Onondaga County Department of WATER ENVIRONMENT PROTECTION

Onondaga Lake

Ambient Monitoring Program: 2010

2010 Annual Report
November 2011
Revised March 2012

Onondaga County, New York
Joanne M. Mahoney, County Executive

ONONDAGA LAKE AMBIENT MONITORING PROGRAM

2010 ANNUAL REPORT

ONONDAGA COUNTY, NEW YORK

Revised March 2012

Prepared for

ONONDAGA COUNTY, NEW YORK

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Key Features of this Report

This report presents the findings of Onondaga County's Ambient Monitoring Program (AMP) for 2010. The County's annual monitoring program is designed to evaluate compliance with water quality standards and trends as improvements to the wastewater collection and treatment infrastructure are completed. Each year, the Onondaga County Department of Water Environment Protection collects extensive water quality and biological data to characterize Onondaga Lake and its watershed. This summary report of 2010 conditions provides a synopsis of the extensive data to the many stakeholders interested in Onondaga Lake.

The 2010 report was prepared and distributed as an electronic document. Key results and supporting tables and graphics are included in the main document, with links to supporting tables, technical reports and graphics in an electronic library. The report and supporting files are available on CD upon request and on the Onondaga County web site www.ongov.net/wep. Throughout the document, the reader will find hyperlinks to additional detailed tables, graphs and related reports. These hyperlinks appear as underlined words in the print copy. Simple definitions of many of the technical terms are included (roll the computer mouse over a highlighted term). These words and phrases will appear as shaded in the print copy. Maps and figures can be viewed at higher magnification by holding down the "ctrl" key and scrolling with the mouse wheel.

Once in the library of supporting documents, the reader can navigate back to the main report using browser navigation tools such as the back arrow. There are more than 200 supporting tables and graphics in the library of supporting materials. While each hyperlink has been checked, it is possible that some features will not be enabled on every computer's operating system. Feedback on the functionality of the electronic features of the document is welcome. Please contact JeannePowers@ongov.net with comments.

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Executive Summary

Introduction

This Annual Report of Onondaga County's Ambient Monitoring Program (AMP) describes the State of Onondaga Lake in 2010. Conducted annually since 1970, the County's monitoring program provides water resource managers, public officials, state and federal regulators, and the entire community a window into the significant changes evident in Onondaga Lake - both in the lake's water quality conditions and in its biological community.

Changes in the lake ecosystem are the result of multiple factors. Some of these factors reflect human intervention, notably, the significant investment in improved wastewater treatment technology and the ongoing efforts to remediate legacy industrial wastes. Other changes in the Onondaga Lake ecosystem reflect biological factors such as the fluctuating population of the alewife and its cascading effects on the lake's food web. The 2010 Annual Report documents the input of water and materials (bacteria, sediment, nutrients and salts) to Onondaga Lake from the watershed and the Metropolitan Syracuse Wastewater Treatment Plant (Metro). The lake's response to these inputs is a focus of the annual program; the AMP examines water quality conditions, compliance with ambient water quality standards, and trends. The AMP also examines the species composition and abundance of fish, phytoplankton, zooplankton, benthic invertebrates, aquatic plants and dreissenid (zebra and quagga) mussels.

Taken together, the 2010 AMP results illustrate an ecosystem in flux. This Executive Summary highlights selected measures of the lake's current water quality and biological conditions. Following this brief summary is the 2010 Annual AMP Report, where the major findings are discussed in detail, along with supporting documentation. These brief highlights are expanded to address additional topics.

Report Format

The 2010 AMP annual report is a concise summary of major findings with hyperlinks to a library of related materials, including tables and graphs of historic data, and reports of biological sampling. This paperless format was developed to advance two objectives: first, to reach a broader audience, and second, to continue to find ways to reduce our environmental footprint, through a commitment to green initiatives. This format was envisioned as a means to enable Onondaga County leaders and citizens to learn about the condition of Onondaga Lake and its watershed. Additional program information is on the County web site http://www.ongov.net/wep/we15.html Annual reports from prior years are at http://www.ongov.net/wep/we1510.html

Finding: Improvements to the Wastewater Collection and Treatment System have Reduced Nutrient Loading to Onondaga Lake

Prior to 2005, excessive discharges of municipal and industrial wastewaters and runoff from urban and rural areas adversely affected the quality of Onondaga Lake and prevented the lake from meeting its designated use for water contact recreation and aquatic life protection. Other factors, including altered water levels and loss of wetlands, contributed to degradation of this once-valued resource. Elevated counts of indicator bacteria and poor water clarity, mostly resulting from elevated phosphorus concentrations and algal blooms, made the lake unsuitable for contact recreation. Elevated ammonia and nitrite nitrogen concentrations, low dissolved oxygen (DO) levels, and lack of habitat contributed to poor conditions for the biological community.

In light of the lake's water quality impairments, Onondaga County undertook a program of engineering improvements to the Metro wastewater treatment plant to enhance ammonia and phosphorus removal. Two new treatment systems came on line. In January 2004, the Biological Aerated Filter (BAF) system providing year-round nitrification (conversion of ammonia to nitrate) became operational and resulted in a 98% decrease in Metro's ammonia loading to the lake (Figure EX-1).

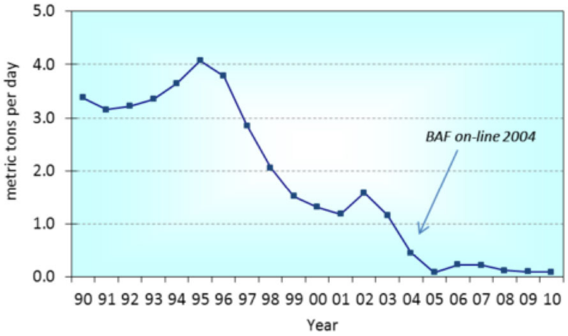


Figure EX- 1. Daily average discharge of Ammonia-N (NH_3-N) to Onondaga Lake from Metro, 1990-2010.

A physical-chemical High-Rate Flocculated Settling (HRFS) technology, known as Actiflo®, came on line in February 2005 to enhance phosphorus removal. This system has resulted in an 86% decline in phosphorus discharged from Metro to Onondaga Lake (Figure EX-2).

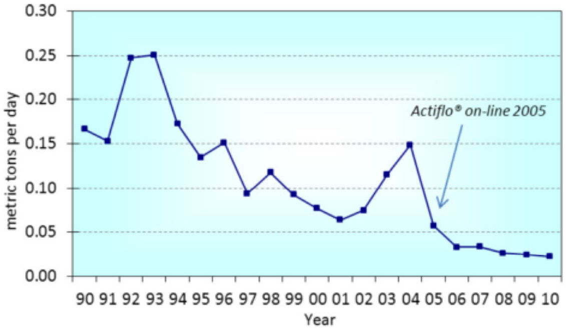


Figure EX- 2. Daily average phosphorus (TP) loading from Metro, 1990-2010.

Finding: Reduced Ammonia and Phosphorus Loading from Metro have Improved Water Quality Conditions

The 2010 monitoring results document the continued significant improvements in Onondaga Lake brought about by reduced ammonia and phosphorus input from Metro. The 98% reduction in ammonia input from Metro has brought Onondaga Lake waters into full compliance with the state ambient water quality standards for ammonia, designed to protect sensitive aquatic life (Figure EX-3). With improved wastewater treatment, Metro has become a far less significant source of ammonia to the lake (Figure EX-4). In recognition of the effectiveness of Metro's ammonia treatment technology, in 2008 NYSDEC removed Onondaga Lake from the state's 303(d) list as impaired by excessive ammonia concentrations. The reduction in ammonia concentrations has allowed many more aquatic species to live and reproduce in the lake.

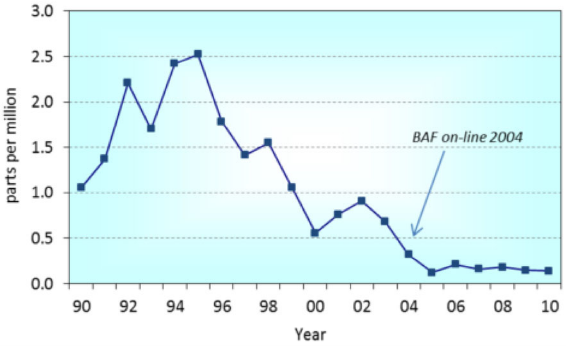


Figure EX- 3. Annual average ammonia-N concentrations, Onondaga Lake upper waters (0-3 m), 1990-2010.

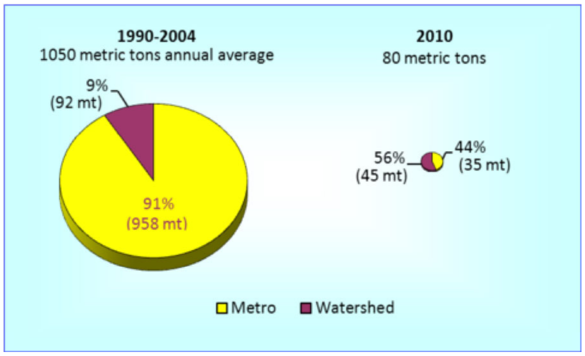


Figure EX- 4. Ammonia input to Onondaga Lake, 1990-2004 and 2010.

Total phosphorus (TP) concentrations in the lake's upper waters have shown a steep decline over the last two decades (Figure EX-5). The summer 2010 upper waters TP averaged 25 µg/l, which is comparable to conditions in nearby Oneida Lake and several of the smaller Finger Lakes. Summer phosphorus levels vary in response to Metro performance and phosphorus inputs from the large watershed. Watershed phosphorus input depends on the amount, timing and intensity of precipitation, as well as with progress toward best management practices and improved stormwater management.

During 2010, less than 20% of the TP input to Onondaga Lake was attributable to Metro, representing a significant decrease from an average of about 60% prior to the major investments in improved wastewater treatment technology (Figure EX-6).

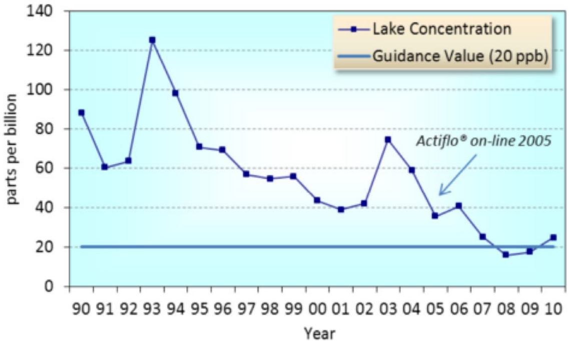


Figure EX- 5. Average total phosphorus concentration, June 1 – Sept 30, Onondaga Lake upper waters (0-3 m), 1990-2010.

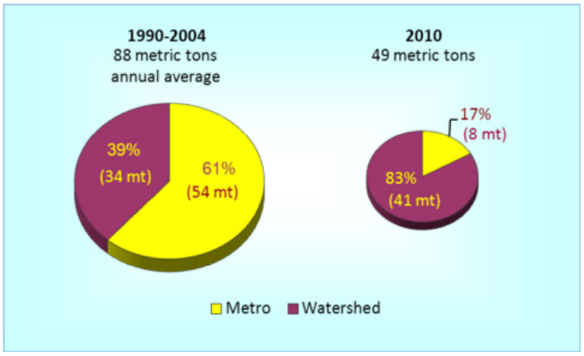
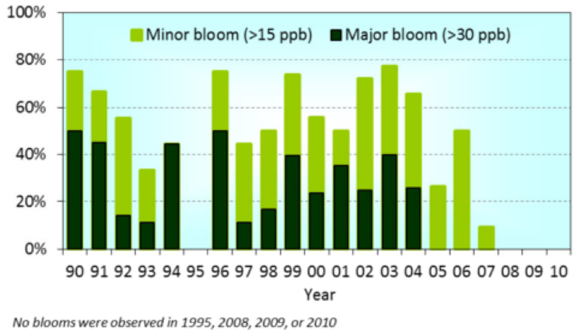


Figure EX- 6. Total phosphorus input to Onondaga Lake, 1990-2004 and 2010.

With the reduction in nutrient levels, algal blooms have become less frequent. Since 2005, the lake has exhibited no major algal blooms, which are defined as chlorophyll-a measurements above 30 µg/L, a unit of measurement equivalent to a part per billion (abbreviated as ppb). Moreover, between 2008 and 2010 there have been no minor algal blooms, which are defined as chlorophyll-a measurements above 15 µg/L, (Figure EX-7). This reduction in algal abundance has improved dissolved oxygen conditions in the lake's deep waters. Algal cells settle through the water column and decompose in the deep waters; this process depletes dissolved oxygen (DO) and ultimately affects aquatic habitat. With the reduction in algal abundance, deep-water DO resources are improving; the volume of the lake affected by low DO and the duration of low DO (reported as volume-days of anoxia) are in decline, indicating improved habitat conditions (Figure EX-8).

