PROGRESS REPORT
Onondaga Lake and Watershed

J. Ryan McMahon II
County Executive

Save the Rain

Onondaga County Department of WATER ENVIRONMENT PROTECTION

Tom Rhoads, P.E.
Commissioner

Dramatic Improvements in Onondaga Lake

Onondaga Lake has been transformed. Once considered among the most polluted lakes in the United States, the lake and shoreline now host hundreds of families, outdoor enthusiasts, and community events each year. The story of the lake's recovery exemplifies the benefits of tackling environmental challenges in a collaborative way. For decades, Onondaga County leaders have fostered a culture of innovation in science and engineering and engaged the community in a discussion of a shared vision for a restored lake. This progress report describes how the investment in science and engineering has improved the lake and watershed and helped attain the community vision for this important natural resource.

Advanced treatment for phosphorus and ammonia at the Metropolitan Syracuse Wastewater Treatment Plant (Metro) reduced the input of these chemicals to Onondaga Lake. In response, the lake now meets water quality standards for phosphorus and ammonia, hosts a diverse community of plants and animals, and is an attractive community asset.

Advanced wastewater treatment processes and expanded capacity at Metro have helped to dramatically improve water quality in Onondaga Lake.

Onondaga County has met or exceeded state and federal regulatory requirements to improve the wastewater collection and treatment system, and the quality of the waters is a testament to the value of this community investment.

A successful stormwater management program has also contributed to improving water quality conditions in Onondaga Lake and its tributary streams. Onondaga County has used a combination of traditional and innovative measures to reduce runoff during wet weather help maintain the capacity of the collection system to direct wastewater to Metro. The County's Save the Rain program has garnered national recognition and awards.

In addition to the municipal investment, actions by Honeywell International to remediate the legacy of industrial pollutants have been successful in improving water quality and habitat conditions. The coordinated efforts to address wastewater, stormwater, and industrial contamination have brought about this remarkable transformation of Onondaga Lake. To understand the magnitude of improvement, it's necessary to review the regulatory process and milestones associated with meeting the federal Clean Water Act goal of "swimmable, fishable" waters and benchmark historical conditions.

Regulatory Framework for Restoring Our Waters

The 1972 federal Clean Water Act defines the regulatory framework for water pollution control in the US. The objective of the 1972 Act was "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" {section 101(a) PWL 92-500}. The same section defined two "national goals": (1) eliminating the discharge of toxic pollutants into navigable waters by 1985, and (2) achieving an interim water quality level that would protect fish, shellfish, and wildlife while providing for recreation in and on the water wherever attainable." Common shorthand for the national goals is "swimmable, fishable" waters; this effectively captures the congressional intent to protect both human uses and aquatic ecosystems.

The Clean Water Act recognizes that the states have primary responsibility for meeting these goals. A well-developed framework for states to evaluate and test their waters, define assimilative capacity (i.e., sensitivity to pollutants), and regulate discharges has emerged. The success of Onondaga Lake's restoration illustrates how this regulatory framework can be effectively applied to address complex pollution issues.

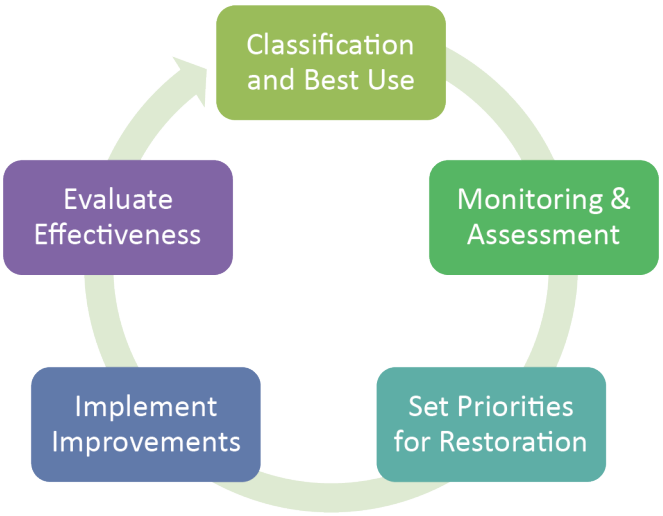

FIGURE 1. Regulatory process to define and address impaired water bodies

Classification and Best Use

The regulatory framework begins with classification (Figure 1). States are required to classify the water bodies within their boundaries according to their "best use." In New York, the Department of Environmental Conservation (NYSDEC) is responsible for classifying lakes, streams, rivers, and estuaries. These waters are classified as suitable for drinking water sources, recreation (swimming and boating), aquatic life protection, industrial cooling water, etc. Water quality standards are defined based on scientific analyses that reflect these designated best uses. For example, a lake serving as a public water supply requires more stringent limits on potential contaminants than a lake used for boating or industrial uses. Regular testing is conducted to ensure that water quality and habitat conditions support these designated uses. Waters that do not meet the water quality standards associated with their classification are considered "impaired" and reported to the federal Environmental Protection Agency (EPA). Efforts to restore impaired waters are given high priority for state and federal funding.

