5.4.6 HARMFUL ALGAL BLOOM

This section provides a profile and vulnerability assessment of the harmful algal bloom (HAB) hazard for Putnam County.

5.4.6.1 Profile

The profile contains a description of the HAB hazard, extent, location, previous occurrences and losses, climate change projections and the probability of future occurrences.

Hazard Description

Algae can be found in a wide range of environments, including fresh water, oceans, hot springs, and even on land. Algae are a diverse group of species ranging from single-celled organisms to kelp seaweeds that can grow to be over 50 yards long. Algae can be found in symbiotic relationships with other organisms, the most common being corals and lichens. Large species of algae that appear to grow off the lake or sea floor are referred to as macroalgae while smaller, microscopic species are referred to as microalgae. Microalgae can be free floating in the water column as phytoplankton or can rest on the bottom of the water body as periphyton.

> Algae blooms are caused by an excess of nutrients available in a waterbody, resulting in a rapid growth and reproduction of algae in what is commonly referred to as a "bloom." Waterbodies that are impacted by runoff of nutrients at high levels of both naturally occurring and manmade, algae can experience overloading of nutrients and become more vulnerable to algal blooms.

Because of their incredible diversity and shared characteristics with plants, the taxonomy of algae has been much discussed. Originally classified as plants, algae are now found in the kingdom Protista. Algae are further broken down into groups commonly grouped by pigmentation. Most species of green algae are only found in fresh water while most species of red algae and brown algae are only found in salt water. Brown algae are among the most complex forms of algae while blue-green algae are one of the simplest forms of algae. Also referred to as cyanobacteria (a bacteria rather than a true algae), blue-green algae are either single celled or colonial. Blue-green algae are the most common form of algae to result in HABs in Putnam County, impacting the county's lakes.

Algae, like plants, photosynthesize, forming the basis of many aquatic and marine food chains. However, unlike plants, algae do not have roots for nutrient intake. Some species of macroalgae appear to have roots because they are attached to the bottom by a structure known as a holdfast, but the holdfast does not absorb and transfer nutrients in the same way that roots do. Instead, algae are able to draw their nutrients directly from the environment that surrounds them. Due to this phenomenon, high nutrients, warm temperatures, and low turbulence at the water's surface all increase the risk of algal blooms.

As the base of the food chain in aquatic systems, phytoplankton populations are under constant threat of being eaten by herbivores. Phytoplankton species employ a variety of natural defenses to limit the amount of population destruction that unabated grazing by herbivores can cause. These may include regulation of population size and seasonal occurrence, growth of spiny exteriors, and the creation of toxins. More than 40 cyanobacterial species are confirmed or suspected to produce toxins (Graham and Wilcox 2000). When these populations of algae grow out of control and produce toxins or have harmful effects, it is typically referred to as a *Harmful Algal Bloom or HAB*. Contact with water containing HABs can cause various health effects including diarrhea, nausea or vomiting; skin, eye, or throat irritation; and allergic reactions or breathing difficulties (NYSDOH 2017).

Traditional methods of in-home treatment systems such as boiling, disinfecting with chlorine/ultraviolet (UV), and water filtration units are not effective in removing HABs and their toxins. Public water is always the best option for drinking, preparing food, cooking, washing, and bathing because water suppliers are required to treat, disinfect, and monitor their water supplies (NYSDOH 2017). Even after a HAB abates, toxins released by algae can remain in the water column for weeks. Water treatment plants with filtration systems can remove variable amounts of microcystin from drinking water; however, as much as 20 percent may escape the treatment process (Carmichael 1997), sometimes leading to plant and water system closures.

