composting and disposal areas) for illicit connections and exposure to stormwater and provide them with tailored education and outreach materials.

13.5 In-Lake Management Actions

In-lake management actions can be used to minimize the recycling of phosphorus from within the lake, minimizing concentrations that are likely leading to HABs. However, reductions in external loading should be prioritized to reduce the amount of phosphorus actually entering the lake. While not an action to reduce phosphorus release, continued, controlled use of an algaecide to reduce HABs could be continued until these other actions become more effective.

13.6 Monitoring Actions

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

Short-term

1. Continue annual CSLAP sampling in order to evaluate long-term trends in nutrient loading and occurrences of HABs. In addition, collect seasonal temperature and dissolved oxygen profiles to further understanding of mixing dynamics and to refine estimates of internal loading in Lake Carmel.
2. Analyze deep water (i.e., > 2 m water depth) quality samples for soluble forms of phosphorus to better understand how much soluble phosphorus is available to algae for growth, relative to total phosphorus concentrations.
3. Continue to collect toxin concentration data during HAB events, particularly when large or lakewide blooms occur. This information will be critical to protect public health, issue advisories, and in conjunction with water quality measurements, provide insight into conditions that lead to blooms with undesirable toxin concentrations. Note that toxin analysis should be accompanied by continued surveillance, documentation, and reporting of the blooms themselves, either through CSLAP or through an independent system within the lake community that looks for and reports blooms to a local outreach coordinator.
4. Collect data regarding the taxa of cyanobacteria and toxin concentrations within Lake Carmel during early summer months (i.e., prior to bloom season) to better understand the lake dynamics.

13.7 Research Actions

To help minimize the stresses that lead to the potential formation of HABs in Lake Carmel, the following research actions may be considered:

Short-term

1. Evaluate the following strategies regarding their effectiveness in reducing internal phosphorus loading:
    a. Removing the legacy phosphorus from the system
    b. Binding the phosphorus in place (e.g., P inactivation)
    c. Capping the phosphorus-rich sediments in place

    d. Use of aeration/oxygenation during periods of low oxygen to reduce phosphorus release from the sediments in deeper portions of the lake where redox-driven nutrient release may be occurring.

2. Evaluate the impact of traditional copper algaecides on:

    a. toxin liberation, thereby subjecting recreational users to toxins after treatments outside of bathing beaches

    b. zooplankton populations

    c. other lake biota

3. Evaluate the use of alternatives to copper-based algaecides, including hydrogen peroxide and ultrasonic devices. If these alternatives are determined to be viable, conduct a demonstration project that evaluates reductions in HABs and any ecological changes in the lake in demonstration project sites.

4. Evaluate upstream sources of nutrients should and measure nutrient levels in tributaries where they enter Lake Carmel to fully characterize watershed inputs. Empirically quantifying the watershed nonpoint source loadings through tributary water quality analyses will inform the effectiveness and benefit of stream stabilization projects relative to septic systems and in-lake management actions.

5. Evaluate the potential to utilize functional traits of dominant cyanobacteria in Lake Carmel to implement strategies aimed at successfully controlling and managing their abundance. In Lake Carmel, the two dominant cyanobacteria that have been documented include *Microcystis* and *Woronichinia*. These two genera are known to regulate their buoyancy within the water column, rising towards the surface to capture adequate sunlight needed for photosynthesis and growth.

    a. To potentially overcome the buoyancy ability of *Microcystis* and *Woronichinia*, evaluate the effectiveness of artificial mixing. Altering the mixing regime in Lake Carmel may limit the competitive advantage of dominant cyanobacteria to stay within the upper waters, photosynthesize, and become abundant.

NYSDEC should support research to better understand how to target dissolved phosphorus with traditional and innovative nonpoint source best management practices.