Onondaga Lake Classification

Onondaga Lake includes both Class B waters (northern segment) and Class C waters (southern segment and near the confluence of Ninemile Creek) (Figure 2). The best uses of Class B waters are for primary and secondary water contact recreation and fishing. Primary water contact recreation includes activities that immerse the body in the water, such as swimming; secondary water contact recreation includes activities without full immersion, such as boating. In addition, Class B waters shall be suitable for fish, shellfish, and wildlife propagation and survival. The best usage of Class C waters is fishing. These waters shall also be suitable for fish, shellfish and wildlife propagation and survival. Class C waters shall be suitable for primary and secondary water contact recreation, although other factors may limit the use for these purposes.

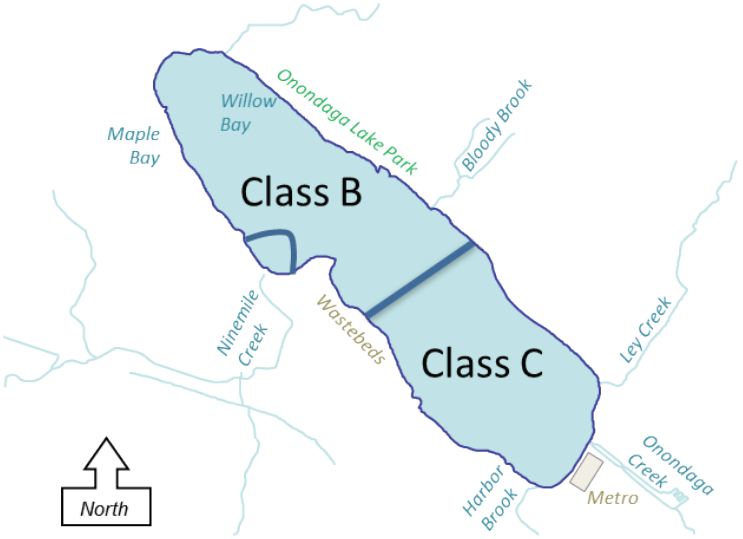

FIGURE 2. Water quality classification, Onondaga Lake

Historical Water Quality: Impairment

Onondaga Lake was included on NYSDEC's inaugural list of impaired waters in 1996, meaning that measured water quality conditions were not adequate to support the designated best use for aquatic life protection and recreation. The lake was listed due to its elevated levels of **ammonia nitrogen**, **phosphorus**, and **bacteria**; and low levels of **dissolved oxygen**.

Treated effluent from Metro was identified as a primary source of phosphorus and ammonia to Onondaga Lake. The low levels of dissolved oxygen (DO) are related to the elevated phosphorus concentrations: phosphorus is the key nutrient supporting the growth of phytoplankton (algae and cyanobacteria) in the lake water. When phytoplankton die and settle into the deep waters, they are decomposed by microorganisms in an aerobic process that depletes the supply of DO. Low concentrations of DO preclude fish and other aquatic animals from surviving in the deeper waters.

Elevated bacteria counts were also linked to the municipal wastewater collection and treatment system. Portions of the City of Syracuse are served by combined sewers; these large underground pipes carry both storm runoff and sewage to Metro. During wet weather, pipe capacity can be exceeded, causing **combined sewer overflows** (CSOs) to nearby streams.

Commitment to Improvements

In 1998, Onondaga County committed to a 15-year phased program of improvements to its wastewater collection and treatment infrastructure as a necessary investment to address the lake's impaired condition. The program, referred to as the **Amended Consent Judgment (ACJ)**, included three central elements:

- Improvements to Metro to enhance ammonia and phosphorus removal;
- Improvements to the collection system to reduce the frequency, magnitude, and duration of CSOs; and
- Comprehensive monitoring through an annual **Ambient Monitoring Program (AMP)** to measure the effectiveness of the improvements and evaluate whether impaired uses are restored.