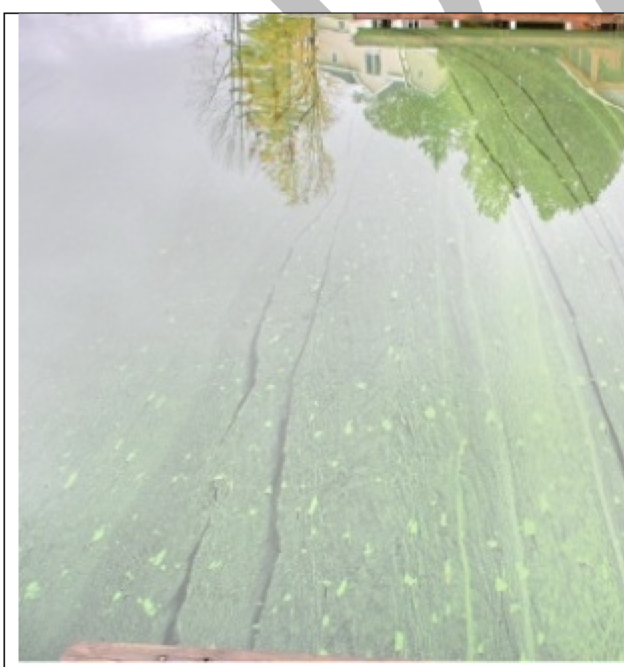
Numerous cases of seafood poisoning have been associated with the accumulation of toxins from algae by fish or shellfish and the subsequent ingestion of those species by humans. These cases include paralytic shellfish poisoning, ciguatera fish poisoning, and amnesiac shellfish poisoning. Most of these cases are from fish found in HABs in coastal oceans, but fish should not be consumed from lakes that are impacted by these blooms (National Research Council 1999).

The presence of HABs will trigger official beach closures, drinking water restrictions, advisory signs, press releases, and notifications on websites such as the NYSDEC Harmful Algal Blooms Notifications Page (NYSDEC 2017b). This page posts weekly notifications from late spring through fall. Children and animals should be kept away from waters suspected of containing HABs, and fishing or eating fish should be prohibited. In Putnam County, the primary threat from HABs is from blue-green algae. Lakes in Putnam County are important economy drivers and recreation areas for residents. In addition, some lakes are used for household water systems.

Identifying Harmful Algal Blooms

The appearance of HABs can vary greatly. According to the NYSDEC, colors can include shades of green, blue-green, yellow, brown, red, or white. The physical appearance of these blooms can include floating dots or clumps and streaks on the water's surface as illustrated in Figure 5.4.6-1. Some blooms can also resemble spilled paint on the water's surface or change the appearance of water to that of pea soup (NYSDEC 2017a).

Figure 5.4.6-2. Examples of Harmful Algal Bloom Visual Appearance



HABs may look like parallel streaks, usually green, on the water surface.

HABs may look like green dots, clumps, or globs on the water surface.

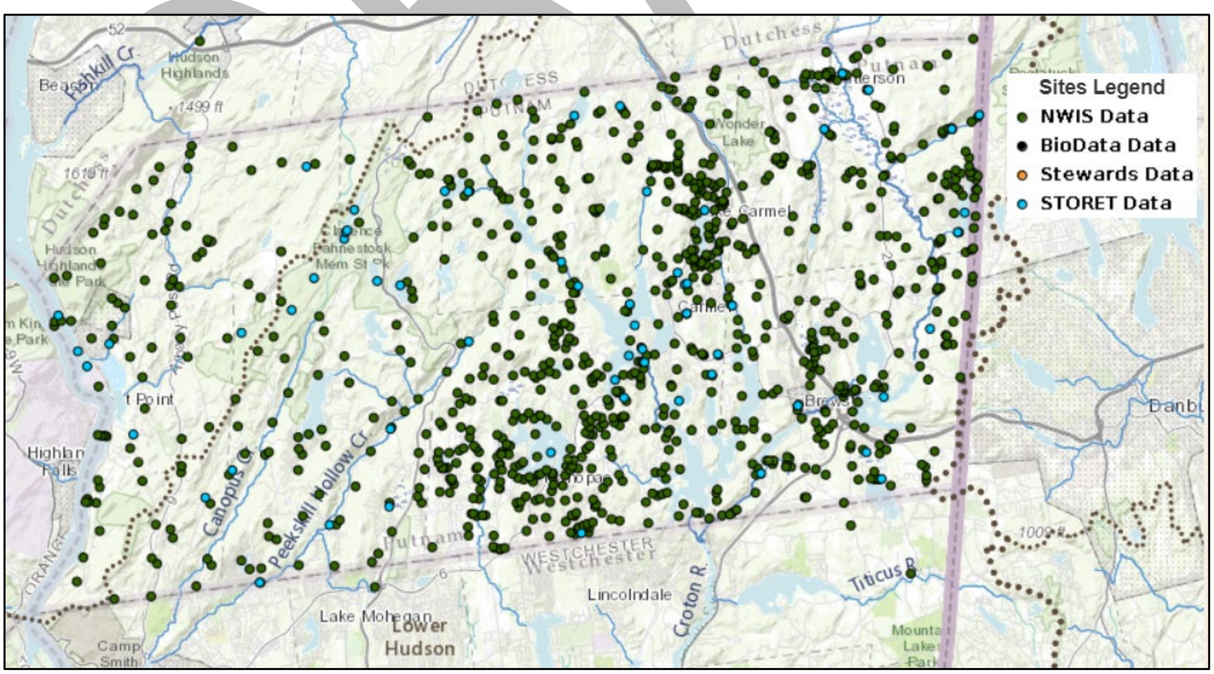
HABs may look like blue, green, or white spilled paint on the water surface.