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

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

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

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

13.8 Coordination Actions

Short-term

1. Encourage public participation in initiatives for reducing phosphorus and documenting/tracking HABs, such as volunteer monitoring networks and/or increasing awareness of procedures to report HABs to NYSDEC.
2. Improve coordination between NYSDEC and owners of highway infrastructure (state, county, municipal) to address road ditch management; including, identify practices, areas of collaboration with other stakeholder groups, and evaluation of current maintenance practices.
3. Continue to support and provide targeted training (e.g., ditch management, emergency stream intervention, sediment and erosion controls, prescribed grazing, conservation skills, etc.) to municipal decision makers, SWCDs, and personnel in order to underscore the importance of water quality protection as well as associated tools and strategies.

Long-term

1. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.
2. Coordinate with Department of Health to support the local health departments to implement onsite septic replacement and inspection activities.
3. 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.
4. 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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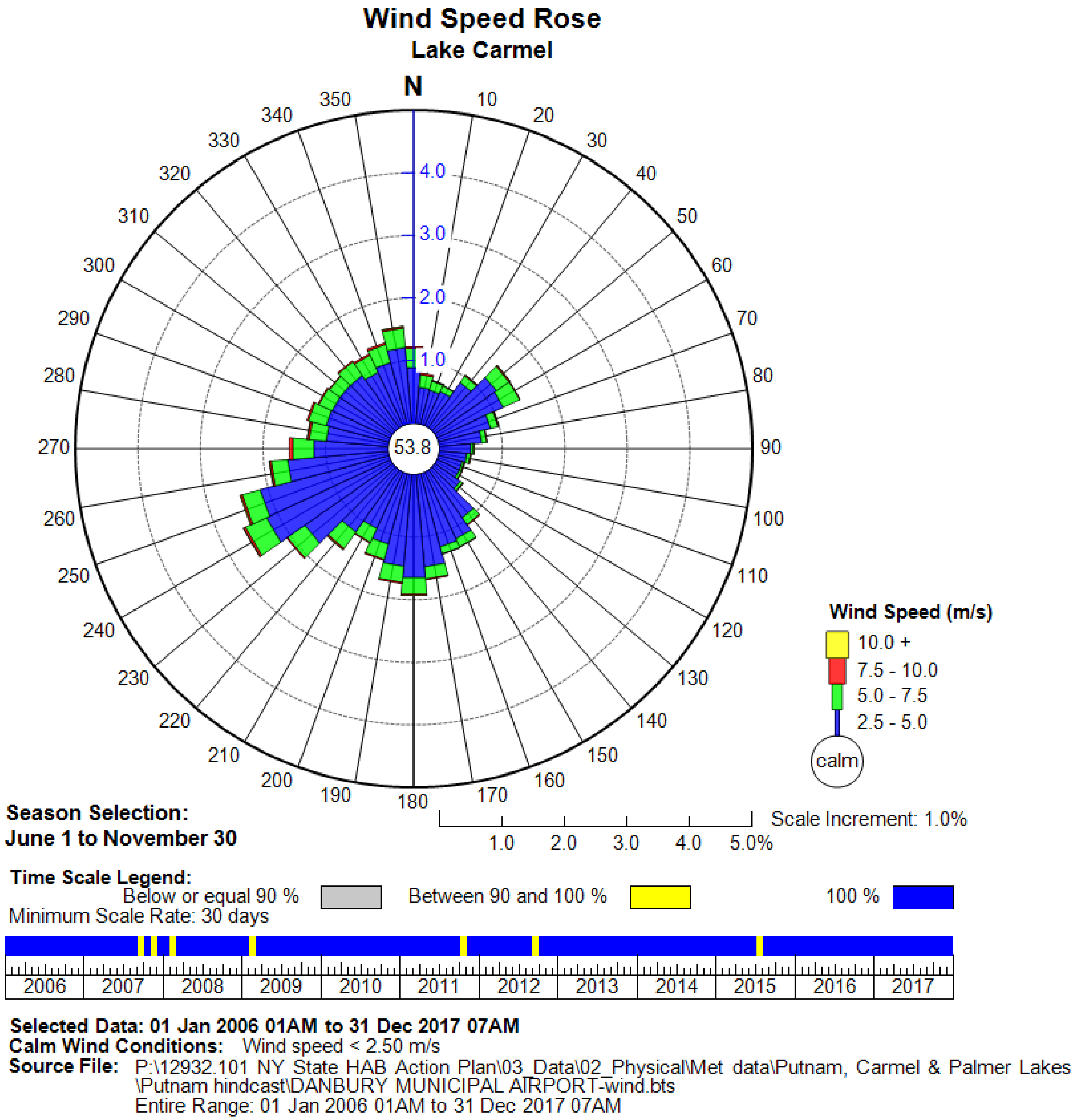
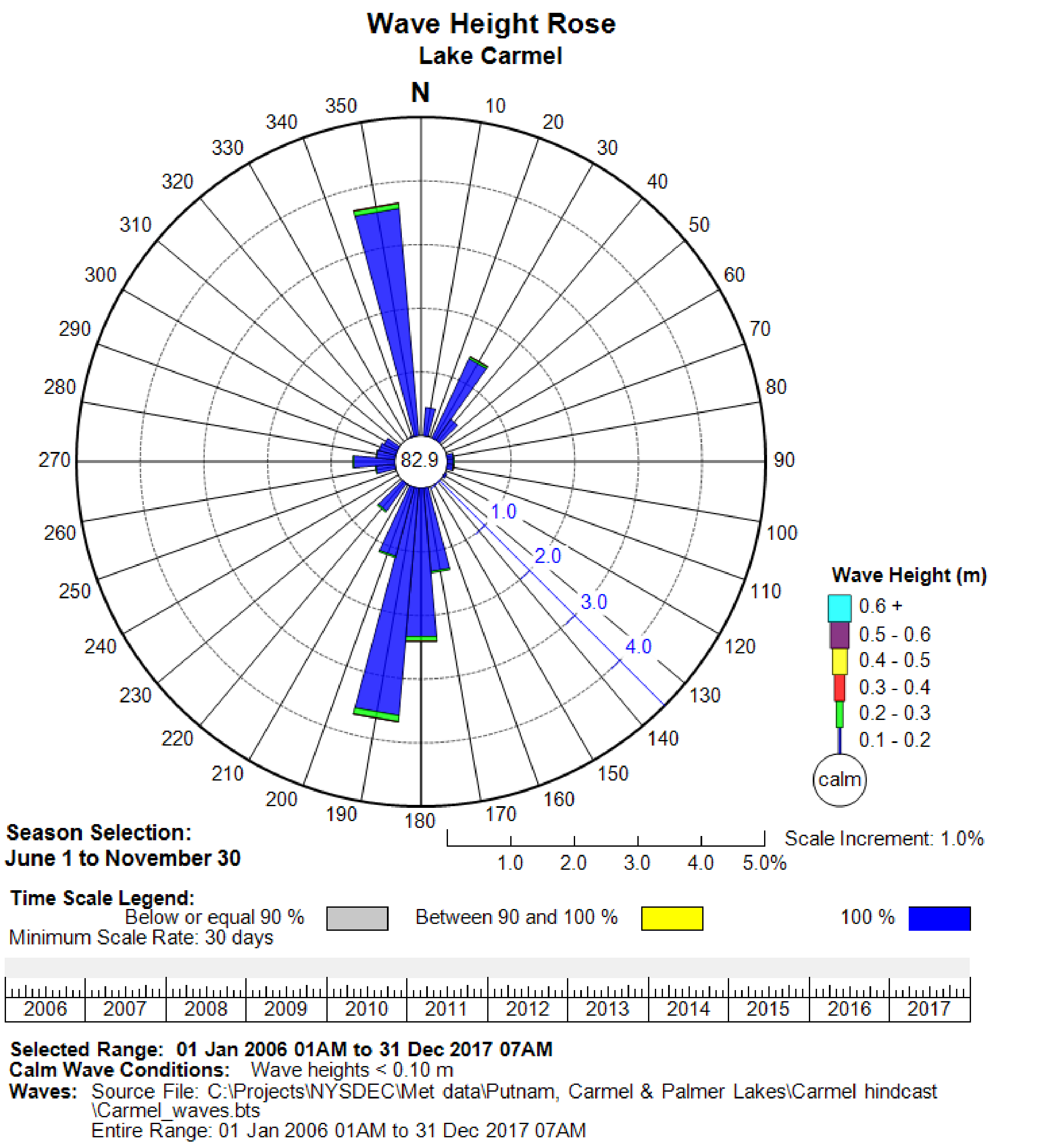
Appendix A. Wind and Wave Patterns