Low DO in upper waters in October – during fall turnover - was one of the lake's most significant water quality impairments with respect to protection of aquatic life. Since the advanced wastewater treatment at Metro became operational in 2005, the fall DO concentrations have remained consistently high, as measured by frequent in-situ profile sampling during the fall mixing period (Figure EX-9).



No blooms were observed in 1995, 2008, 2009, or 2010

Figure EX- 7. Summer algal bloom frequency, Onondaga Lake, 1990 – 2010.

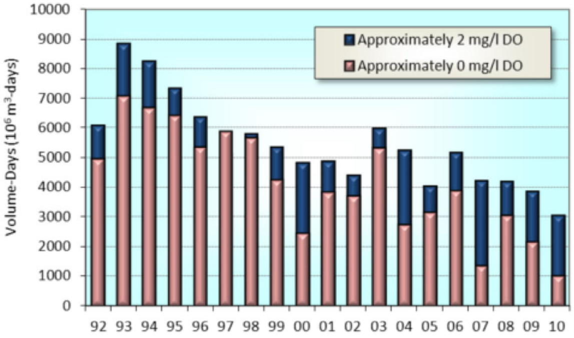


Figure EX- 8. Volume-days of anoxia (dissolved oxygen less than 0.5 mg/l) and hypoxia (dissolved oxygen less than 2 mg/l), Onondaga Lake 1992-2010.

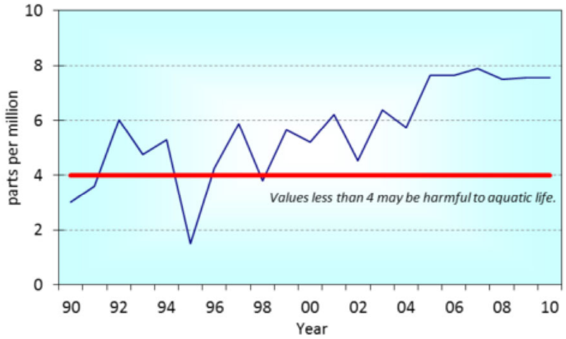


Figure EX- 9. Minimum DO concentration in upper waters (0-3 m) during fall turnover (October) in Onondaga Lake, 1990 – 2010.

Finding: Reduced Nutrient and Algae Levels, and Improved Oxygen Resources are reflected in a Changed Biological Community

The reduction in phosphorus and algae has resulted in clearer water throughout the lake. Light penetrates deeper into the lake, and supports the growth of macrophytes (rooted aquatic plants and bottom-dwelling algae) in nearshore shallow waters (the littoral zone). Macrophytes are an important component of the lake's ecology; they produce food for other organisms, provide habitat for aquatic invertebrates, fish, and wildlife, and help stabilize sediments. The percent of the littoral zone with macrophytes has increased five-fold since 2000 (Figure EX-10).

Not only are there more plants, a 2010 macrophyte survey revealed that the lake's macrophyte community has become far more diverse (Figure EX-11). Five of the 23 species found during the 2010 survey were not present in the 2000 or 2005 surveys. The increasing macrophytes provide spawning and nursery habitat, shelter and food for the fish community. Angler catch rates of gamefish such as largemouth bass have generally increased since 2000, while the catch of smallmouth bass is declining (Figure EX.12).

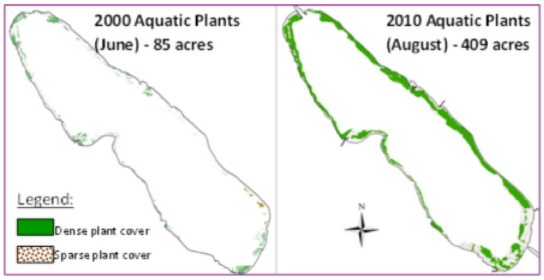


Figure EX- 10. Aquatic plant coverage, 2000 and 2010.

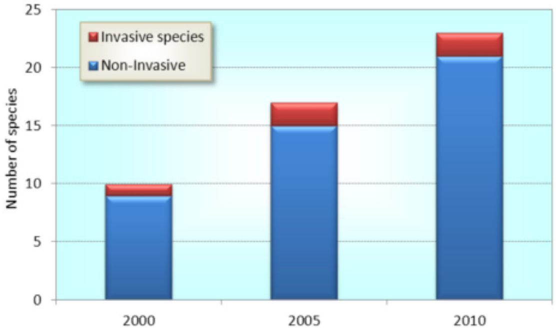


Figure EX- 11. Number of macrophyte species identified in Onondaga Lake, 2000, 2005 and 2010.

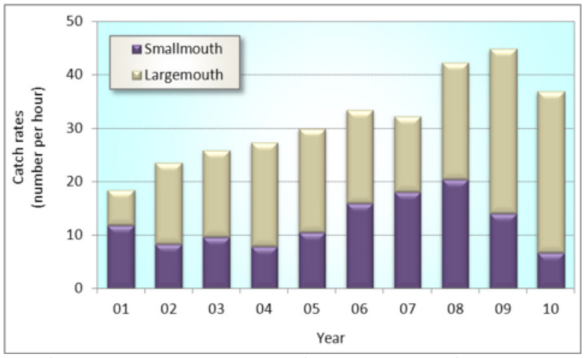


Figure EX- 12. Bass (smallmouth and largemouth adults) captured by electrofishing in Onondaga Lake, 2001 – 2010.

Several important metrics of the fish community consider the diversity and richness of the adult fish community, both littoral (near-shore) and pelagic (open water). Richness is a count of the number of species within a community, while diversity considers both the number of species present and their relative abundance. In Onondaga Lake, richness has increased over the decade of AMP monitoring, from 24 species in 2000 to 28 species in 2010; researchers at SUNY College of Environmental Science and Forestry have captured additional species using different sampling methods. Surveys conducted since 1987 have identified a total of 64 fish species in the lake, making the species richness of Onondaga Lake comparable to that of regional waters. The lake is an open system, with easy migration into and from connected waterways through the Seneca River system.

Diversity of the fish community fluctuates in response to the periodic peaks and crashes of two species of clupeid, the alewife (*Alosa pseudoharengus*) and gizzard shad (*Dorosoma cepedianum*). Abundance of these two species of the herring family is highly variable, as Onondaga Lake is near the northern edge of their range, and both species periodically exhibit significant winter mortality. Extremes in recruitment are common; both species periodically produce very strong year classes that dominate the catch for years, as individual fish can live 10 years or longer. In 2010, the alewife dominated the lake fish community, representing almost 74% of the entire catch; yellow perch and pumpkinseed sunfish were the next dominant species.

Onondaga Lake's aquatic food web continues to include new species, both native and non-indigenous (exotic), with increasingly complex pathways of material and energy transfer among the life stages of the biota. This increasing complexity with regard to energy sources and energy flow results in an ecosystem that may be more resilient to environmental stress. The results of the 2010 AMP indicate that this is an ongoing process and that more changes are likely to occur. As lake water quality continues to improve, resulting in more diverse and higher quality habitat conditions, increases in aquatic species diversity, abundance, and interrelatedness can also be expected.

Finding: Biological Impacts on Water Clarity are Increasingly Apparent

Because the AMP includes monitoring water quality and biological parameters, it is possible to analyze the relative effects of "bottom-up" (nutrient management) controls and "top-down" (food web) controls on the lake's trophic condition. Clearly, nutrient reductions at Metro have affected the lake's algal abundance, water clarity and DO concentrations. Food web effects are also important, however, and now that Onondaga Lake is in the mesotrophic range, the impact of fluctuations in the abundance of two key species – alewife and dreissenid mussels - has become increasingly apparent.

The alewife and dreissenid mussels have a major impact on food web dynamics in Onondaga Lake. Analysis of the 2010 data has indicated that another strong year class of alewife was produced in 2009, comparable to 2002. This fish is a selective grazer of the larger zooplankton species; heavy predation by the alewife in 2010 virtually eliminated large zooplankton in the lake. The average zooplankton size in 2010 declined to the lowest value measured during the AMP (Figure EX-13).

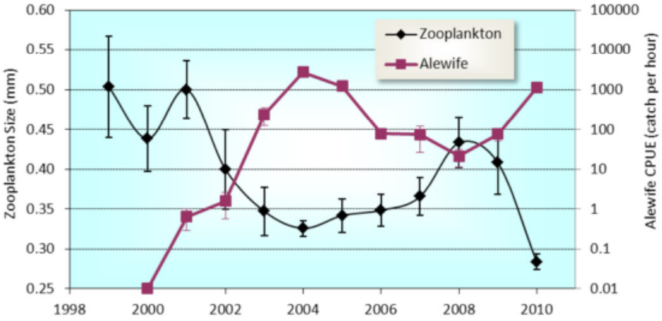


Figure EX- 13. Average zooplankton size (all taxa combined) and alewife catch rates from electrofishing, 2000-2010, Onondaga Lake.
Note: error bars are standard error of the mean.

The loss of larger zooplankton, which are far more efficient grazers of phytoplankton, was evident in the 2010 algal community as well. Without the larger zooplankton to graze on phytoplankton, the standing crop increased and water clarity diminished (Figure EX-14).

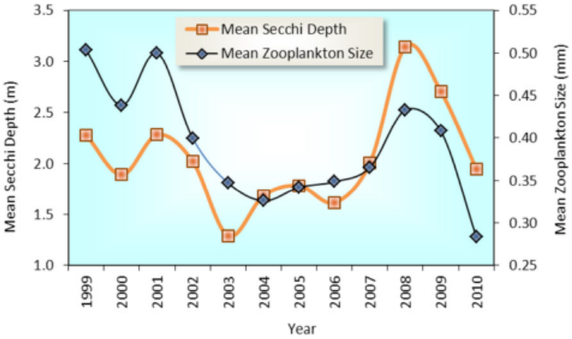


Figure EX- 14. Mean Secchi disk depth measurements and mean zooplankton size, Onondaga Lake, 1999 – 2010.

Finding: Monitored Locations in the Lake's Class B Nearshore Areas Met Bacteria and Water Clarity Standards for Recreational Contact

The 2010 data from the County's monitoring program indicate that bacterial levels at the monitoring stations were less bacteria standards for contact recreation, except along the southern shoreline following high rainfall and runoff conditions. The southern shoreline is in the Class C segment of Onondaga Lake, this segment remains on the New York State 2010 List of Impaired Waterbodies for fecal coliform bacteria. The fecal coliform bacteria standard is used by NYSDEC to evaluate water quality and by NYS Department of Health to evaluate suitability for swimming at designated beaches.

For water clarity, the NYSDOH has a swimming safety guidance value of 1.2 m (4 ft.) at designated beaches. Secchi disk measurements at the Class B nearshore stations were greater than the 1.2 m guidance value, while a few incidences of diminished water clarity were detected at the Class C stations along the southern shoreline in 2010. These incidences were associated with high rainfall and runoff conditions.

Measuring Progress toward Improvement: Metrics

Onondaga County Department of Water Environment Protection, in consultation with NYSDEC and the Onondaga Lake Technical Advisory Group, has developed a suite of metrics to help organize and report on the extensive AMP data set each year. These metrics relate to the lake's designated "best use" for water contact recreation, fishing and protection of aquatic life. The 2010 results (Table EX-1) document that water quality conditions fully support the lake's designated uses in the Class B segment.

Table EX- 1. Summary of metrics, Onondaga Lake 2010.