HABs may make the water look bright green or similar to pea soup.

Source: NYSDEC 2016

The NYSDEC Lake Classification and Inventory Program, Citizen Statewide Lake Assessment Program volunteers and partnered HAB monitoring programs collect and report information about the status of waterbodies in New York that may be impacted by HABs (NYSDEC 2018). Figure 5.4.6-2 shows the location of waterbodies that are monitored in Putnam County or bordering Putnam County.

Figure 5.4.6-3. NYSDEC Lakes Monitoring Program Map (Putnam County)



Source: National Water Quality Monitoring Council 2020

Location

Putnam County has significant exposure and vulnerability to the HAB hazard, as described below.

- Shorelines of the Putnam County waterbodies with documented HABs are publicly accessible, which can increase the chance of exposure. Many of the county's lakes are popular recreation lakes and have an abundance of lake users, tourism and shoreline development.
- HABs are generally limited to lakes and ponds but any surface water can experience harmful algal blooms as evinced by prior events in Putnam Lake and Lake Carmel.
- The widespread use of septic systems in the County is a major contributing factor to HABs.
- Putnam County's waterbodies are relied upon as part of the Croton Aqueduct system, which delivers waters to New Yorkers in the southern section of the state, including 10% of New York City's drinking water.
- Locations that rely on surface water intake for drinking water are most exposed to the impacts of HABs. However, most of the County relies on groundwater from deep wells.

NYS DEC records indicate 22 waterbodies in Putnam County had documented HABs in recent years. In total, these waterbodies have a combined 5,004 acres and 104.9 miles of shoreline in Putnam County. Table 5.4.6-1 breaks down the total shoreline miles per lake and the shoreline miles per lake in Putnam County.

Table 5.4.6-1. Shoreline of Major Waterbodies in Putnam County with Documented HABs in recent years

Lake	Acreage	Shoreline Length (miles)
Black Pond	92.1	2.8
Bryant Pond	592.5	8.4
Cat Pond	45.9	2
Cortlandt Lake	126.2	4.1
Croton Falls Reservoir	85.6	6.3
E Branch Croton River Reservoir	9.1	0.5
East Branch Reservoir	70.4	2.2
Kentwood Lake	138.7	2.7
Kirk Lake	151.9	2.6
Lake Carmel	124.9	4.5
Lake Casse	1,076.5	15.5
Lake Celeste	20.5	1
Lake Dutchess	31.7	1.5
Lake Mahopac	7.3	0.8
Lake Peekskill	220.0	6.2
Middle Branch Reservoir	10.8	0.9
Peach Lake	396.0	6
Pine Pond	14.9	1.3
Putnam Lake	221	3.9
Roaring Brook Lake	1,084.2	19.8
Sagamore Lake	51.6	1.4
Secor Brook	57.9	1.8

Lake	Acreage	Shoreline Length (miles)
Solomon Lake	221.0	3.9
Upper Cranberry Pond	35.6	1.4
Wawayanda Lake	70.5	1.9
West Branch Reservoir	3.1	0.3
Wonder Lake	49.4	1.2
Total	5,009.3	**104.9**

Source: NYS GIS
*Note: * - Indicates major drinking water source.*

While most HAB contact occurs along shorelines, blooms can take place throughout surface waters. According to the 2010 Census, approximately six percent of Putnam County is made up of surface water.