Combined sewer overflow to Onondaga Creek during an intense rain storm, Syracuse, NY

The 1998 estimate for the required infrastructure improvements was $380 million, and Onondaga County received substantial state and federal aid. The ACJ was subsequently modified to include additional projects and to extend through 2018. As of December 2017, the ACJ projects to address wastewater collection and treatment and stormwater management total over $640 million. Onondaga County has shouldered an increasing share of the costs of more recent projects, including the Save the Rain green infrastructure projects. The local share of the total $640 million investment is approximately 56%.

Improvements to Wastewater Treatment

Enhanced Ammonia Removal at Metro

In the 1990s, concentrations of ammonia nitrogen in the lake waters were above regulatory standards designed to protect sensitive aquatic life forms, including early life stages of fish. Treated effluent from Metro represented over 90% of the external ammonia input to Onondaga Lake. As part of the ACJ, NYSDEC required Onondaga County to undertake a phased program to upgrade and expand the wastewater treatment capacity and processes at Metro in order to reduce

effluent ammonia levels. Onondaga County implemented best management practices and maximized existing Metro capacity while searching for an effective long-term solution.

The County consulted with international experts for advice on emerging technologies capable of reliable nitrification (biological conversion of ammonia to nitrate, a non-harmful form of nitrogen) in cold climates like Syracuse. A Biological Aerated Filtration (BAF) system was selected; the engineering team completed pilot tests to confirm its effectiveness at cold temperatures and brought the process on-line in January 2004. BAF technology uses millions of tiny polystyrene beads to provide the vast surface area needed for the microbial community to metabolize ammonia to nitrate nitrogen. Metro's contribution of ammonia to Onondaga Lake has declined in response to the interim measures and, most dramatically, when the BAF system came on-line (Figure 3).

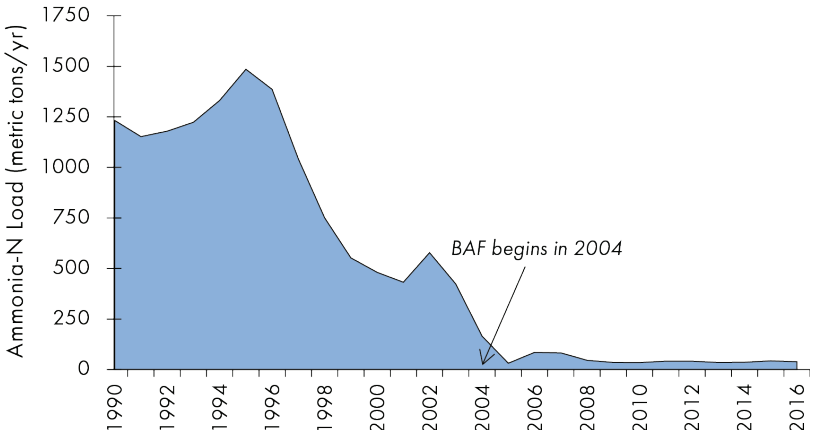

FIGURE 3. Discharge of Ammonia-N to Onondaga Lake from Metro, 1990–2016

Lake Response to Reduced Ammonia Inputs

The interim actions to enhance ammonia removal after the ACJ began in 1998 helped improve the lake's water quality. Installation of the BAF system in 2004 brought about a 98% reduction in Metro's ammonia loading. The lake response to the load reduction was rapid and dramatic, as shown in Figure 4. Since 2007, Onondaga Lake has consistently met the regulatory standards designed to protect sensitive aquatic life. In 2008, NYSDEC formally de-listed Onondaga Lake as impaired by ammonia–N (Table 1).