Metrics	Measured By	Target	2010 Results	Significance
Improved Suitability for Water Contact Recreation				
Indicator bacteria	Percent of months in compliance with AWQS[1] for fecal colilform bacteria and with federal criteria for E. coli, April – October (disinfection period). Measured at nearshore sites, Class B segment	100% (both indicators)	100% (both indicators)	Class B segments of Onondaga Lake met the designated use for water contact recreation
Water clarity	Percent of observations with Secchi disk transparency at least 1.2 m (4 ft.) to meet swimming safety guidance[2], June – Sept (recreational period). Measured at nearshore sites, Class B segment	100%	100%	
Improved Aesthetic Appeal				
Water clarity	Summer average Secchi disk transparency at least 1.5 m Measured at South Deep during the summer recreational period (June- Sept.).	Summer average 1.5 m	Summer average 1.9 m	By these metrics, the lake met its designated use as an aesthetic resource
Algal blooms	Algal abundance low in summer and the lake is free of nuisance algal blooms[3]. Measured by the magnitude, frequency and duration of elevated chlorophyll-a during the summer recreational period (June- Sept).	No more than 15% of chlorophyll –a measurements are above 15 ppb; no more than 10% of observations are above 30 ppb	100% of observations less than 15 ppb	
Algal community structure	Low abundance of cyanobacteria (blue-green algae)	Cyanobacteria represent no more than 10% of the algal biomass	Cyanobacteria were less than 1% of the algal biomass	
Improved Aquatic Life Protection				
Ammonia	In-lake Ammonia N concentrations compared to AWQS[1]	100% of measurements in compliance, all depths and all times	100% of measurements in compliance, all depths and all times	By these metrics, the lake met its designated use for aquatic life protection (warm water fishery)
Nitrite	In-lake Nitrite N concentrations[1] (upper waters)	100%	100%	
Dissolved oxygen	Daily average during fall turnover[1] Instantaneous minimum[1]	>5 mg/l >4 mg/l	7.6 mg/l 7.4 mg/l	
Improving Sustainable Recreational Fishery				
Habitat quality	Percent of the littoral zone that is covered by macrophytes	40%	54%	Littoral zone macrophyte coverage provides high quality habitat for warm water fish community
Fish reproduction	Reproduction of target species: • Bass and sunfish • yellow perch • black crappie • rock bass • walleye and northern pike	 Occurring Occurring Occurring Occurring Occurring	 Occurring No evidence No evidence No evidence No evidence	Fish reproduction for several target species has not been observed. Adult population of these species are stable and, in some cases, increasing.
	The lack of suitable spawning habitat, not water quality, is the limiting factor for the reproduction of some fish species in the lake. Habitat restoration and enhancement are included in the Honeywell lake restoration efforts.			
Fish community structure	Percent of fish species intolerant or moderately intolerant of pollution	Increasing presence of fish species sensitive to pollution	4%	The Onondaga Lake fish community includes mostly warmwater species. Most warmwater fish species are classified as relatively tolerant of pollution.

[1] Ambient water quality standards (AWQS), criteria and guidance regulatory citations are as follows:

- *E. coli* Ambient Water Quality Criteria for Bacteria 1986 - EPA440/5-84-002, (http://water.epa.gov/type/oceb/beaches/upload/2009_04_13_beaches_1986crit.pdf)
- fecal coliform bacteria 6 NYCRR Part 703.4 (http://www.dec.ny.gov/regs/4590.html#16133)
- ammonia-N and nitrite-N 6 NYCRR Part 703.5 (http://www.dec.ny.gov/regs/4590.html#16130)
- dissolved oxygen 6 NYCRR Part 703.3 (http://www.dec.ny.gov/regs/4590.html#16132)

[2] Secchi depth water clarity swimming safety guidance of 4 ft. NYSDOH Title 10, Section 7-2.11 - Recreational safety (http://www.health.ny.gov/nysdoh/phforum/)

[3] Algal blooms defined as "impaired" at >15 ug/l (USEPA threshold for public perception as impaired for recreational use); defined as "nuisance" at >30 ug/l (threshold for public perception of nuisance bloom, Restoration and Management of Lakes and Reservoirs by G.D. Cooke)

Biological metrics were developed in consultation with members of the Onondaga Lake Technical Advisory Committee and other stakeholders participating in the annual meetings and reviews.

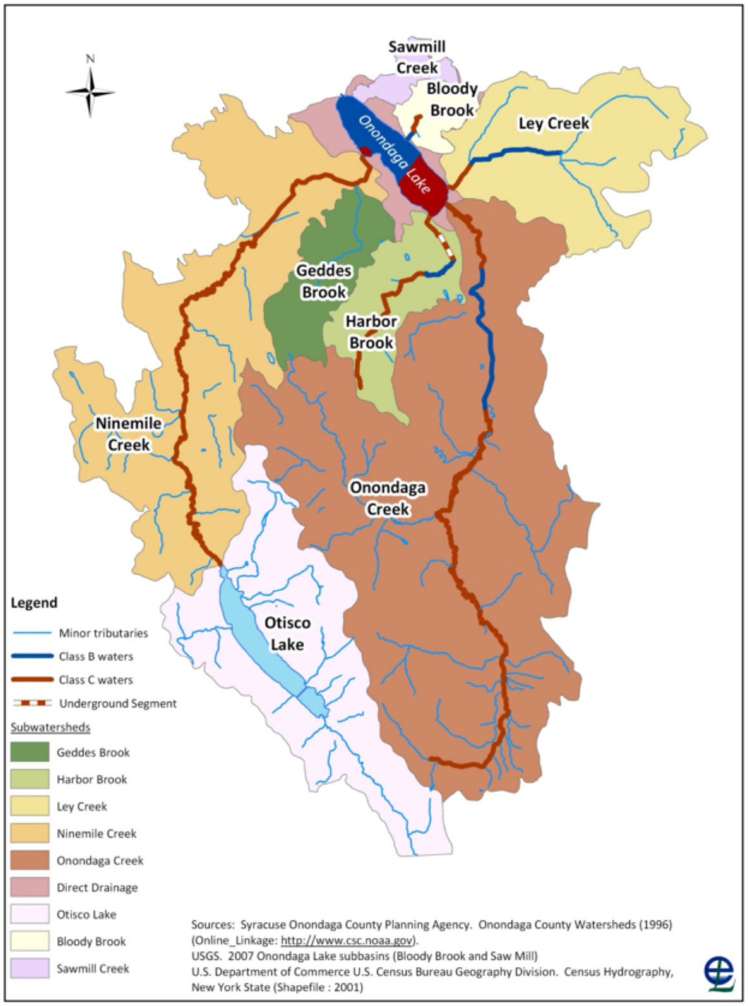
Section 1. Introduction to the AMP

1.1 Regulatory requirements

The 2010 Annual Ambient Monitoring Program (AMP) report has been prepared and submitted to the New York State Department of Environmental Conservation (NYSDEC) to comply with a judicial requirement set forth in the 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation. The parties have modified the ACJ four times since 1998, most recently by stipulation in November 2009. The ACJ requires a series of improvements to the County's wastewater collection and treatment infrastructure, and an extensive monitoring program (the AMP) to document the improvements achieved by these measures. Onondaga County Department of Water Environment Protection (WEP) is responsible for implementing the AMP and reporting on its findings. Links to the ACJ and the fourth stipulation are posted on the Onondaga County web site http://www.ongov.net/wep/we15.html.

1.2 Classification and Best Use

NYSDEC classifies surface waters, including lakes, rivers, streams, embayments, estuaries and groundwater with respect to their best use. Onondaga Lake and its tributaries are currently classified as Class B and Class C waters (Figure 1-1). The best usages of Class B waters are primary and secondary water contact recreation and fishing (NYCRR Part 701.7). 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 (NYCRR Part 701.7). 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 (NYCRR Part 701.8).



Sources: Syracuse Onondaga County Planning Agency. Onondaga County Watersheds (1996) (Online_Linkage: http://www.csc.noaa.gov).
USGS. 2007 Onondaga Lake subbasins (Bloody Brook and Saw Mill)
U.S. Department of Commerce U.S. Census Bureau Geography Division. Census Hydrography, New York State (Shapefile : 2001)

Figure 1-1. Tributary and lake regulatory classifications and subwatershed boundaries.

1.3 AMP Objectives and Design

Onondaga County WEP designed the AMP to meet several specific objectives related to the effectiveness of the required improvements to the wastewater collection and treatment infrastructure. Trained field technicians collect representative samples from a network of permanent sampling locations along the lake tributaries, nearshore and deep stations in Onondaga Lake (Figure 1-2), and along the Seneca River (see Figure 7-1, in Section 7), and evaluate water quality conditions and the nature of the biological community. These data are interpreted to determine whether designated uses are, in fact, supported in the waterways.

In addition to the overall assessment of use attainment, Onondaga County personnel rely on the AMP data for several related objectives:

- to identify sources of materials (nutrients, sediment, bacteria and chemicals) entering the lake,

to evaluate stream and lake water quality conditions with respect to compliance with ambient water quality standards (AWQS) and guidance values,
to understand the interactions between Onondaga Lake and the Seneca River,
to track the nature of the biological community, and
to support development of mechanistic models for managing water quality conditions.

A Data Analysis and Interpretation Plan (DAIP) (Table 1-1) guides program design and is a component of the annual workplan, and thus subject to NYSDEC review and approval. In addition to approving the annual workplan and AMP report, NYSDEC participates in technical discussions of the AMP results and their implications.

Each year, Onondaga County reviews the laboratory data for quality assurance/quality control criteria prior to uploading the analytical data set to the database; this custom database archives the complete set of Onondaga Lake and tributary monitoring results since 1970. In addition, field activities of both the water quality and biological monitoring programs are audited annually to ensure that they are carried out in accordance with the approved workplan. The Onondaga County Laboratory participates in a program of Environment Canada documenting proficiency of low-level phosphorus and mercury analyses in natural waters.

The ACJ directs Onondaga County to consider results of other investigators in framing a conceptual model of how the lake functions. To this end, the County maintains a bibliography of published materials related to Onondaga Lake. The bibliography serves the AMP team and the community at large by compiling references to investigations by agencies of local government, regulatory agencies, university researchers, and private companies working on various aspects of the Onondaga Lake restoration effort. The findings of these investigations help inform the AMP team in data analysis and interpretation.

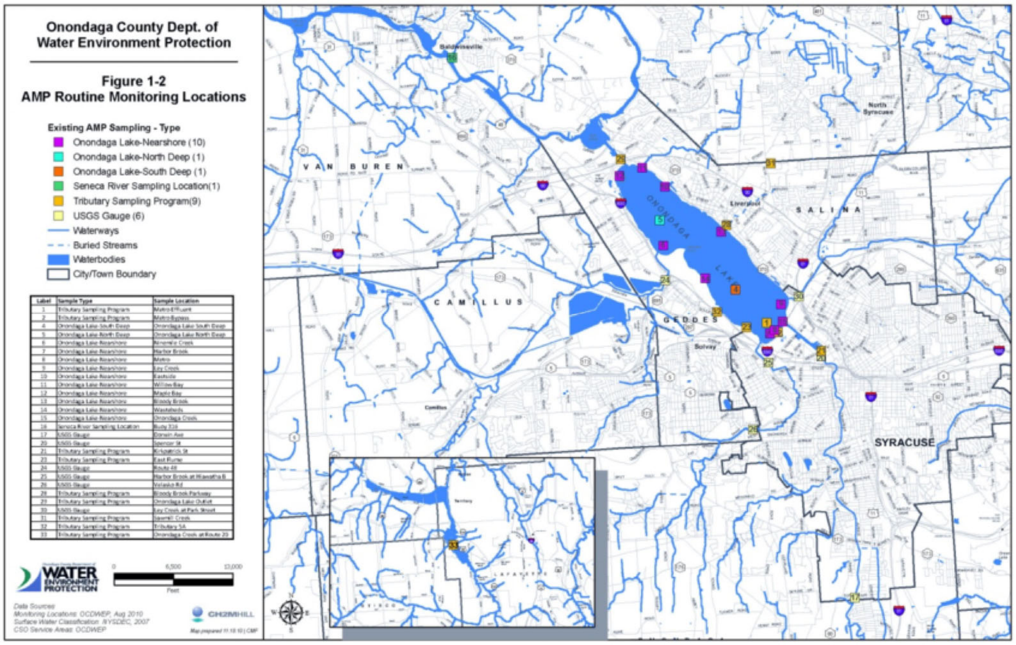


Figure 1-2. Map of monitoring locations, Onondaga Lake and tributaries.

Table 1-1. Overview of AMP data analysis and interpretation plan.

Parameters	Sampling Locations	Compliance	TMDL Analysis	Trend Analysis	Trophic Status	Load Analysis	Model Support	Use Attainment	Effectiveness of CSO control measures	Indicator of Water Clarity	Nutrient Cycling	Habitat Conditions	Lake Ecology
Chemical													
Alkalinity	L, T			✓									
Bacteria	L, T	✓		✓		✓	✓	✓	✓				
BOD-5	L, T, R			✓		✓	✓						
Carbon	L, T, R			✓	✓	✓	✓						
Mercury	L, T	✓		✓									
Metals/Salts	L, T, R	✓		✓		✓	✓						
Nitrogen	L, T, R	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Phosphorus	L, T, R	✓	✓	✓	✓	✓	✓				✓		✓
Silica	L				✓								✓
Solids	L, T, R	✓		✓			✓						
Sulfides	L						✓						
Physical													
Conductivity	L, T, R	✓		✓			✓	✓					
Dissolved oxygen	L, T, R	✓		✓	✓		✓	✓					✓
LiCor illumination	L, R			✓	✓		✓	✓		✓			✓
Salinity	L, T, R	✓		✓			✓	✓					
Secchi transparency	L, R	✓		✓	✓		✓	✓		✓			✓
Turbidity	L, T, R	✓		✓			✓			✓			
Biological													
Chlorophyll/algae	L, T, R			✓	✓		✓	✓					✓
Zooplankton	L			✓									✓
Macrophytes	L			✓			✓					✓	✓
Macroinvertebrates	L, T			✓								✓	✓
Fish	L			✓								✓	✓

Locations:
L = Lake; T = Tributaries; R = Seneca River.