Wind speeds at Lake Carmel from 2006 to 2017, during the months of June through November, indicate that stronger winds were generated from the southwest and south.



Wave height patterns from 2006 to 2017, during the months of June through November, indicate wave heights were greater in the northern and southern extents of Lake Carmel.

Appendix B. Waterbody Classifications

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

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

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

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

Class A:	Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes
Class B:	The best usage is for primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival
Class C:	The best usage is for fishing, and fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
Class D:	The best usage is for fishing. Due to such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or stream bed conditions, the waters will not support fish propagation. These waters shall be suitable for fish survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
Class (T):	Designated for trout survival, defined by the Environmental Conservation Law Article 11 (NYS, 1984b) as brook trout, brown trout, red throat trout, rainbow trout, and splake.
Class (TS):	Designated for trout spawning waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout, trout spawning, trout waters, or trout spawning waters applies.

Appendix C. WI/PWL Summary

Lake Carmel (1302-0006) Impaired

Waterbody Location Information

Revised: 05/01/2018

Water Index No: H- 31-P44-23-P59- 6-P62..P62a
Water Class: B
Hydro Unit Code: East Branch Croton River (0203010102)
Drainage Basin: Lower Hudson River
Water Type/Size: Lake/Reservoir 186.6 Acres
Reg/County: 3/Putnam (40)
Description: entire lake

Water Quality Problem/Issue Information

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

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

Known: NUTRIENTS (PHOSPHORUS), Algal/Plant Growth
Suspected: ---
Unconfirmed: Ammonia, Low D.O./Oxygen Demand,

Source(s) of Pollutant(s)

Known: Internal Loading, ON-SITE/SEPTIC SYST, Streambank Erosion, Urban/Storm Runoff
Suspected: ---
Unconfirmed: Agriculture

Management Information

Management Status: Strategy Implementation Scheduled or Underway
Lead Agency/Office: USEPA Reg 2
IR/305(b) Code: Impaired Water, TMDL Completed (IR Category 4a)

Further Details

Overview
Lake Carmel is assessed as an impaired waterbody due to primary and secondary contact recreation uses that are known to be impaired by phosphorus from urban/stormwater runoff and failing on-site septic systems.

Use Assessment
This segement is a Class B waterbody, required to support and protect the best use of primary and secondary contact recreation, and fishing, but not as a source of water supply for drinking.

Primary and secondary contact recreation are considered to be impaired due to elevated nutrients (phosphorus), excessive algae, and poor water clarity, and due to frequent closures of public beaches for swimming due to the presence of harmful algal blooms (HABs). These periodic blooms have been managed using Cutrine Plus, a copper-based pesticide, to control algal blooms. Additional bacteriological sampling is needed to more fully evaluate the impact of pathogen levels on public bathing (swimming) use. Non-contact recreation (boating, fishing) is also affected by excessive aquatic vegetation and the presence of invasive plant growth (Eurasian watermilfoil).