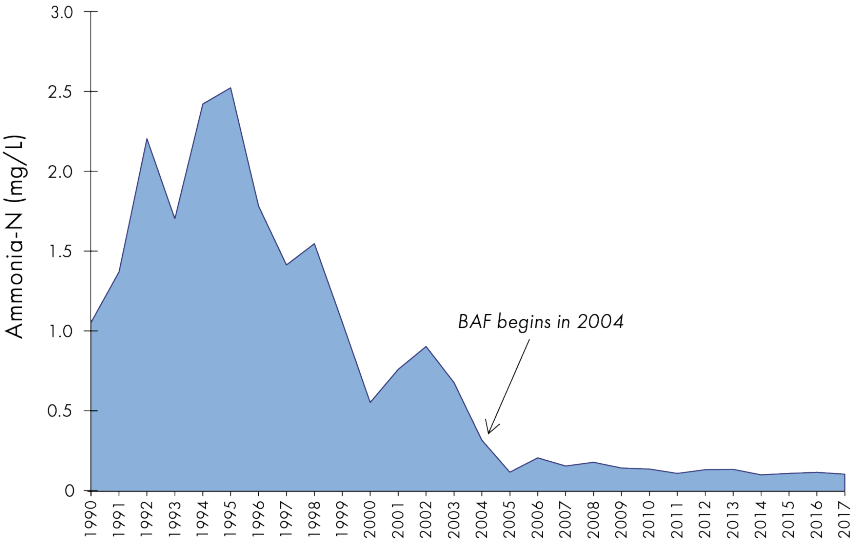

FIGURE 4. Time series of reduction in ammonia N, Onondaga Lake upper waters, 1990–2017

TABLE 1. Measured compliance with ammonia N standard, Onondaga Lake, 1998–2017

Depth (m)	Percent measurements in compliance, NYS standard												
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010-2017
0	64	62	86	95	68	96	100	100	100	100	100	100	100
3	45	67	90	90	68	96	100	100	100	100	100	100	100
6	50	86	90	95	73	100	100	100	100	100	100	100	100
9	41	76	90	95	73	100	100	100	100	100	100	100	100
12	18	52	90	81	50	80	100	100	100	100	100	100	100
15	23	52	57	52	41	56	80	100	100	100	100	100	100
18	23	48	52	38	32	48	75	95	95	100	100	100	100

Enhanced Phosphorus Removal at Metro

The search for cutting-edge technology extended to the phosphorus treatment as well. Onondaga County engaged experts to identify alternatives and conduct pilot tests. Among the performance indicators for the pilot tests was an examination of effluent phosphorus bioavailability. That is, how "potent" was the treated effluent in growing phytoplankton (algae and cyanobacteria)? Because phosphorus is the limiting nutrient for phytoplankton growth in Onondaga Lake, and because Metro contributed about 60% of the external loading, reducing bioavailable phosphorus in treated effluent was projected to have a dramatic impact on lake quality.

To measure how well the various technologies were able to reduce bioavailable phosphorus, samples of Metro effluent from pilot tests were sent to a specialty testing laboratory. Filtered and unfiltered samples of treated Metro effluent were incubated with algal cells under controlled conditions; all other nutrients except phosphorus were added to the laboratory vessels. The amount of algae grown in the vessels is an indicator of phosphorus bioavailability.

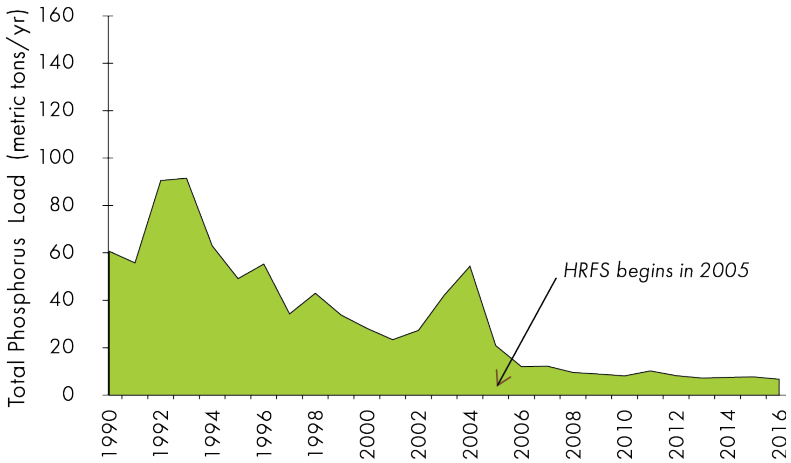

FIGURE 5. Total P input from Metro to Onondaga Lake, 1990–2016

Based on the bioavailability testing results, among other factors, a High Rate Flocculation System (HRFS), trade name Actiflo®, was selected and installed at Metro. Actiflo® is a physical-chemical treatment process that uses microsand particles along with iron salts to enhance coagulation and settling of particulate materials from the wastewater stream. The introduction of HRFS to the Metro treatment train in 2005 reduced the phosphorus loading to the lake from Metro by approximately 86% (Figure 5) and achieved a significant reduction in bioavailable phosphorus to the lake.