1.4 Amended Consent Judgment Milestones

The ACJ stipulates a series of specific engineering improvements to the County's wastewater collection and treatment infrastructure. Onondaga County has agreed to undertake a phased program of Metro improvements (Table 1-2).

Other remedial programs abate the impacts of combined sewer overflows (Table 1-3). Combined sewer overflows (CSOs) serve older portions of the City of Syracuse. These utilities carry both sewage and storm water in a single pipe. During heavy rain and snowmelt, the pipes can overflow, and a mixture of stormwater and untreated sewage flows into creeks and ultimately reaches Onondaga Lake. When these overflows occur, the mixture of stormwater and untreated sewage carries bacteria, floating trash, organic material, nutrients and solid materials through the CSOs to the waterways. Together, the improvements to the wastewater collection and treatment infrastructure are scheduled through 2018.

Table 1-2. Metro compliance schedule.
(lb/d = pounds per day; mg/l = milligrams per liter)

Parameter	SPDES Limit	Effective Date	Achieved Date
Ammonia	*Stage I :* 8,700 lb/d (7/1-9/30) 13,100 lb/d (10/1-6/30)	January 1998	January 1998
	Stage II: 2 mg/l (6/1-10/31) 4 mg/l (11/1-5/31)	May 2004	February 2004
	Stage III: 1.2 mg/l (6/1-10/31) 2.4 mg/l (11/1-5/31)	December 2012	February 2004
Total Phosphorus	*Stage I :* 400 lb/d (12-month rolling average)	January 1998	January 1998
	Stage II: 0.12 mg/l (12-month rolling average)	April 2006	April 2006
	Revised Interim Stage II: 0.10 mg/l (12-month rolling average)	November 2010	November 2010
	Stage III: 0.020 mg/l (or as modified by TMDL)	December 2015 (or as modified by TMDL)	Pending

Table 1-3. CSO compliance schedule.

Project Phase	Goal	Effective Date
Stage I	Capture for treatment or eliminate 89.5% of combined sewage* during precipitation, within the meaning of EPA's National CSO Control Policy	Dec 31, 2013
Stage II	Capture for treatment or eliminate 91.4% of combined sewage during precipitation, within the meaning of EPA's National CSO Control Policy	Dec 31, 2015
Stage III	Capture for treatment or eliminate 93% of combined sewage during precipitation within the meaning of EPA's National CSO Control Policy	Dec 31, 2016
Stage IV	Capture for treatment or eliminate 95% of combined sewage during precipitation within the meaning of EPA's National CSO Control Policy	Dec 31, 2018

**on a system-wide annual average basis*
(per fourth stipulation to ACJ, Nov. 2009)

1.5 Projects to address legacy industrial pollution

Honeywell International is proceeding with a number of projects to address industrial contamination issues, with oversight by the federal Environmental Protection Agency (EPA) and NYSDEC. Projects include intercepting and treating contaminated groundwater, removing contaminated sediments and restoring shoreline and littoral habitats. Detailed descriptions of Honeywell's planned remedial projects, designed to prevent the flux of contamination into the lake and restore aquatic habitat, are on the NYSDEC web site http://www.dec.ny.gov/chemical/48828.html.

1.6 Use of metrics to measure and report progress

Onondaga County, in consultation with members of the Onondaga Lake Technical Advisory Committee (OLTAC), has selected a suite of metrics to organize and report on the extensive AMP data collected each year. The metrics focus on key indicators of the lake's health and are used to track progress toward compliance and attainment of designated uses (refer to Table EX-1). Metrics selected for Onondaga Lake address both human uses and ecosystem function:

- water contact recreation;
- aesthetics;
- aquatic life protection; and
- sustainable recreational fishery.

In addition to the annual snapshot provided in the table of metrics, series of more detailed tables are prepared to describe progress toward improvement with respect to specific water quality and biological attributes of Onondaga Lake. These summaries provide an overview of the monitoring program design, criteria used to evaluate progress, and a summary of temporal trends.

Section 2. Onondaga Lake and Watershed

2.1 Watershed size and hydrology

The Onondaga Lake watershed encompasses approximately 285 square miles almost entirely within Onondaga County, including six natural sub-basins: Onondaga Creek, Ninemile Creek, Ley Creek, Harbor Brook, Bloody Brook and Sawmill Creek (refer to Figure 1-1). Tributary 5A and the East Flume direct runoff and industrial discharges into the lake. Onondaga County's Metro treatment plant discharges to Onondaga Lake. Onondaga Creek is the largest water source to the lake, followed by Ninemile Creek, Metro, Ley Creek, Harbor Brook, minor tributaries and direct runoff (Figure 2-1). Much of the annual volume of treated wastewater flowing to Onondaga Lake though the Metro treatment plant originates outside of the watershed; water supply for the City of Syracuse is drawn from Skaneateles Lake, and for suburban towns and villages, Lake Ontario. Onondaga Lake discharges into the Seneca River, which flows in a northerly direction and joins the Oneida River to form the Oswego River, ultimately discharging into Lake Ontario.

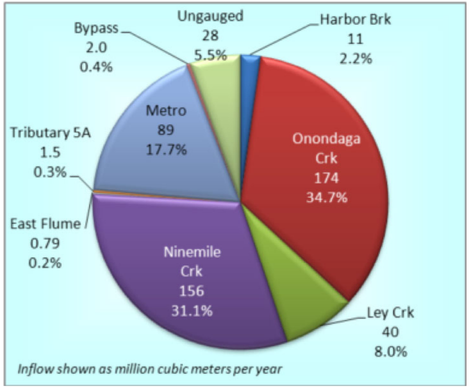
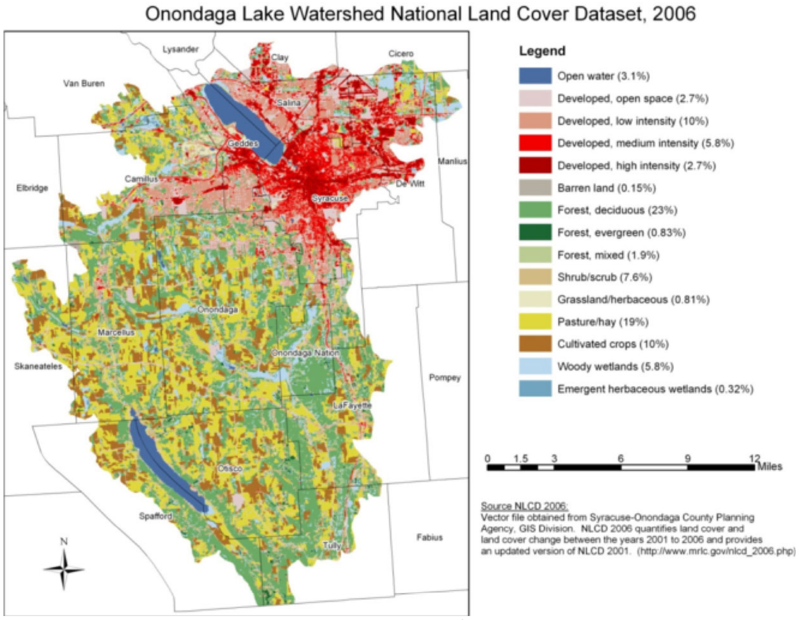


Figure 2-1. Annual average inflows to Onondaga Lake, 2001-2010.

Each year, the tributaries convey surface runoff and groundwater seepage from the large watershed toward Onondaga Lake. The volume of runoff, and consequently streamflow varies each year depending on the amount of rainfall and snow cover. Overflows from the combined sewer system also vary in response to the intensity and timing of rainfall events, and, to a lesser degree, snowmelt. The Metro effluent volume exhibits less annual variation, although the effects of extreme wet or dry years can be detected due to the portion of the service area served by combined sewers.

2.2 Land use

Compared with other lakes in the Seneca-Oneida-Oswego river basin, the watershed of Onondaga Lake is relatively urbanized, as displayed in Figure 2-2, a map of land cover updated in 2006. The National Land Cover Dataset classified approximately 28% of the watershed as developed (urban/suburban), 33% as forested or scrub/shrub, and 30% as cultivated lands or pasture. The remaining 9% is comprised of wetlands, lakes and barren land. Urban areas of the City of Syracuse, two towns and two villages border the lake.



Source NLCD 2006:
Vector file obtained from Syracuse-Onondaga County Planning Agency, GIS Division. NLCD 2006 quantifies land cover and land cover change between the years 2001 to 2006 and provides an updated version of NLCD 2001. (http://www.mrlc.gov/nlcd_2006.php)

Figure 2-2. Land cover classification map.

2.3 Morphometry

Onondaga Lake is relatively small. The lake's depth averages 10.9 meters (m), with a maximum of 19.5 m. Its bathymetry is characterized by two minor depressions, referred to as the northern and southern basins (also referred to as North and South Deep in much of the literature), separated by a shallower region near the center of its longitudinal axis (Figure 2-3). The littoral zone, defined as the region of the lake where light reaches the sediment surface and consequently supports the growth of rooted plants, is constricted as illustrated by the proximity of the depth contours on the bathymetric map. Under current water clarity conditions, macrophyte growth extends to a water depth of approximately 6 m; this is a more extensive littoral zone than evident in the late 1990s.

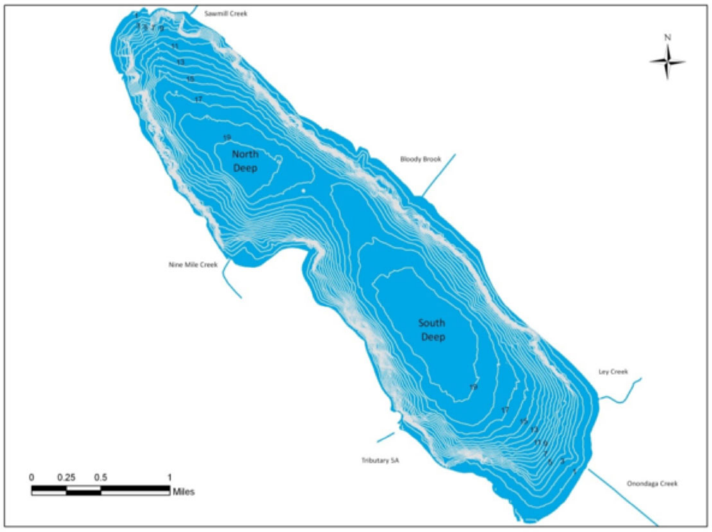


Figure 2-3. Bathymetric map.

The Onondaga Lake shoreline is highly regular with few embayments. Onondaga County owns most of the shoreline, and maintains a popular park and trail system. Syracuse residents and visitors use the parklands for varied recreational activities and cultural entertainment. The lake is increasingly popular for boating; sailboats, motorboats, kayaks and canoes are familiar sights on summer days. Local and regional fishing tournaments attract anglers to the lake and shoreline each year.

Because Onondaga Lake is relatively small and shallow, and receives drainage from a large watershed, the water residence time is short. Water residence time is defined as the average time water remains in the lake, and is dependent on lake size, depth, and inflow volume. A large watershed with a small lake will have a shorter water residence time. For Onondaga Lake, there are 62 km^2 of watershed area for each km^2 of lake surface area. Because of the large watershed and abundant rainfall, the inflowing water is sufficient to replace the entire lake volume about four times each year; the average water residence time is about three months. Deeper lakes with smaller watersheds have a longer water residence time. For example, Skaneateles Lake has a watershed area to lake area ratio of 4.3 and a water residence time of 18 years. Oneida Lake provides another example; this large, shallow lake has a watershed area to lake area ratio of 17 and a water residence time of one-half year.

Section 3. Onondaga County Actions

By signing the ACJ in 1998, Onondaga County agreed to design and construct a series of engineering improvements to the Metro service area. The County has now completed many improvements to the Metro wastewater treatment plant and the wastewater collection system, including the combined sewers (Table 3-1). The improvements to Metro have altered the speciation of nitrogen in the fully-treated effluent; and resulted in year-round nitrification of the wastewater effluent.