Extent

The NYSDEC uses visual observations, photographs, and laboratory sampling results to determine if blooms are comprised of cyanobacteria or other types of algae. Figure 5.4.6-3 is a photograph of a cyanobacteria bloom at Lake Casse. NYS DEC staff will set bloom statuses for waterbodies that are being investigated for harmful algal blooms:

- **Suspicious Bloom**: NYSDEC staff have determined that conditions fit the description of a cyanobacteria HAB based on visual observations and/or digital photographs. Laboratory analysis has not been conducted to confirm whether this suspicious bloom is a HAB. It is not known if toxins are present in the water.
- **Confirmed Bloom**: Water sampling results have confirmed the presence of a cyanobacteria HAB, which may produce toxins or other harmful compounds.
- **Confirmed with High Toxins Bloom**: Water sampling results have confirmed that toxins are present in enough quantities to potentially cause health effects if people and animals come in contact with the water through swimming or drinking (NYSDEC 2018).

Suspicious blooms are reported to NYSDEC, local health departments, or the NYSDOH (NYSDOH 2017).

Figure 5.4.6-4. Cyanobacteria Bloom in Lake Casse, Putnam County

Source: The Examiner News 2019

Palmer Lake, Lake Carmel, and Putnam Lake have been subject to Harmful Algal Bloom Action Plans by the New York Department of Environmental Conservation. These three lakes account for one-quarter of the twelve priority waterbodies identified by the New York State Water Quality Rapid Response Team. Each lake was identified for focus due to its function as part of the Croton System of the New York City water supply reservoirs and historic occurrence of HABs, in addition to impaired waterbody status.

The NYSDEC has previously identified HABs in 22 waterbodies in Putnam County. There is a possibility for unidentified HABs occurring in waterbodies in Putnam County not subject to monitoring. The extent of a harmful algal bloom is an estimate of the area of the waterbody that is impacted. The NYSDEC has four categories to classify extent within their monitoring program (NYSDEC 2018):

- **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. Special precautions should be taken in situations when a “Confirmed with High Toxins Bloom” is reported with an open water extent because toxins are likely to be even higher in shoreline areas.

Wind currents can play a large role in the concentrations of algae that float at or near the water surface. Consistent winds can accumulate algae at downwind shorelines. In Lake Carmel and Putnam Lake, prevailing wind patterns result in accumulations of cyanobacteria in the northern and eastern ends of the lakes. Shorelines containing coves or other features that could capture floating algae may be more susceptible to HABs. In instances where freshwater intakes are impacted by these blooms, the extent may also include the area that is serviced by the impacted water utility or the private/residential intake.

Previous Occurrences and Losses

For this HMP update, HAB events were researched from 2012 to 2019. The NYSDEC began HAB testing and issuing notifications for New York waterbodies in 2012. The 2018 DEC Lake Monitoring Program includes the Lake Classification and Inventory Survey (LCI), the Citizens Statewide Lake Assessment Program (CSLAP) and several individual lake sampling programs. Table 5.4.6-1 lists events identified by the NYSDEC HAB Program between 2012 and 2019. This table includes events specific to Putnam County as well as events listed for neighboring counties but on a shared waterbody. This list may not include all HABS events that occurred in the County during this time period.