To understand the significance of the Metro phosphorus reductions in meeting lake water quality goals, samples from the lake tributaries were also subjected to bioassay studies, using the standard laboratory incubation technique described above. This 2009 study focused on the particulate fraction of phosphorus, since almost all dissolved phosphorus supports phytoplankton growth. The results confirmed the results from the pilot testing. Only a tiny percent of the particle-bound phosphorus in Metro effluent is available to the algal community. In contrast, particles entering Onondaga Lake through the watershed tributaries exhibit much higher potential for supplying phosphorus to support phytoplankton (Table 2).

TABLE 2. Bioavailability of P bound to particles, Onondaga Lake inflows

Source	Bioavailable Fraction of Particulate P
Metro Effluent	1%
Metro Bypass	25%
Onondaga Creek	50%
Ninemile Creek	20%
Ley Creek	6%
Harbor Brook	20%
Tributary 5A	20%
East Flume	20%

Source: Upstate Freshwater Institute, 2009

Lake Response to Reduced Phosphorus Inputs

As displayed in Figure 6, implementation of the High Rate Flocculated Settling technology Actiflo® had an immediate impact on lowering phosphorus concentrations in Onondaga Lake waters. Since 2007, summer average TP levels have fluctuated around the NYSDEC 20 µg/L guidance value; concentrations are slightly higher during wet summers when there is ample runoff from the watershed.

The lower summer TP has led to a decline in algal abundance and the frequency, magnitude, and duration of algal blooms in Onondaga Lake. Once a frequent summer phenomenon, algal blooms are now rare and of limited duration when they do occur. The County's AMP tracks the concentration of chlorophyll-*a*, the primary photosynthetic pigment as an indicator of phytoplankton abundance. The decline in phytoplankton blooms (Figure 7) is evidence

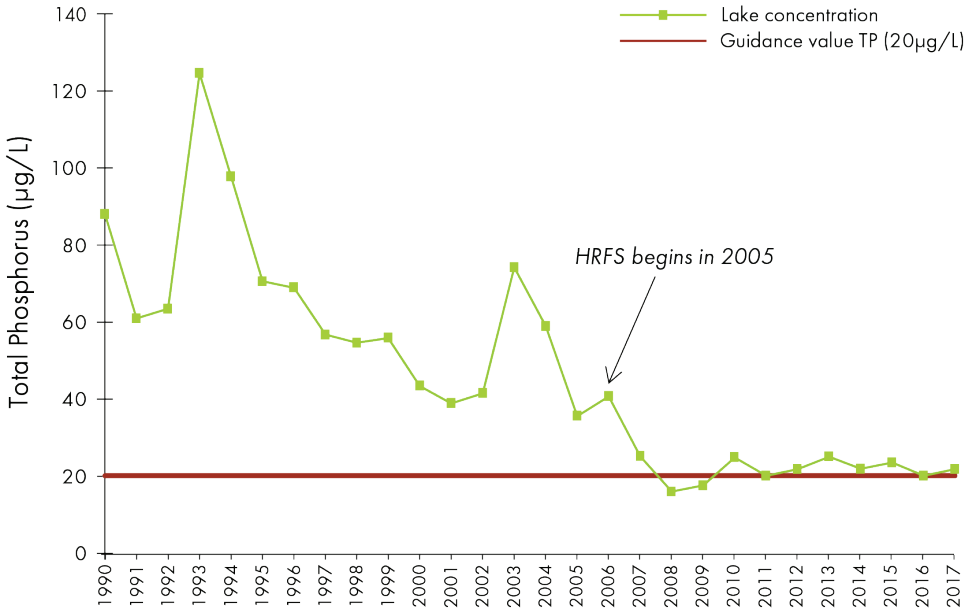

FIGURE 6. Summer average TP in Onondaga Lake's upper waters compared to NYS guidance value, 1990–2017