Abating the CSOs is a significant challenge. The County has employed four strategies to reduce wet weather discharges from the combined sewer system to the Metro treatment plant; these methods include separating sewers, constructing regional treatment facilities, capturing floatable materials and maximizing system storage capacity (Figure 3-1), or "gray infrastructure" (Table 3-2). In 1998, there were 70 active CSOs in the collection system. The ACJ projects have closed or minimized 32 of these collection system overflow points, by separating combined sewers where feasible, maximizing the capacity of the sewerage system, building the Hiawatha and Midland regional treatment facilities, and installing six floatable control facilities.

County facilities and other urban areas have begun to implement "green infrastructure" solutions to help manage urban storm runoff before it enters the CSO system. Green infrastructure encourages infiltration, capture and reuse of storm runoff before it enters the sewer system. By the end of 2010, construction was completed on 37 green infrastructure projects; these projects included replacement of traditional pavement with porous pavement in parking lots, construction of vegetated roofs, installation of rain barrels and infiltration trenches, removal of pavement from some areas, and other techniques to reduce storm water runoff. By preventing storm water runoff from entering the combined sewers, more capacity is available for sanitary sewage flow to reach Metro for treatment. A "Save the Rain" initiative is underway to educate watershed residents about ways to capture and use rainwater. An informational website describes current initiatives and incentive programs for watershed residents to reduce impervious areas http://savetherain.us/.

Table 3-1. Summary (timeline) of significant milestones and pollution abatement actions and lake water quality conditions.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Achievements	Biological Response
1998	Amended Consent Judgment (ACJ) signed	Cap on annual ammonia and phosphorus load to the lake, begin selection and design of improvements	Evaluation and implementation of nine minimum control measures	Summer TP 55 µg/l in lake's upper waters	County begins design of integrated biological monitoring program
1999		Completed upgrade of aeration system for secondary clarifiers at Metro	Maltbie Floatables Control Facility (FCF)		
2000			Franklin FCF Harbor Brook Interim FCF		Biological AMP begins Littoral zone plant coverage in June: 11%.
2001			Teall FCF Hiawatha Regional Treatment Facility (RTF)		
2002			Erie Blvd Storage System repairs completed Kirkpatrick St. Pump Station Upgrade		Strong alewife year class followed by declines in large zooplankton
2003	Three Rivers Water Quality Model peer review completed		Progress with sewer separation *(refer to 2009)*	Compliance with AWQS for DO in lake upper waters during fall	
2004		Year-round nitrification of ammonia at Metro using BAF; Stage III SPDES limit for ammonia met.	Progress with sewer separations *(refer to 2009)*	Compliance with AWQS for ammonia in lake upper waters, and for fecal coliform bacteria in lake Class B segments during Metro disinfection period.	
2005		Actiflo® system on-line to meet Metro Stage II SPDES limit for TP (0.12 mg/l)	Progress with sewer separations *(refer to 2009)*		No summer algal blooms Littoral zone plant coverage in June: 49%.
2006	ACJ Amendment motion filed by NYS Attorney General's Office		Progress with sewer separations *(refer to 2009)*	Compliance with AWQS for nitrite in the lake's upper waters	
2007		Metro meets Stage 2 SPDES limit for TP on schedule. Onondaga Lake Water Quality Model development/calibration review (Phase 2).	Progress with sewer separations *(refer to 2009)*	Compliance with AWQS for ammonia in the lake, all depths Summer TP 25 µg/l in lake's upper waters	Mesotrophic conditions achieved
2008			Midland Ave. Phase I and II conveyance, storage and RTF	Onondaga Lake declared restored for ammonia. Summer TP 15 µg/l in lake's upper waters	Alewife population decline followed by resurgence of large zooplankton
2009	ACJ amended by Stipulation #4.		Clinton St. conveyance Green Infrastructure (GI) program begins 13 sewer separation projects completed 1999- 2009	Summer TP 17 µg/l in lake's upper waters	Strong alewife year class
2010		Compliance with interim Stage II TP limit of 0.10 mg/l	Harbor Brook Interceptor replacement Close to 40 GI projects complete by 2010, converting approx. 16.7 acres of impervious surfaces	Summer TP 25 µg/l in lake's upper waters	Resurgence of alewife; loss of larger zooplankton

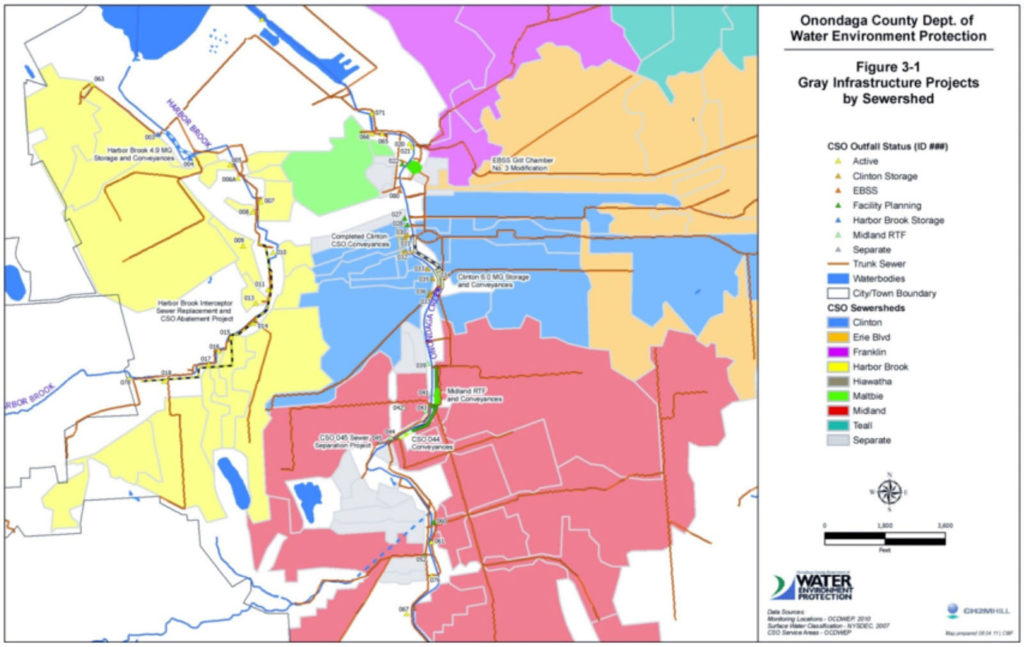


Figure 3-1. Map of CSO areas.

Table 3-2. CSO remedial projects (gray infrastructure) planned.

Receiving Water/ CSO service area	Affected CSO Outfalls	Facility (*pending approval of facility plans)*	Completion Date
Harbor Brook	014, 015 and 017	Interceptor replacement	12/31/2010
	018	Wetlands treatment with floatables control	12/31/2013
Lower Harbor Brook	003, 004	3.7 million gallon storage tank	12/13/2013
Onondaga Creek/ Clinton	030, 034	6.0 million gallon storage tank	12/31/2013
Onondaga Creek/ Midland	052, 060/077	In design, anticipated that overflows will be captured by Midland RTF	12/31/2018

Section 4. Tributary Results: 2010 Results and Trends

4.1 Climatic conditions

Precipitation in 2010 was a mixture of wet and dry months in Syracuse. There was an overall precipitation deficit of 4.3 inches from January through May, followed by a precipitation surplus of 8.2 inches for the period from June through September. Total precipitation for the year was 41.47 inches, above the 30- year average (1980 – 2009) of 38.02 inches. June was the wettest month; April was the driest. The winter (2009-2010) had lower than average snowfall; 106 inches were recorded which is less than the long-term average of 121 inches.

Despite these variations, the average 2010 precipitation and temperature patterns were consistent with those measured over the previous 30 years. The climatic conditions were reflected in the streamflow conditions; streamflow conditions in the major tributaries remained close to long-term average conditions, with discharge spikes in late winter and June, and additional spikes from storms later in the summer.

4.2 Tributaries

4.2.1 Compliance with ambient water quality standards

Several segments of Onondaga Lake's tributary streams are included on the 2010 NYSDEC compendium of impaired waters. NYSDEC places waterbodies on this list when there is evidence that water quality conditions do not meet applicable standards, and/or the water bodies do not support their designated use. Results of the County's AMP are among the primary data sets used to evaluate compliance with standards and use attainment. The 2010 tributary data indicate that the major tributaries are generally in compliance (Table 4-1) with ambient water quality standards (AWQS). With some exceptions, the 2010 findings were consistent with those of previous years. Tributary 5A, which receives treated industrial wastewater from Crucible Specialty Metals, did not meet the AWQS for copper in 75% of the quarterly samples. The East Flume exceeded the AWQS for ammonia, fecal coliform bacteria, nitrite and pH on a regular basis during 2010. In addition, mercury was measured at detectable levels - ranging from 0.026 to 0.05 µg/L - in each sample from the East Flume in 2010, exceeding the AWQS of 0.0007 µg/L.

AMP data confirmed exceedances of standards of AWQS for fecal coliform bacteria in 2010 in the influent streams, except for Tributary 5A at State Fair Blvd, and for the lake's outlet to the Seneca River. NYSDEC calculates compliance with the AWQS for fecal coliform bacteria as the geometric mean of a minimum of five observations per month. Beginning in April 2010, Onondaga County increased frequency of bacterial sampling at each tributary sampling location to a minimum of five samples per month, thus enabling compliance assessment.

The abundance of fecal coliform bacteria in the lake tributaries during wet weather is affected by stormwater runoff and functioning of the combined sewer system. CSO remedial measures and improved stormwater management measures are underway. Among the objectives of the AMP is to track changes in the inflow of bacteria to Onondaga Lake during wet weather. WEP also tracks bacterial abundance during non-storm periods; these data provide a means of identifying potential connections of sanitary waste to the stormwater collection system, or portions of the sewerage infrastructure in need of repair.

To help meet these two related objectives, bacterial quality of the CSO-affected streams is evaluated at both low flow and high flow conditions by segregating the data set based on antecedent precipitation. The detailed storm sampling results confirm that wet weather conditions transport substantial loads of bacteria to the lake, especially from the CSO-affected tributaries. The impact of wet weather on bacterial abundance is seen in the nearshore lake data as well; this is discussed further in Section 5.7. Spikes in the abundance of bacteria occur during storms and typically occur for limited time duration. The biweekly monitoring program, which is supplemented by high flow event monitoring, does not capture every storm. As a result, the annual load estimates are associated with a high standard error (low precision), due to the variability in the measurements. For example, a simple segregation of the annual bacterial loads into wet years and dry years does not reveal a consistent annual pattern; wet years are not always associated with higher annual loading estimates. This is likely due to the sporadic nature of the sources and the timing of sample collection. However, examining the individual sampling results does confirm the significant impact of wet weather on bacterial counts in the streams. Additional analysis of the bacteria data is planned for the 2011 Annual AMP report.

Both Harbor Brook and Onondaga Creek have stations upstream and downstream of the urban CSO-affected corridor. Comparing these upstream and downstream stations reveals changes in loading as the streams flow through the urban corridor. Ninemile Creek receives stormwater runoff from a separate sewer system. As expected, fecal coliform bacteria counts are higher when flows are higher and counts are elevated downstream of CSOs. The abundance of fecal coliform bacteria during summer low flow conditions is consistently higher downstream of the urban corridor served by combined sewers. Since CSOs are not active during dry weather conditions, the higher concentrations observed downstream are not attributable to this source or to storm runoff from the urban corridor. Seepage from damaged sewer pipes and illicit connections of sanitary waste to the stormwater collection system are potential sources. Urban wildlife is also a potential source, although the urban downstream monitoring locations do not provide good wildlife habitat.

During 2010, elevated fecal coliform bacteria counts in the tributaries were generally associated with high flow (wet weather) conditions (Figure 4-1). Consistent with data measured in previous years, fecal coliform bacterial counts were higher at monitoring stations downstream of CSOs. Wet weather fecal coliform bacteria counts were particularly elevated at the downstream station (Hiawatha) on Harbor Brook in 2010.