Table 5.4.6-2: Reported HABS in Putnam County

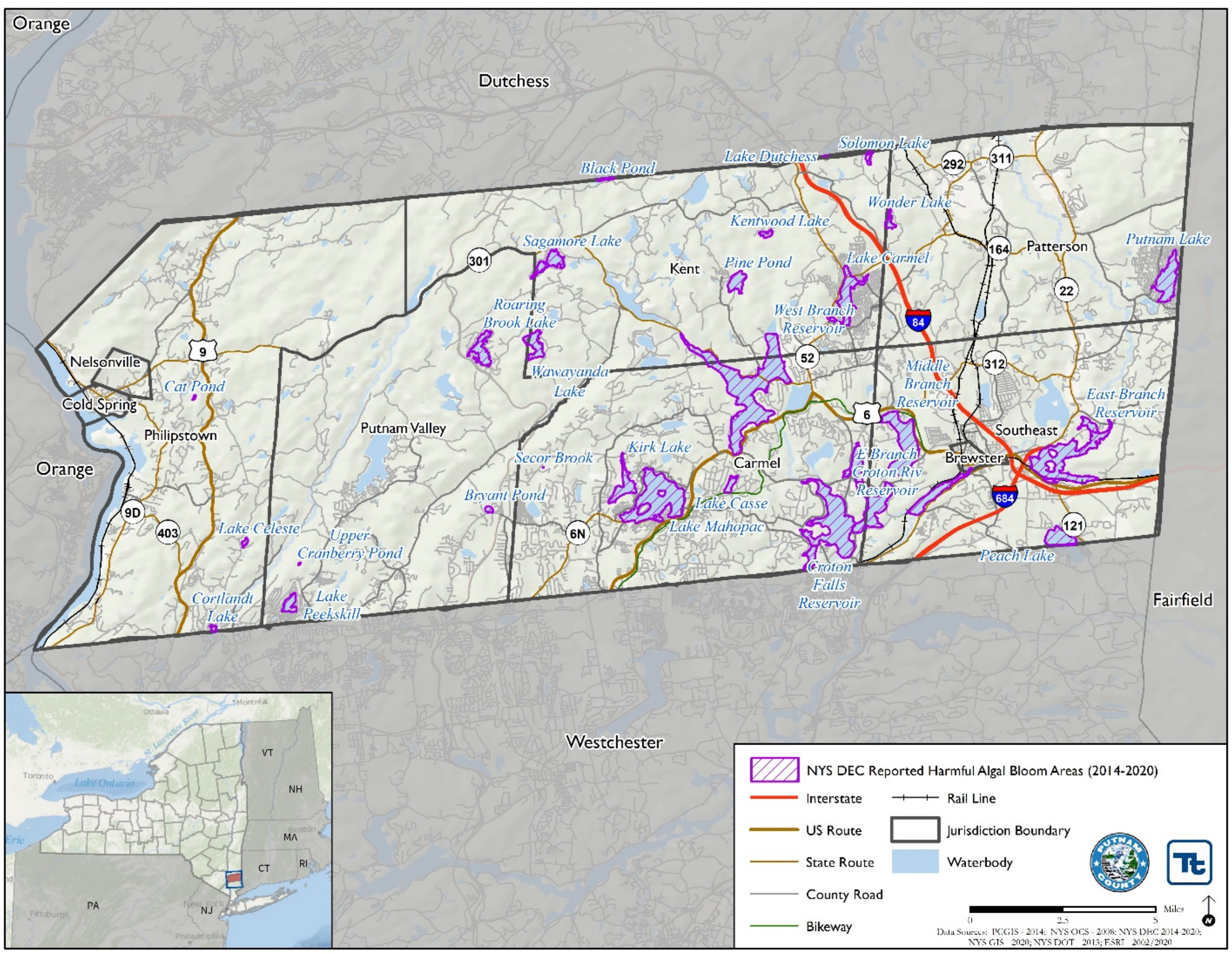
Lake	Weeks on DEC Notification List	Lake	Weeks on DEC Notification List
Town of Carmel			
Croton Falls Reservoir	**17**	**Long Pond**	**1**
2016	6	2019	1
2017	5	**Kirk Lake**	**30**
2018	2	2014	4
2019	4	2015	9
Lake Mahopac	**5**	2016	8
2018	5	2017	1
Secor Lake	**1**	2018	6
2017	1	2019	2
Lake Casse	**27**	**West Branch Reservoir**	**1**
2016	1	2019	1
2017	10		
2018	12		
2019	4		
Town of Kent			
China Pond	**1**	**Barrett Pond**	**1**
2017	1	2019	1
Lake Carmel	**35**	**Palmer Lake**	**4**
2015	4	2017	2
2016	5	2019	2
2017	11	**Kentwood Lake**	**X**
2018	11	2020	X
2019	4	**White Pond**	**X**
		2020	X
Town of Patterson			
Pattersons Park Pond	**4**	**Putnam Lake**	**36**
2014	4	2014	5
Herrlich Pond	**X**	2015	3
2020	X	2016	6
		2017	3
		2018	16
		2019	3
Town of Philipstown			
Cortlandt Lake	2		
2018	1		
2019	1		
Town of Putnam Valley			
Barger Pond	**34**	**Lake Peekskill**	**32**
2015	4	2014	10
2016	5	2015	3
2017	2	2017	6

Lake	Weeks on DEC Notification List	Lake	Weeks on DEC Notification List
2018	6	2018	9
2019	17	2019	4
Indian Lake	**5**	**Roaring Brook Lake**	**50**
2017	2	2015	9
2018	3	2016	2
		2017	15
		2018	14
		2019	10
Town of Southeast			
Lake Tonetta	**4**	**Peach Lake**	**18**
2014	4	2015	4
Diverting Reservoir	**3**	2016	4
2018	3	2018	5
		2019	5

Source: NYSDEC 2020

Figure 5.4.6-4. following the table shows the spatial extent of reported HABS in the County. HABS have impacted most of the County's largest lakes and reservoirs. Note that this map may not account for all HABS that have occurred in the County during the study period.