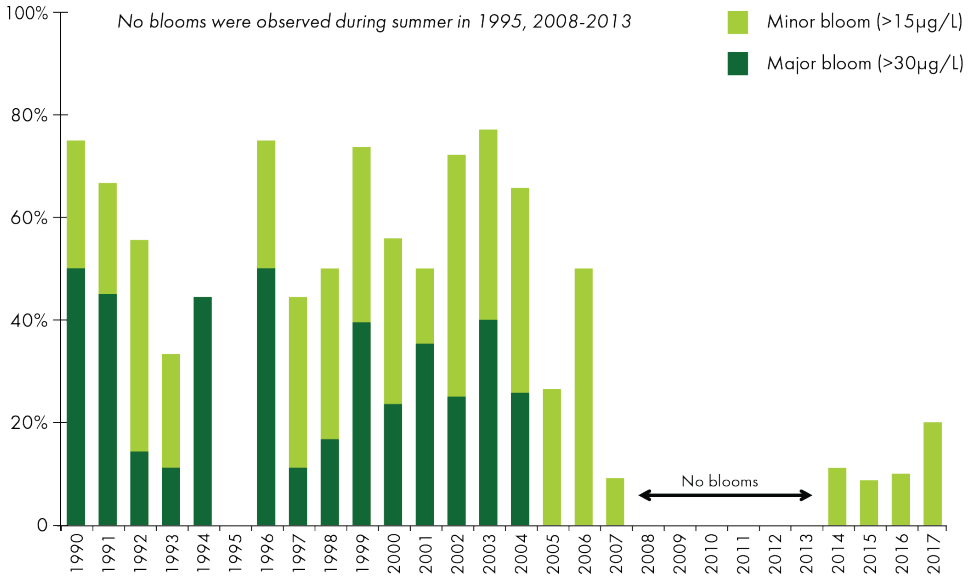

FIGURE 7. Percent of sampling events detecting algal blooms in Onondaga Lake, June 1–Sept. 30, 1990–2017

of the effectiveness of the controls on phosphorus inputs to the lake. The AMP also identifies and enumerates the phytoplankton community and tracks the percent of cyanobacteria in the assemblage. Cyanobacterial blooms, also known as harmful algal blooms, can impair water quality for recreation. These data further document the lake's return to a healthy condition (Figure 8).

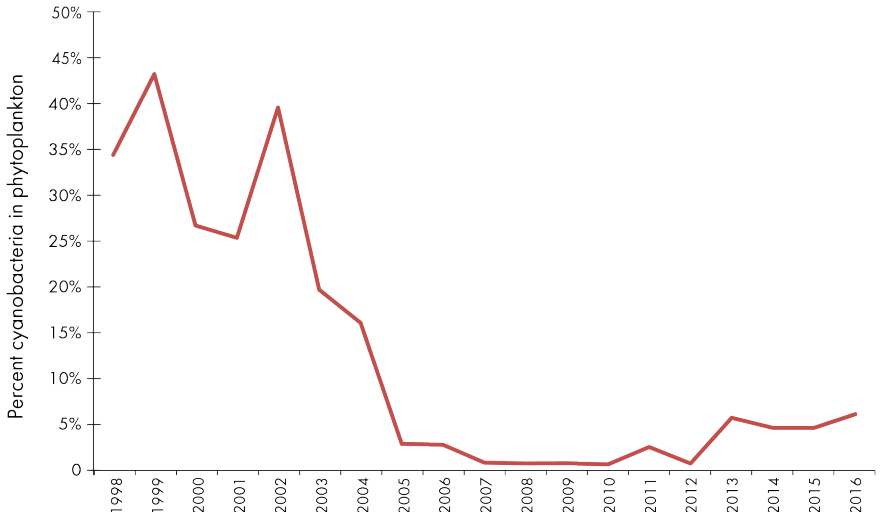

FIGURE 8. Cyanobacterial contribution to phytoplankton biomass, Onondaga Lake, June 1–Sept. 30, 1990–2016

Addressing the Combined Sewers

Like many older cities, portions of the City of Syracuse are served by combined sewers. These large pipes convey both wastewater and stormwater to Metro for treatment. During wet weather, the pipe capacity can be overwhelmed, resulting in overflows to nearby waterways and periodic exceedances of bacteria counts in the receiving waters.

Onondaga County is required to capture or eliminate 95% of the volume of combined sewage reaching the waterways by December 31, 2018. Save the Rain enabled the County to meet this aggressive goal in 2014, four years ahead of schedule.

In 2009, Onondaga County launched its **Save the Rain** program to meet the challenges of addressing combined sewer overflows. The program uses a multi-pronged approach that involves both conventional and innovative strategies. Since combined sewers convey both storm runoff and sewage to Metro, two conventional strategies to reduce the frequency and magnitude of overflow events include **sewer separation** (reconfiguring/adding pipes resulting in one for storm runoff and one for sewage) and **storage** (installing large tanks or tunnels to capture a portion of wet weather flows, thus ensuring pipe capacity and reducing the risk of overflows). The captured wet weather flows are conveyed to Metro for treatment once the storm is over. These measures are referred to as **gray infrastructure** because of the substantial concrete construction component of the projects. Seven gray projects have been completed at a cost of $147 million. This investment in sewer separation, piping, and storage facilities prevents over 201 million gallons of combined stormwater runoff and sewage from reaching Onondaga Lake and its tributaries each year.