Table 4-1. Summary of tributary compliance with ambient water quality standards, 2010.
(underlined parameters are specified in the ACJ)

Site	Ammonia -N	Arsenic	Cadmium	Chromium	Copper	Cyanide	Dissolved Oxygen	Fecal Coliform	Lead	Mercury	Nickel	Nitrite	pH
Allied East Flume	57%	100%	100%	100%	100%	100%	100% >4; 96% >5	86%	100%	*See note*	100%	0%	89%
Bloody Brook at Old Liverpool Road	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	0%	100%		100%	100%	100%
Bloody Brook at Onondaga Lake Parkway	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	20%	100%		100%	100%	100%
Harbor Brook at Hiawatha	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	25%	100%		100%	100%	96%
Harbor Brook at Velasko	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	67%	100%		100%	100%	100%
Ley Creek at Park	100%	100%	100%	100%	100%	100%	100% >4; 94% >5	13%	100%		100%	100%	100%
Ninemile Creek at Lakeland	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	63%	100%		100%	100%	98%
Onondaga Creek at Dorwin	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	50%	100%		100%	96%	100%
Onondaga Creek at Kirkpatrick	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	11%	100%		100%	100%	100%
Onondaga Lake Outlet (12ft)	100%	100%	100%	100%	100%	100%	100% >4; 100% >5	--	100%		100%	100%	100%
Onondaga Lake Outlet (2ft)	100%	100%	100%	100%	100%	100%	100% >4; 98% >5	100%	100%		100%	100%	100%
Sawmill at Onondaga Lake Recreation Area	100%	100%	100%	100%	100%	100%	95% >4; 91% >5	0%	100%		100%	100%	100%
Tributary 5A at State Fair Blvd.	100%	100%	100%	100%	75%	100%	100% >4; 96% >5	100%	100%		100%	96%	100%

Note on Mercury: Onondaga County laboratory received certification for low-level mercury analysis as of June 1, 2010. The 2010 data set has two method reportable limits (equivalent to Practical Quantitation Limits, PQL) for mercury: 0.02 µg/l (standard analysis) and 0.001 µg/l (ultra-low level analysis). Both method reportable limits are at least one order of magnitude greater than the AWQS of 0.0007 µg/l. In 2010, 72% of all tributary samples were reported with results below the applicable method reportable limit. Since the analytical methods cannot measure mercury at the level of the AWQS, percent compliance with the AWQS cannot be assessed.

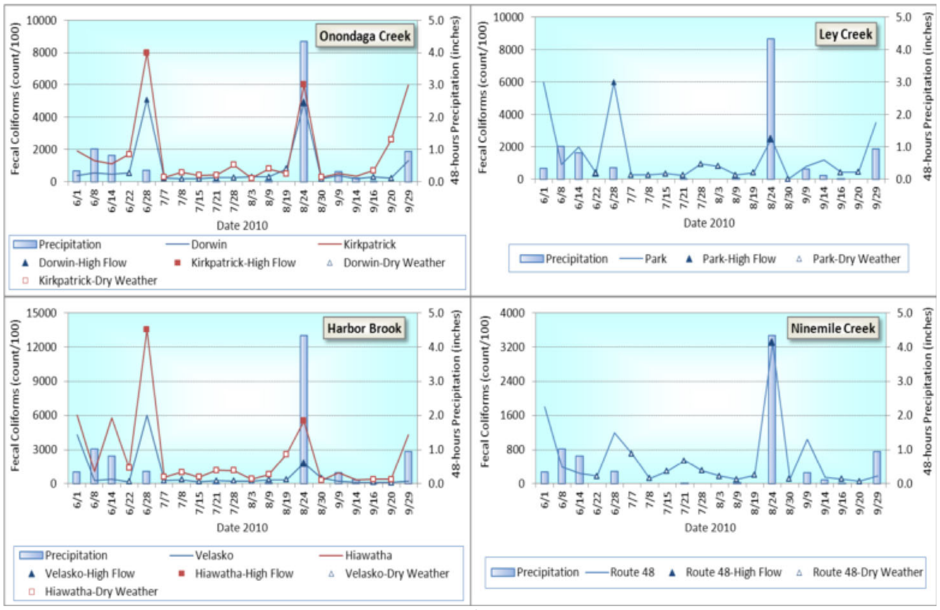


Figure 4-1. Fecal coliform bacteria abundance, Onondaga Lake tributaries, 2010.

High flow is defined as flows greater than one standard deviation above the long-term monthly average flow.
Dry weather is defined as a period of at least 48 hours prior to the sampling event with less than 0.08 inches of rain, as measured at the Metro Weather station.
Precipitation shown in the graphic represents the 48-hour total precipitation used to identify whether a sample event occurred during dry weather.

4.2.2 Loads

The 2010 flow-weighted average concentrations of total and soluble reactive phosphorus (TP and SRP), ammonia-N, TKN, total suspended solids, fecal coliform bacteria and chloride measured in the Onondaga Lake tributaries and Metro effluent are summarized in Table 4-2. For additional detail, including the relative standard error of the means, refer to the Library Table L05.2. Note that fully treated Metro effluent exhibits TP concentrations comparable to those measured in the natural tributaries. Approximately 98% of flow reaching Metro in 2010 received advanced treatment and entered the lake through Outfall 001; the remaining 2% (approximately 374 million gallons) received primary treatment and entered the lake through Outfall 002 (bypass). Fully treated Metro effluent is also much less turbid (clearer) than water flowing to the lake from the natural tributaries.

Table 4-2. Flow-weighted average concentration of selected parameters in Onondaga Lake tributaries, 2010.
Note: N represents the number of samples included in the annual flow-weighted average calculation.

Parameter* Units	TP µg/l (N)	SRP µg/l (N)	NH3-N mg/l (N)	TKN mg/l (N)	TSS mg/l (N)	Chloride mg/l (N)	F.Coli*** cells/100ml (N)
Metro**:							
Treated Effluent	79 (363)	3.6 (57)	0.32 (363)	1.2 (363)	5.0 (363)	387 (75)	580 (211)
By-pass	1076 (43)	347 (7)	5.9 (43)	10 (43)	62 (43)	245 (2)	136,296 (39)
Watershed:							
Onondaga Creek	148 (27)	16 (27)	0.057 (27)	0.74 (27)	80 (27)	289 (27)	2,582 (54)
Ninemile Creek	80 (27)	16 (27)	0.17 (27)	0.70 (27)	22 (27)	224 (27)	1,917 (53)
Ley Creek	72 (24)	13 (24)	0.20 (24)	0.70 (24)	13 (24)	276 (24)	1,004 (51)
Harbor Brook	65 (27)	29 (27)	0.052 (27)	0.50 (27)	12 (27)	258 (27)	3,210 (53)
Tributary 5A	101 (25)	35 (25)	0.15 (25)	0.49 (25)	15 (25)	307 (25)	61 (52)
East Flume	93 (23)	20 (23)	1.1 (23)	1.8 (23)	11 (23)	693 (23)	299 (46)

Notes:

Watershed tributary results are reported for downstream sampling locations closest to Onondaga Lake.

Flow-weighted average concentrations were computed on each sampled day using instantaneous flows for Storm Event samples and daily mean flows for Routine samples.

**Parameters: TP = Total Phosphorus; SRP = Soluble Reactive Phosphorus; NH3-N = Ammonia as N; TKN = Total Kjeldahl Nitrogen; TSS = Total Suspended Solids; F.Coli = Fecal Coliform bacteria*

*** Metro: Treated effluent NH3-N, TP, and TSS were based on daily measurements, SRP, chloride and F.Coli were measured less frequently. Metro By-pass was only sampled when active (during high flow events where the capacity of the treatment plant was exceeded).*

**** Bacteria concentrations are highly variable.*

Of the monitored tributaries, Harbor Brook exhibited the highest abundance of fecal coliform bacteria in 2010. In Ninemile Creek, which does not receive CSOs, fecal coliform bacterial abundance was comparable to levels measured in Onondaga Creek and Ley Creek. Onondaga Creek has active CSOs; outfalls on Ley Creek are captured and directed to the Hiawatha RTF. This finding illustrates the importance of non-CSO sources of bacteria over a range of precipitation and streamflow regimes. Prior Onondaga County WEP investigations have documented elevated fecal coliform bacteria counts during storms of sufficient magnitude to trigger CSOs. AMP reports are archived at http://www.ongov.net/wep/we1510.html.

The 2010 loading of selected parameters (Table 4-3) illustrates the importance of the relative flow volume on total external loading of nutrients, sediment, chloride and bacteria to the lake. For example, while the flow-weighted average concentration of fecal coliform bacteria was highest in Harbor Brook, loading of fecal coliform bacteria from this source was lower than from other tributaries with higher flow. Dr. William Walker developed customized software for Onondaga County WEP staff to calculate annual loads using the program AUTOFLUX, method 5. This model uses the detailed flow record and results of water quality grab samples to generate the annual loading values presented in Table 4-3. Note that the significant figures in the table should not be interpreted as representing precision of the annual loading estimates.

Table 4-3. Load of selected nutrients, salts and bacteria to Onondaga Lake, 2010.

Notes: mt = metric tons. N represents the number of water quality samples included in the annual load calculation.

Parameter*	**TP**		**SRP**		**NH3-N**		**TKN**		**TSS**		**Chloride**		**F.Coli****	
Units	**mt (N)**		**mt (N)**		**mt (N)**		**mt (N)**		**mt (N)**		**mt (N)**		**10^{10} cfu (N)**	
Metro:														
Treated Effluent(1)	6.6	(363)	0.30	(57)	26	(363)	100	(363)	417	(363)	32169	(75)	48,283	(211)
By-pass(2)	1.5	(43)	0.49	(7)	8.4	(43)	14	(43)	81	(43)	348	(2)	193,766	(39)
Watershed:														
Onondaga Creek	25	(27)	2.7	(27)	9.7	(27)	125	(27)	13678	(27)	49223	(27)	439,632	(54)
Ninemile Creek	12	(27)	2.4	(27)	25	(27)	105	(27)	3234	(27)	33286	(27)	285,073	(53)
Ley Creek	2.8	(24)	0.50	(24)	7.7	(24)	27	(24)	502	(24)	10583	(24)	38,431	(51)
Harbor Brook	0.66	(27)	0.30	(27)	0.53	(27)	5.0	(27)	118	(27)	2621	(27)	32,637	(53)
Tributary 5A	0.092	(25)	0.032	(25)	0.13	(25)	0.45	(25)	13	(25)	280	(25)	56	(52)
East Flume	0.10	(23)	0.023	(23)	1.2	(23)	2.0	(23)	13	(23)	774	(23)	333	(46)

Notes:

Tributary results are reported for downstream sampling locations closest to Onondaga Lake.

The flow-weighted-mean concentration is computed for each day before being used in computing loads.

**Parameters: TP = Total Phosphorus; SRP = Soluble Reactive Phosphorus; NH3-N = Ammonia as N; TKN = Total Kjeldahl Nitrogen; TSS = Total Suspended Solids; F.Coli = Fecal Coliform bacteria.*

(1) Metro Outfall 001 calculated loads of NH3-N, TP, TSS are based on daily measurements; METRO TKN based on 5 measurements/2 wks

(2) Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events where the capacity of the treatment plant is exceeded).

*** Fecal bacteria loads are associated with a very high standard error- i.e., they are imprecise, due to the episodic nature of the inputs.*

The percent of the total load attributed to each source is summarized in Table 4-4. Note that 2010 loading results for all measured parameters, as well as the historical loading (1990-2010) are included in the library of this report. The magnitude of TP load from non-Metro sources varies each year; annual rainfall influences the total loading from the watershed, with the highest nonpoint source loads evident in wet years (Figure 4-2). Note that the concentrations of total and soluble phosphorus are an order of magnitude higher in Outfall 002 (Metro bypass) as compared with the other sources. However, the small volume of this discharge on an annual basis results in a small overall contribution of this source to the annual loading (3.1 % of the TP and 7.3% of the SRP).

Table 4-4. Percent annual loading contribution by gauged inflow, 2010.

Parameter	TP	SRP	NH3-N	TKN	TSS	Chloride	F. coli bacteria	Water
Metro:								
Treated Effluent	14%	4.5%	33%	26%	2.3%	25%	4.7%	18%
By-pass	3.1%	7.3%	11%	3.7%	0.45%	0.27%	19%	0.31%
Watershed:								
Onondaga Creek	52%	39%	12%	33%	76%	38%	42%	37%
Ninemile Creek	24%	36%	32%	28%	18%	26%	27%	33%
Ley Creek	5.6%	7.4%	10%	7.1%	2.8%	8.2%	3.7%	8.4%
Harbor Brook	1.3%	4.4%	0.66%	1.3%	0.66%	2.0%	3.1%	2.2%
Tributary 5A	0.19%	0.47%	0.16%	0.12%	0.07%	0.22%	0.005%	0.20%
East Flume	0.21%	0.33%	1.6%	0.52%	0.071%	0.60%	0.032%	0.25%

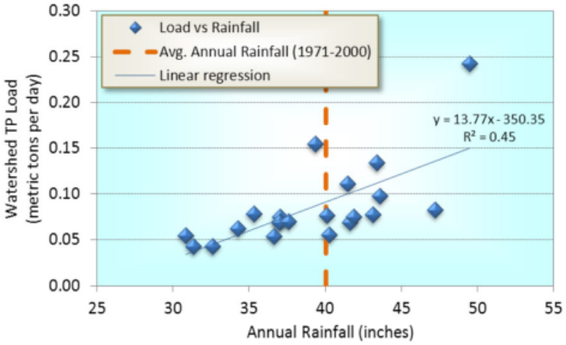


Figure 4-2. Watershed (non-Metro) TP annual load and annual rainfall, 1990-2010.