Figure 5.4.6-5. Reported HABS in Putnam County, 2012-2019



Probability of Future Events

HABs appear to be a recent occurrence in Putnam County or have only recently been officially reported and recorded. Even with these blooms becoming increasingly common, season and year-to-year fluctuations make predicting their occurrence difficult (EPA 2017). Despite this uncertainty, the impact of HABs on the environment, human health, and local economies cannot be discounted.

Table 5.4.6-2 lists probabilities of occurrences of HAB events. The information used to calculate probabilities of occurrences is based on NYSDEC database records that only date back to 2012. It is possible that HABs were present in waterbodies before 2012 but were not identified or monitored. It is also possible that events have taken place in waterbodies that went unreported.

Table 5.4.6-3. Probability of Occurrence of Harmful Algal Bloom-Related Events

Hazard Type	Number of Occurrences Between 2012 and 2019	Percent Chance of Occurrence in Any Given Year
Harmful Algal Bloom	23	100%

Sources: NYS DEC 2020
Note: Probabilities were calculated from years 2012 to 2019 based on the number of waterbodies impacted in the County over the course of the year. NYS DEC data only included harmful algal bloom events back to 2012.

The occurrence of harmful algal blooms was discussed at several Steering Committee meetings during the planning process. The County also provided documentation of the occurrence of HAB's in the County. In Section 5.3, the identified hazards of concern for Putnam County were ranked. Probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Partnership, the probability of occurrence of HAB in Putnam County is considered "frequent" (hazard event has 100% annual probability and may occur multiple times per year).

Climate Change Impacts

Increases in temperature may result in increased frequency of HABs. Most HABs take place during the summer months when water temperatures are warmest. Cyanobacteria in particular prefer warmer water. When lakes are at their warmest, mixing of the water column is less likely. When lakes are stagnant, algae are able to grow thicker and faster. In addition, the lower density of warm water allows algae to float to the surface faster. As algae grow and reproduce, they absorb more sunlight at the surface, further increasing the lake temperature and promoting more blooms (EPA 2017a).

Annual average precipitation is projected to increase by up to five by the 2050s and by up to 10 percent by the 2080s. During the winter months, additional precipitation will most likely occur, in the form of rain, and with the possibility of slightly reduced precipitation projected for the late summer and early fall. Northern parts of New York State are expected to see the greatest increases in precipitation (NYSERDA 2014).

The projected increase in precipitation is expected to occur via heavy downpours and less in the form of light rains. Rising air temperatures intensify the water cycle by increasing evaporation and precipitation, which can cause an increase in rain totals during storm events, with longer dry periods between those events. Alternating periods of drought and heavy rainfall increase the likelihood of nutrient runoff into waterways, which can fuel algal blooms (EPA 2017a).

Warmer temperatures could lead to an increase of the length of the algal growing season and increase the likelihood of algal blooms. In addition to warmer temperatures and heavy precipitation events, carbon dioxide levels are forecast to continue to increase. Higher levels of carbon dioxide in the atmosphere and water can lead to increased algal growth, particularly for cyanobacteria that float at the surface (EPA 2017a).

5.4.6.2 Vulnerability Assessment

To understand risk, a community must evaluate assets that are exposed and vulnerable to the identified hazard. All assets surrounding and relying on the waterways and water in the County are exposed to the harmful algal bloom hazard. The following text evaluates and estimates the potential impact of the harmful algal bloom hazard on the County.

Impact on Life, Health, and Safety

Impacts of harmful algal blooms on life, health, and safety depend on several factors, including the severity of the event and whether or not citizens and tourists have become exposed to waters suspected of containing a harmful algal bloom. Routes of exposure include consumption, inhalation, and dermal exposure. The population living near or visiting waterbodies is at risk for exposure as well as those that use those waterbodies for recreation, fishing, and water supply. Contact with water containing harmful algal blooms can cause various health effects including diarrhea, nausea or vomiting; skin, eye, or throat irritation; and allergic reactions or breathing difficulties (CDC 2020).

> Populations in Putnam County that rely on surface water intake for drinking water are most exposed to the impacts of harmful algal blooms. Surface waters in the Croton, Catskill and Delaware watersheds provide Putnam County residents with drinking water.