Save the Rain also spearheads **green infrastructure** projects to **reduce the volume of stormwater runoff** that enters the combined sewer system. As a result of this program, Onondaga County has become a nationally recognized leader in application of green infrastructure solutions for stormwater management. Hundreds of projects have been installed across Syracuse, including green roofs, rain barrels, rain gardens, porous pavement, tree plantings, and vegetated swales. To date, more than 200 unique green infrastructure projects have been completed, including both public and private Green Improvement Fund (GIF) projects, with a total investment of $58.8 million; these projects—some large, some small—prevent an estimated 154 million gallons of stormwater from reaching the collection system.

Onondaga Lake as a Recreational Resource

Water quality conditions in much of Onondaga Lake support water contact recreation, and have for many years as displayed in Figure 9. With the exception of sites along the southern shoreline, where CSO-affected streams enter the lake, bacteria counts are within New York State health standards for water contact recreation. As documented in the technical report "Attainment of Designated Uses in Onondaga Lake" a beach located at Willow Bay would have been open continuously during the summer since 2008.

Much of the lake shoreline is in public ownership, with ongoing projects designed to connect the lake with the City of Syracuse and surrounding areas through trails, parklands, and destination venues. A collaborative research and monitoring program that includes the County's Department of Water Environment Protection (OCDWEP), SUNY College of Environmental Sciences and Forestry (SUNY-ESF), NYSDEC, and Honeywell is in place to track the fish community's response to changing water quality and habitat conditions.

This collaborative program documents that Onondaga Lake's fish community includes a diverse group of native and non-native species. Surveys conducted since the late 1980s have identified 66 fish species. Onondaga Lake is part of the Oswego River Basin and the fish community is similar to those found in Oneida Lake and the Seneca River. In the 1980s, the Onondaga Lake fish community consisted almost entirely of pollution-tolerant species; the current fish community includes pollution-sensitive species as well. The program has documented increasing numbers and expanding distribution of brown trout.

Many lake fishes are highly valued by anglers, including largemouth bass, smallmouth bass, walleye, brown trout, brown bullhead, yellow perch, and sunfish. Some fish, such as alewife, golden shiner, and other small species, are a food source for predatory fish. Still other species, such as longnose gar, bowfin, and the state-threatened lake sturgeon, are important for their unique appearance, life history, or relative scarcity.

Invasive species present in Onondaga Lake, like the zebra mussel, round goby, and alewife, have a profound effect on the lake ecosystem by altering food-web relationships, affecting water clarity, and changing nutrient exchange between the water and the bottom sediments. The research and monitoring efforts provide early warning of new invasive species. Further changes in the lake's fish community are anticipated as water quality and habitat conditions continue to improve.

Once rarely caught in Onondaga Lake, brown trout now persist throughout most of the year due to improved dissolved oxygen levels.

Similar to many New York State waterbodies, there are health advisories limiting consumption of fish from Onondaga Lake. The New York State Department of Health (NYSDOH) recommends that women under age 50 and children under age 15 eat no fish from the lake. This advisory is in place for several water bodies in the Finger Lakes region. The NYSDOH further advises eating no walleye, carp, channel catfish, or white perch from Onondaga Lake. The health advisory also applies to largemouth and smallmouth bass over 15 inches; these larger fish should not be consumed. Other fish species are considered safe for adult men, but with some warnings: limit consumption of brown bullhead and pumpkinseed to four meals per month, and other species to one meal per month.