Data source for average annual rainfall http://www.nws.noaa.gov/climate/xmacis.phpwfo=bgm

Because Onondaga Lake is relatively small and receives drainage from a large watershed, the water residence time is short, as discussed in Section 2.3. External inputs of phosphorus during the summer months may consequently have an immediate effect on Onondaga Lake's summertime water quality as compared with larger lakes with longer water residence time. During dry summers, treated effluent from Metro represents a proportionally greater contribution to the total water flow into the lake; this pattern reverses during wet summers. Monthly phosphorus loads between 2007 and 2010 illustrate the potential magnitude of the differences. The Actiflo® process results in effluent phosphorus with very low bioavailability (i.e., capacity to stimulate algal growth), thus dry summers are now associated with lower algal abundance in Onondaga Lake.

4.2.3 Trends

With the reduction in phosphorus load from Metro resulting from the Actiflo® system, the total external TP load to Onondaga Lake is lower, and watershed load is increasingly important (refer to Figure EX-6). The decrease in TP load is statistically significant. The relationship between the external phosphorus load and the summer average concentration at the South Deep station is illustrated in Figures EX-2 and EX-5, and is further discussed in Section 5.7.

Comparison of phosphorus loading before the ACJ (1990-1998) and after implementation of the Actiflo® system at Metro (2007-2010) indicates the magnitude of reduction in phosphorus loading realized by this technology (Tables 4-5, 4-6 and 4-7). The treatment technology has also converted much of the phosphorus into particulate forms that are not biologically available, as evident by the decline in SRP and TDP concentrations in the effluent.

As part of the development of the Onondaga Lake Water Quality Model (OLWQM), the Onondaga Lake Partnership contracted for testing the bioavailability of phosphorus (i.e., its potential to stimulate algal growth) within Metro effluent and the lake's major tributaries. The 2009 bioassay studies completed by UFI concluded that the particulate phosphorus within the Metro effluent is bound up within iron-enriched solids, escaping the high rate flocculation settling (HRFS) process; these solids were also found to settle rapidly. The particles from the tributaries are predominantly finer and remain suspended in the lake waters for longer periods. The bioavailability assays indicated that only 1% of the particle-bound phosphorus in the Metro effluent is available for release into the water column to stimulate algal growth.

Table 4-5. Tributary and Metro Total Phosphorus (TP) Loading to Onondaga Lake, pre-ACJ and post-Actiflo® implementation.
(mt = metric tons; concentrations flow-weighted).

SITE	1990-1998 (pre-ACJ) Flow (%)	TP (mt)	TP (% load)	TP (mg/l)	2007-2010 (post-Actiflo®) Flow (%)	TP (mt)	TP (% load)	TP (mg/l)
Metro:								
fully treated	21%	52	57%	0.56	18%	7.8	20%	0.092
bypass	0.94%	8.5	7.5%	1.8	0.35%	2.0	5.1%	1.2
Watershed:								
Onondaga Creek	34%	20	19%	0.12	37%	16	39%	0.094
Ninemile Creek	32%	10	10%	0.065	34%	10	25%	0.064
Ley Creek	8.7%	5.7	5.8%	0.14	8.2%	3.2	8.2%	0.084
Harbor Brook	2.1%	0.71	0.71%	0.070	2.4%	1.1	2.8%	0.092
Tributary 5A	0.72%	0.17	0.19%	0.054	0.23%	0.11	0.29%	0.11
East Flume	0.23%	0.19	0.18%	0.20	0.18%	0.10	0.26%	0.11
Summary	**100%**	**97**	**100%**	**0.38**	**100%**	**40**	**100%**	**0.23**

Table 4-6. Tributary and Metro Soluble Reactive Phosphorus (SRP) Loading to Onondaga Lake, pre-ACJ and post-Actiflo® implementation.
(mt = metric tons; concentrations flow-weighted).

SITE	1990-1998 (pre-ACJ) Flow (%)	SRP (mt)	SRP (% load)	SRP (mg/l)	2007-2010 (post-Actiflo®) Flow (%)	SRP (mt)	SRP (% load)	SRP (mg/l)
Metro:								
fully treated	21%	12	59%	0.13	18%	0.30	5.8%	0.004
bypass	0.94%	2.5	9.7%	0.50	0.37%	0.42	8.0%	0.26
Watershed:								
Onondaga Creek	34%	3.3	16%	0.021	37%	1.8	34%	0.011
Ninemile Creek	32%	1.7	7.9%	0.011	34%	1.7	32%	0.011
Ley Creek	8.7%	1.4	6.1%	0.033	8.3%	0.53	11%	0.014
Harbor Brook	2.1%	0.25	1.1%	0.024	2.4%	0.41	8.1%	0.036
Tributary 5A	0.72%	0.030	0.17%	0.010	0.22%	0.033	0.66%	0.032
East Flume	0.23%	0.065	0.29%	0.092	0.21%	0.031	0.61%	0.033
Summary	**100%**	**21**	**100%**	**0.103**	**100%**	**5.2**	**100%**	**0.050**

The improvements to Metro have also resulted in a statistically significant reduction in the input of ammonia-N to Onondaga Lake (refer to Figure EX-4). While loading of ammonia-N has been reduced, the total nitrogen (sum of nitrogen species) in the effluent has remained relatively constant. The Biologically Aerated Filtration (BAF) process that came on-line in 2004 achieved year-round nitrification (biologically-mediated oxidation) of ammonia to nitrate-N. Prior to completion of the BAF, Metro effluent (fully-treated discharge through Outfall 001 plus bypass) represented about 90% of the external ammonia loading to Onondaga Lake; both the percent contribution of Metro to the total load (refer to Table 4-4) and the total load itself are now greatly diminished.

Table 4-7. Tributary and Metro Total Dissolved Phosphorus (TDP) Loading to Onondaga Lake, pre-ACJ and post-Actiflo® implementation.
(mt = metric tons; concentrations flow-weighted).

SITE	1990-1998 (pre-ACJ) Flow (%)	TDP (mt)	TDP (% load)	TDP (mg/l)	2007-2010 (post-Actiflo®) Flow (%)	TDP (mt)	TDP (% load)	TDP (mg/l)
Metro:								
fully treated	21%	na	na	na	18%	2.3	22%	0.028
bypass	0.94%	na	na	na	0.37%	0.58	5.3%	0.36
Watershed:								
Onondaga Creek	34%	na	na	na	37%	2.7	25%	0.016
Ninemile Creek	32%	na	na	na	34%	3.8	33%	0.024
Ley Creek	8.7%	na	na	na	8.3%	0.93	9.0%	0.024
Harbor Brook	2.1%	na	na	na	2.4%	0.48	4.4%	0.042
Tributary 5A	0.72%	na	na	na	0.22%	0.044	0.44%	0.044
East Flume	0.23%	na	na	na	0.21%	0.053	0.51%	0.055
Summary	**100%**	**na**	**na**	**na**	**100%**	**10.9**	**100%**	**0.074**

A statistical analysis of the prior ten years of tributary data (Table 4-8) documents increasing and decreasing trends in several important water quality parameters. Ammonia-N (NH3-N) concentrations exhibited decreasing trends over the 2001-2010 period, and chloride concentrations exhibited increasing trends, at five of the ten monitoring locations. Total P concentrations increased at Metro bypass, the Dorwin Ave. station, which is upstream of the CSOs, and Harbor Brook at Hiawatha Blvd over the ten-year period. The reasons are unknown. However, one might conjecture that the increased TP and TSS at the Dorwin Ave site are the result of increasing frequency of higher intensity rain events over this period. The increasing trend in TP and SRP at Hiawatha Blvd (lower Harbor Brook) is also unknown. The increasing trend in TP concentration at Outfall 002 (Metro Bypass) is based on fewer samples, as this source is sampled only during bypass events. Note that there is no corresponding increase in SRP concentration at this monitoring location, nor is there a trend toward increased load of either form of phosphorus at Outfall 002. The AMP will continue its focus on the tributaries and inflows to Onondaga Lake, with respect to both in-stream water quality and total loading.

Increasing concentrations of salts are evident at several monitoring locations as well. These increases are consistent with a USGS conceptual model of changes to regional groundwater salinity, as reported by William Kappel to the OLTAC (see also Yager, Kappel and Plummer 2007).

Table 4-8. Ten-year trends in tributary concentrations (2001-2010) – summary.

Variable		Metro *Treated Effluent*	 *By-pass*	Onondaga Creek *Dorwin*	 *Kirkpatrick*	Harbor Brook *Velasko*	 *Hiawatha*	Ley Creek *Park*	Ninemile Creek *Route 48*	Tributary 5A	East Flume
Nitrogen	Ammonia-N (NH_3-N)	↓	○	↓	↓	↓	↓	○	↓	○	○
	Nitrite-N (NO_2-N)	↓	○	○	○	○	○	○	○	○	○
	Nitrate-N (NO_3-N)	↑	○	○	↓	○	○	↓	↓	○	○
	Organic Nitrogen	↓	○	○	○	↑	○	↓	○	○	↓
	Total Kjeldahl Nitrogen (TKN)	↓	○	○	○	○	○	↓	↓	○	○
Phosphorus	Total Phosphorus (TP)	↓	↑	↑	○	○	↑	↓	○	○	↓
	Soluble Reactive Phosphorus (SRP)	↓	○	↑	○	○	↑	↓	○	↓	↓
Solids	Total Suspended Solids (TSS)	↓	○	↑	○	○	○	○	○	○	↓
	Total Dissolved Solids (TDS)	↑	○	○	○	↑	○	↑	↓	↓	○
	Volatile Suspended Solids (VSS)	○	○	-	-	-	-	-	-	-	-
Carbon	Total Inorganic Carbon (TIC)	↓	○	○	○	○	○	○	○	↑	○
	Total Organic Carbon (TOC)	↓	○	○	○	↓	↓	○	○	○	↓
	Total Organic Carbon, filtered (TOC_F)	↓	○	○	○	↓	○	○	○	○	↓
Other	Alkalinity	↓	○	○	○	↑	○	↑	○	↑	
	BOD_5*	↓	○	-	-	-	-	-	-	-	-
	Calcium (Ca)	↑	○	○	○	↑	○	↑	↓	○	○
	Chloride (Cl)	↑	○	○	○	↑	↑	↑	↓	↓	↑
	Conductivity	○	○	○	○	↑	○	↑	↓	↓	↑
	Dissolved Oxygen (DO)	○	○	○	○	○	↑	○	○	○	○
	Fecal Coliform Bacteria	○	○	↑	○	○	○	○	↑	○	○
	Hardness	↑	○	○	○	↑	○	↑	↓	○	○
	Magnesium (Mg)	○	○	○	○	○	○	↑	↓	↓	↓
	Sodium (Na)	○	○	○	○	↑	↑	↑	↓	↓	↑
	pH	○	○	○	○	○	↑	○	↑	↑	↓
	Silica (SiO_2)	○	○	○	○	○	○	○	○	↑	○
	Sulfates (SO_4)	○	○	○	↓	○	○	○	○	↓	○
	Temperature	○	○	○	○	↓	○	○	○	○	○

Notes:

Significance level, two-tailed, seasonal Kendall test accounting for serial correlation.

↓ indicates decreasing trend ($p > 0.1$)

↑ indicates increasing trend ($p < 0.1$)

○ indicates no trend ($p = 0.1$)

- Dash indicates parameter is not measured at this location.

*BOD_5 (Biochemical Oxygen Demand (5-day)) trend analysis results are accurate only for METRO & BYPASS because of the preponderance of data less than the MRL (PQL) in other inputs.

On a loading basis (Table 4-9), the treated effluent from Metro exhibited decreasing or stable trends for each of the measured parameters except for nitrate-N (NO_3-N). An increase in NO_3-N is consistent with the implementation of year-round nitrification in 2004. In Tributary 5A, loading of nearly all measured parameters – except fecal coliform bacteria and solids (TSS) – exhibited decreasing trends; in contrast, the East Flume exhibited increasing trends for all but fecal coliform bacteria, organic carbon, phosphorus and solids. Note that the loading of TP in both Onondaga Creek and Ninemile Creek has increased over the decade; this increase is considered likely to be the result of increasing rainfall and intensity of storms over this period. The increased loading of suspended solids in Onondaga Creek is attributed to the resurgence of mud boil activity in the Tully Valley. Details are presented in Library Reference 5.8.

Table 4-9. Ten-year trends in tributary loading (2001-2010) – summary.