According to the 2018 American Community Survey 5-Year Population Estimates, Putnam County has 99,070 persons living in its communities. Although not all residents rely on these surface water resources for drinking water, these watersheds are also used for recreational activities. According to the New York Department of Environmental Conservation, dozens of harmful algal blooms have been seen at Putnam Lake, Lake Carmel, and Palmer Lake (NYSDEC 2020). Putnam Lake and Lake Carmel have experienced collectively more than 48 weeks of harmful algal blooms since 2012. Observation of these blooms has led the County to shut down the parks around the lake and tributaries to keep the public safe during periods where the blooms create dangerous conditions.

Impact on Critical Facilities

The typical impact harmful algal blooms have on critical facilities are shutdowns of water intakes from the surface waters that are impacted by blooms and their toxins. Water treatment plants can remove variable amounts of microcystin from drinking water depending on the active removal process used by the water treatment plant (EPA 2020). However, applying the wrong treatment process at a specific state in treatment could damage the facility and release cyanotoxins rather than remove them. The EPA has summarized the effectiveness of treatment options for harmful algal blooms (refer to Table 5.4.6-3.).

Table 5.4.6-4. Assessment of Treatment Options for HABs

Treatment Process	Relative Effectiveness
Intracellular Cyanotoxins Removal (Intact Cells)	
Pre-treatment oxidation	Oxidation often stresses or lyses cyanobacteria cells releasing the cyanotoxin to the water. If oxidation is required to meet other treatment objectives, consider using lower doses of an oxidant less likely to lyse cells. If oxidation at higher doses must be used, sufficiently high doses should be used to not only lyse cells but also destroy total toxins present (see extracellular cyanotoxin removal).
Coagulation/ Sedimentation/ Filtration	Effective for the removal of intracellular toxins (cyanobacteria cells). Ensure that captured cells accumulated in sludge are removed frequently to release toxins. Ensure that sludge supernatant is not returned to the supply after sludge separation.
Membranes	Effective for removal of intracellular cyanotoxins (cyanobacteria cells). Microfiltration and ultrafiltration are effective when cells are not allowed to

Treatment Process	Relative Effectiveness
	accumulate on membranes for long periods of time. More frequent cleaning may be required during a bloom event.
Flotation	Flotation processes, such as Dissolved Air Flotation (DAF), are effective for removal of intracellular cyanotoxins since many of the toxin-forming cyanobacteria are buoyant.
Extracellular (Dissolved) Cyanotoxins Removal	
Membranes	Depends on the type of cyanotoxin, membrane material, membrane pore size distribution, and influent water quality. Nanofiltration is generally effective in removing extracellular microcystins. Reverse osmosis filtration is generally applicable for removal of microcystins and cylindrospermopsin. Cell lysis is highly likely. Further research is needed to characterize performance.
Potassium Permanganate	Effective for oxidizing microcystins and anatoxins. Further research is needed for cylindrospermopsin. Not effective for oxidizing saxitoxin.
Ozone	Very effective for oxidizing microcystins, anatoxin-a, and cylindrospermopsin. Not effective for oxidizing saxitoxin.
Chloramines	Not effective.
Chlorine dioxide	Not effective at doses typically used in drinking water treatment.
Free Chlorine	Effective for oxidizing microcystins as long as the pH is below 8. Effective for oxidizing cylindrospermopsin and saxitoxin. Not effective for oxidizing anatoxin-a.
UV Radiation	UV radiation alone is not effective at oxidizing microcystins and cylindrospermopsin at doses typically used in drinking water treatment. When UV radiation is coupled with ozone or hydrogen peroxide (called "advanced oxidation"), the process is effective at oxidizing anatoxin-a, cylindrospermopsin, and with high UV doses, microcystins.
Activated Carbon Adsorption	Powdered activated carbon (PAC): Effectiveness of PAC adsorption varies based on type of carbon, pore size, type of cyanotoxin, and other water quality parameters such as natural organic matter (NOM) concentration. Wood-based activated carbons are generally the most effective at microcystins adsorption. More research is needed to evaluate PAC's effectiveness at adsorbing cylindrospermopsin, anatoxin-a, and saxitoxin, however the limited research has demonstrated promising results. Doses in excess of 20mg/L may be needed for complete toxin removal, especially if NOM concentrations are high. Granular activated carbon (GAC): Effectiveness of GAC adsorption varies based on type of carbon, pore size, type of cyanotoxin, and other water quality parameters such as NOM concentration. GAC is effective for microcystins, and likely effective for cylindrospermopsin, anatoxin-a and saxitoxin. The condition of the carbon is an important factor in determining GAC's effectiveness for cyanotoxin removal. GAC may need to be regenerated more frequently to ensure adequate adsorption capacity for HAB season.