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

Water Quality Information
Water quality sampling of Lake Carmel has been conducted through the Citizens Statewide Lake Assessment Program (CSLAP) 2016 through 2017. The lake was also monitored by the NYSDEC Lake Classification and Inventory (LCI) program in 2013. Results of sampling from both programs indicate the lake is best characterized as eutrophic, or highly productive. Chlorophyll/algal levels typically exceed criteria corresponding to impaired recreational uses, while phosphorus concentrations are most always above 20µg/L NYSDEC guidance value. Lake clarity measurements indicate water transparency often does not meet the recommended minimum criteria for swimming beaches. Readings of pH typically fall within the range established in state water quality standards for protection of aquatic life. (DEC/DOW, BWAM/LMAS, February 2018)

This waterbody was included in the NYSDEC HABs Notification program in 2015 (cited as having suspicious blooms), 2016 (cited as having confirmed blooms), and 2017 (cited as having confirmed blooms). In 2017, Lake Carmel was on the HABs Notification List for 11 weeks. The blooms observed in 2017 were best characterized as small localized, but did become widespread toward the end of the recreational season. There were four bathing beaches that were closed for an average of 12 days for HABs in 2017. NYSDEC water quality monitoring related to the HABs notices found mid- to late-summer shoreline blooms in 2016 and 2017 comprised of *Aphanizomenon (2016), Dolichospermum, and Woronichinia (2017), all cyanobacteria (blue green algae).* This sampling showed low but detectable levels of microcystin and anatoxin in one shoreline bloom sample in 2017, and undetectable levels of these toxins in 2016. Open water (center of lake) samples in 2017 indicated blooms comprised of multiple taxa in late summer of 2017, but no other open water blooms in either 2016 or 2017 (DEC/DOW, BWAM/LMAS, February 2018)

Source Assessment
The Total Maximum Daily Load (TMDL) for Phosphorus in Lake Carmel (2016) characterizes all loads of phosphorus to the lake. The primary sources of phosphorus to the lake per the TMDL are internal loading, failing septic systems, and streambank erosion.

Management Actions
This waterbody is considered a highly valued water resource as a a multi–use waterbody for swimming, boating, and fishing. 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 Carmel was identified for inclusion in this initiatve as it is vulnerable to HABs.

Lake Carmel is tributary to the Croton System of New York City water supply reservoirs (see New Croton Reservoir, Segment 1302–0010). A Watershed Agreement is in place between NYCDEP and the Croton Watershed communities which sets forth programs and funding for watershed protection.

The NYSDEC finalized its Croton Watershed Phase II Phosphorus TMDL Implementation Plan in January 2009. Since then, NYSDEC has been actively working with its partners to implement a number of programmatic initiatives contained in the Implementation Plan. Examples includes the East of Hudson Stormwater Retrofit and Septic Maintenance Programs. The Stormwater Retrofit Program has installed over 200 stormwater best management practices in the East of Hudson watershed, resulting in over 600 kg of phosphorus reductions. The Septic Maintenance Program requires homeowners to pump out their septic system at least once every five years.

The Lake Carmel TMDL for Phosphorus was approved by USEPA in 2016.

Section 303(d) Listing
Lake Carmel is currently included on the NYS 2016 Section 303(d) List of Impaired Waters. The waterbody is included on Part 1 of the List as an impaired waterbody requiring TMDL for phosphorus. However a TMDL for Lake Carmel was approved in September 2016 and the current phosphorus listing should be moved to Category 4a during the next update of the List. The waterbody was first listed for phosphorus impairment in 2002. (DEC/DOW, BWAM/WQAS, February 2018)

Segment Description
This segment includes the entire are of Lake Carmel.

Appendix D. NYSDEC Water Quality Monitoring Programs

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

Appendix E. Road Ditches

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

Road Ditch Impacts

Roadside ditch management represents a critical, but overlooked opportunity to help meet watershed and clean water goals in the Lake Carmel 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.