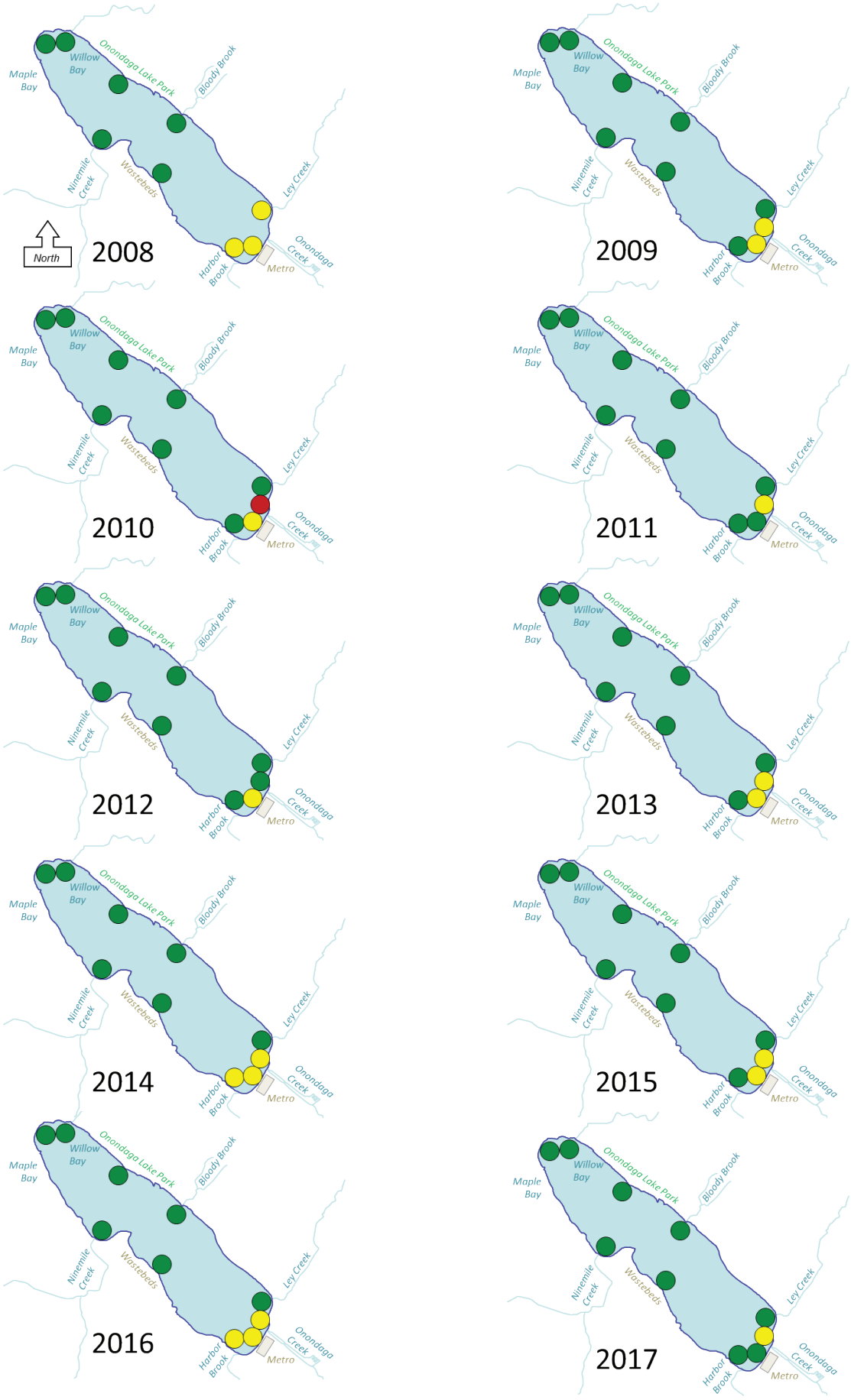

Figure 9. Percentage of summer months that meet water quality standards for bacteria at ten nearshore stations in Onondaga Lake, 2008–2017

Conclusions

This progress report describes how the changes in wastewater collection and treatment have brought about major improvements to Onondaga Lake. The large reductions in phosphorus and ammonia loading from Metro have profoundly altered the water quality and habitat conditions in Onondaga Lake. Improved stormwater management and Save the Rain's innovative green infrastructure projects have helped prevent bacteria-laden combined sewer overflows from reaching streams and nearshore lake areas.

The lake's biota has responded to the improving water quality and habitat conditions with increasing numbers of species as well as a shift in community composition to include more pollution-sensitive organisms. As algal blooms have become rare, increased light penetration has enabled the rooted aquatic plant (macrophyte) community to expand into deeper water. These macrophytes provide improved spawning and nursery habitat and stabilize the lake sediments, which further benefits water clarity. With the improving aesthetic conditions, thousands more people visit Onondaga Lake parks and shoreline each year to enjoy walking, fishing, biking, paddling, and community events. The investment in innovative wastewater and stormwater solutions has allowed the community to meet its vision and reconnect with Onondaga Lake.

MORE INFORMATION

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