Source: EPA 2020

Impact on the Economy

Economic impacts from harmful algal bloom events are difficult to quantify in Putnam County. Nationally, these events have caused significant economic loss. For example, the Centers for Disease Control and Prevention estimates that the fishing industry loses as much as $34 million a year in sales due to contamination (CDC 2020). Recreation and tourism industries also lose millions of dollars each year because of shutdowns. Further, monitoring and management programs can cost states millions of dollars each year.

Overall, Putnam County may experience the greatest economic impact in its tourism sector if a harmful algal bloom event occurs. News of a closure of a body of water or beach can result in tourists avoiding the area. Even after closures are lifted, negative public reaction can persist and continue to impact tourism revenue and property values.

Impact on the Environment

Harmful algal blooms can release toxins that lead to fish and invertebrate kills. Animals that prey on fish and invertebrates in surface waters, such as birds and mammals, may be affected if they ingest impacted prey. Both harmful and non-harmful algal blooms can have drastic impacts on oxygen levels in surface waters. When algae begin to die off following a bloom, bacteria begin to decompose the organic material. This decomposition consumes dissolved oxygen and releases carbon dioxide. If the bloom and die off is large enough, dissolved oxygen levels in aquatic systems can rapidly crash. Anoxic conditions connected to algal blooms have resulted in large fish and invertebrate kills (CDC 2020).

Cascading Impacts on Other Hazards

Harmful algal blooms can exacerbate the impacts of disease outbreak. Species and persons that are exposed to cyanobacteria may become poisoned, experience gene alterations, or disease (EPA 2020). More information about disease outbreaks can be found in Section 5.4.10 (Disease Outbreak).

Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in the county can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The county considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Projected Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the county. Harmful algal blooms could impact any areas of growth located near waterbodies that are vulnerable to harmful algal blooms. As increased development is often associated with stormwater and runoff issues, harmful algal blooms may become more likely in areas of increased development. The specific areas of development are indicated in tabular form and/or on the hazard maps included in the jurisdictional annexes in Volume II, Section 9 of this plan.

Projected Changes in Population

According to the U.S. Census Bureau, the population in Putnam County has decreased by approximately 0.7-percent between 2010 and 2018 (US Census Bureau 2018). However, estimated population projections provided by the 2017 Cornell Program on Applied Demographics indicates that the County's population will increase slowly into 2040, increasing the total population to approximately 100,435 persons (Cornell University Program on Applied Demographics 2017). As a result, an increase in the population could also change the number of persons at risk of becoming exposed to a harmful algal bloom event. Furthermore, persons that are already located in the County may move into locations nearby the waterways at risk of having a harmful algal bloom event. If waterways containing cyanobacteria flood, persons living within the flood prone areas are at even greater risk of exposure. Refer to Section 4 (County Profile), for additional discussion on population trends.

Climate Change

Putnam County will see an increase in both temperature and precipitation amounts as a result of climate change. As discussed above, a warming climate will allow for an extended growing period for algal blooms.

Additionally, increases in precipitation will generate more stormwater runoff, which can lead to increased nutrient loads entering waterways from leached nutrients in the soil or fertilizers on agricultural lands. Warmer temperatures and increased nutrient loads will allow for algal blooms to grow and spread more rapidly. These changes will increase the County's overall vulnerability to harmful algal blooms.

Change of Vulnerability Since the 2015 HMP

Harmful algal blooms are a new hazard of concern for Putnam County.

Identified Issues

Putnam County's lakes are a major component of the County's identity and a major water supplier for the New York City aqueduct system. As algal blooms have increased in frequency in recent years, some lakes have been closed for the entire summer season. These impacts post severe quality of life and economic threats to the County.

There is a need to better track and identify which lakes are experiencing harmful algal blooms and build better relationships with lake committees to communicate information about blue-green algae.

Mitigation options for harmful algal blooms range from expensive structural projects (e.g. replacement of septic systems with community to wastewater) to minor projects such as the installation of aerators, or maintenance projects such as dredging legacy chemicals found in lake sediments. Due to varying intensities of development and use across Putnam County lakes, there is likely not a "one-size-fits-all" approach to HABS mitigation.