		Metro		**Onondaga Creek**		**Harbor Brook**		**Ley Creek**	**Ninemile Creek**		
Variable		***Treated Effluent***	***By-pass***	***Dorwin***	***Kirkpatrick***	***Velasko***	***Hiawatha***	***Park***	***Route 48***	**Tributary 5A**	**East Flume**
Nitrogen	Ammonia-N (NH_3-N)	↓	○	↓	↓	↓	↓	↓	○	↓	↑
	Nitrite-N (NO_2-N)	↓	○	↑	↑	○	○	○	○	↓	↑
	Nitrate-N (NO_3-N)	↑	↓	○	○	○	○	↓	○	↓	↑
	Total Kjeldahl Nitrogen (TKN)	↓	○	↑	○	○	○	↓	○	↓	↑
Phosphorus	Total Phosphorus (TP)	↓	○	↑	↑	○	○	○	↑	↓	○
	Soluble Reactive Phosphorus (SRP)	○	○	↑	↑	○	○	○	↑	↓	○
Solids	Total Suspended Solids (TSS)	↓	○	↑	↑	○	○	○	○	○	○
Carbon	Total Inorganic Carbon (TIC)	↓	○	○	○	○	○	○	○	↓	↑
	Total Organic Carbon (TOC)	↓	○	○	○	○	○	○	○	↓	○
	Total Organic Carbon, filtered (TOC_F)	↓	○	○	○	○	○	○	○	↓	○
Other	Alkalinity	↓	○	○	○	○	○	○	○	↓	↑
	BOD_5*	↓	○	-	-	-	-	-	-	-	-
	Calcium (Ca)	○	○	○	○	○	○	○	○	↓	↑
	Chloride (Cl)	○	○	○	○	○	○	○	↓	↓	↑
	Fecal Coliform Bacteria	↓	○	○	○	○	○	○	○	○	○
	Sodium (Na)	○	○	○	○	○	○	○	○	↓	↑
	Silica (SiO_2)	○	○	○	○	○	○	○	○	↓	↑

Notes:

Significance level, two-tailed, seasonal Kendall test accounting for serial correlation. ↓ indicates decreasing trend ($p > 0.1$) ↑ indicates increasing trend ($p < 0.1$) ○ indicates no trend ($p = 0.1$)

* BOD_5 trend analysis results are accurate only for METRO & BYPASS because of the preponderance of data less than the MRL (PQL) in other inputs.

4.2.4 Tributary macroinvertebrates

Macroinvertebrates are an important component of the aquatic food web. Because they have limited migration patterns or a sessile mode of life, they are well suited for assessing site--specific impacts of point and nonpoint discharges. Many state agencies, including NYSDEC, use macroinvertebrate community structure as an indicator of the biological health of surface waters.

Macroinvertebrate sampling is among the requirements of the ACJ; Onondaga County is required to periodically assess the macroinvertebrate communities of the CSO-affected tributaries. WEP conducted macroinvertebrate sampling at ten sites within Ley Creek, Harbor Brook and Onondaga Creek in the tributaries every two years.

Three metrics are calculated to analyze the tributary data: 1) NYSDEC Biological Assessment Profiles (BAP), an index of overall impact on the macroinvertebrate community; 2) the Hilsenhoff Biotic Index (HBI), a measure of community impairment due to organic enrichment; and 3) the percent contribution of oligochaetes to the macroinvertebrate community, another measure of organic enrichment from sewage or animal wastes. In addition, the NYSDEC Impact Source Determination (ISD) is calculated to determine the primary factor(s) affecting community structure. In 2010, the extent of deformities of certain Chironomidea (midge) species was evaluated; the incidence of deformities is used as an indicator of potential sediment toxicity.

Results of the AMP macroinvertebrate monitoring program indicate no consistent trends toward improving conditions in the monitored portions of the watershed since monitoring began in 2000 (Figure 4-3)**.** Some individual sites have shown varying levels of change, both positive and negative, with no apparent relation to CSO abatement projects. All ten of the monitoring locations show some level of impact, though those in the upper portions of the watersheds are generally less impaired. Impairment is greatest in the lower portions of Ley Creek and Harbor Brook. ISD analyses indicate that the primary causes of impairment include excessive organic loading, primarily from sewage or animal wastes, and influences from municipal/industrial development. The macroinvertebrate community has been quite stable over the period of the AMP, despite some changes in land use and land cover in the subwatersheds.

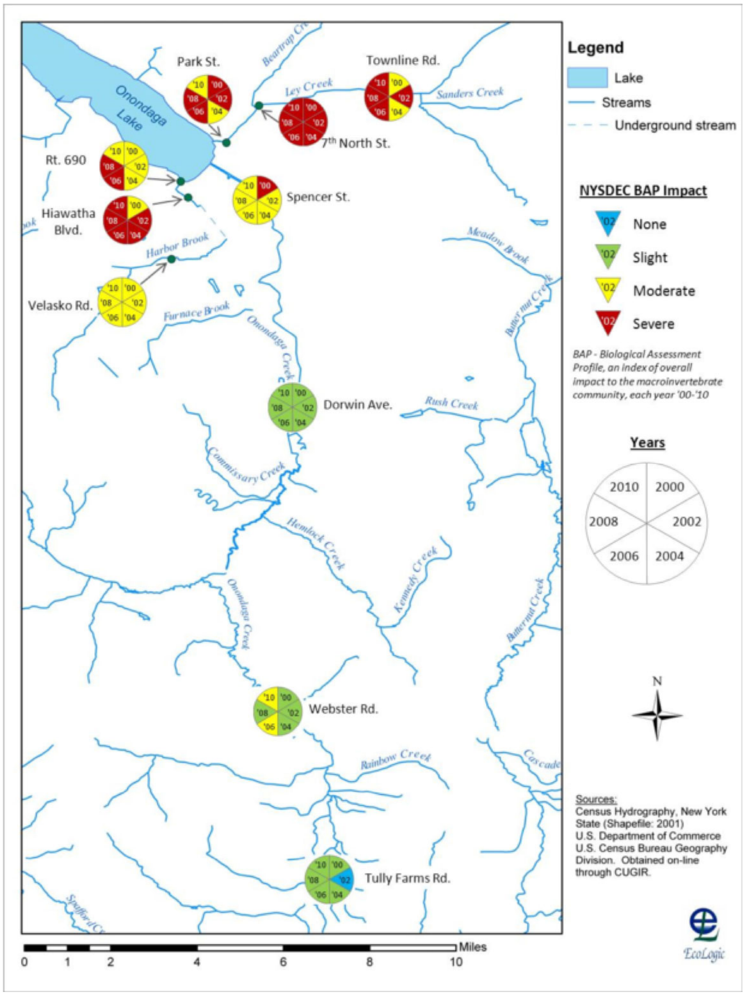


Figure 4-3. Biological assessment designations, Onondaga Lake tributaries, 2000- 2010.

Sites on Onondaga Creek showed a wide range of conditions in 2010 with a trend towards increasing impacts downstream (refer to Figure 1 in L05.9 report). This downstream trend has been evident since 2000, and is likely related to downstream increases in loading due first to changes from forested to agricultural land use in the upper watershed followed by a shift to urban land use downstream. Impacts to the macroinvertebrate community are generally slight upstream (Sites 1, 2 and 3) of urban areas and CSOs and moderate downstream (Site 4) of urban areas and CSOs.

Ley Creek tends to show the greatest degree of overall impact of the three Onondaga Lake tributaries monitored for macroinvertebrates. Sites in Ley Creek have been consistently assessed as *severely impacted* by the NYSDEC BAP and HBI scores, and percent oligochaete values also indicate a high degree of impact (refer to Figure 2 in L05.9). In 2010, the HBI score improved slightly at site 1, but all sites on the stream still show considerable impact to the macroinvertebrate community.

Sites on Harbor Brook ranged from *moderately* to *severely impacted* based on BAP scores (refer to Figure 3 in L05.9). The two sites downstream of the most highly urbanized areas and all CSOs showed a greater degree of impact than the upstream reference site.

There were too few chironomid larvae in the 2010 tributary samples to support a statistical evaluation of whether the percent of deformities exceeds what researchers consider as natural background (approximately 3%). Results of the 2010 analyses (Table 4-10) suggest that the percent of chironomid deformities in the tributaries was relatively low, and consistent with a finding of no sediment toxicity for the Onondaga Creek and Harbor Brook sites. Along Ley Creek, the incidence of chironomid deformities detected at the Park Street and Seventh North Street sampling sites suggests that the benthic community may be affected by sediment toxicity.

Table 4-10. Incidence of chironomid deformities, Onondaga Lake tributaries, 2010.

Sampling Location	Average Percent of Chironomids with Deformities (N)
Onondaga Creek	
Tully Farms	1.7 (16)
Webster Road	6.1 (5)
Dorwin Avenue	2.5 (35)
Spencer Street	3.1 (13)
Harbor Brook	
Velasko Road	0 (5)
Hiawatha Blvd	0 (5)
Route 690	3.1 (13)
Ley Creek	
Townline Road	6.9 (30)
7th North Street	21.6 (12)
Park Street	15.6 (10)

Notes:

1. *The maximum number of Chironomidae found in any of the 2010 tributary samples with deformed Chironomidae was 48 (Ley Creek, 7th North St.), and the majority of samples with deformed Chironomidae had 15 or fewer total Chironomidae.*

2. *(N) represents average number of Chironomidae in samples from each site.*

4.3 Metro performance

Effluent ammonia N remained well below the seasonal limits of 1.2 mg/l (June 1 to October 31) and 2.4 mg/l (November 1 to May 31), as displayed in Figure 4-4. Phosphorus concentrations were also consistently low throughout 2010 (Figure 4-5). As part of the November 2009, fourth stipulation to the ACJ, the interim Stage II TP effluent limit became 0.10 mg/l. Compliance with the revised interim limit, which is expressed as a 12-month rolling average, was evaluated beginning in November 2010.

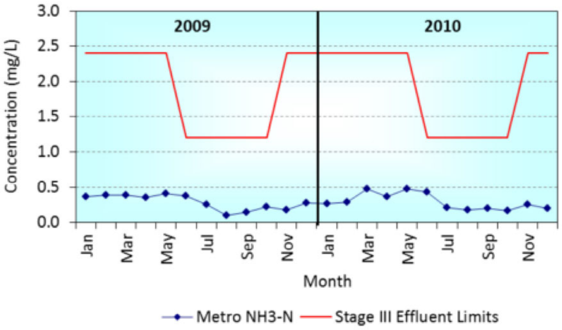


Figure 4-4. Metro NH3-N, 2010 effluent concentration compared to permit limits.

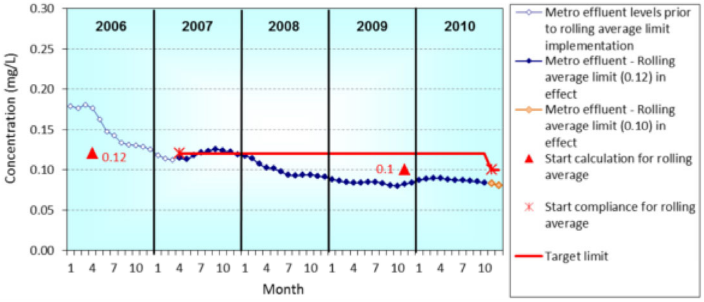


Figure 4-5. Metro TP, 2010 effluent concentration compared to permit limit.

During 2010, Outfall 002 activated on 42 occasions, for a cumulative duration of 314 hours. As a result of the discharge through Outfall 002, a total of 374 million gallons of wastewater reached Onondaga Lake following primary settling and disinfection. On four occasions between July and September 2010, the plant headworks were bypassed during intense rainfall events. The total duration of headwork bypass was 22.3 hours, an estimated 43 million gallons of wastewater and stormwater reached the lake during these events.

Documentation of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) throughout the Onondaga County service area is included in the library. The most significant SSO occurred on August 22, 2010 when the Syracuse region received torrential rains totaling about 4.6 inches, and SSO resulted in 17.8 million gallons of stormwater and sanitary wastewater (combined sewage) entering Ley Creek, Ninemile Creek and Onondaga Lake. On December 1, 2010 a power failure took the Ley Creek pump station out of service for almost three hours, allowing approximately 2.75 million gallons of combined sewage to reach Ley Creek and Onondaga Lake.

Section 5. Onondaga Lake Water Quality: 2010 Results and Trends

5.1 Sampling Locations

Trained WEP technicians collect samples from Onondaga Lake throughout the year to characterize water quality and biological conditions. Most sampling occurs between April and November when the lake is free of ice. As conditions allow, winter sampling conducted. The AMP encompasses multiple parameters (refer to Table 1-1) with a focus on compliance with AWQS and trends toward attainment of designated use. WEP also tracks physical factors, such as the development and extent of ice cover. The cold winter of 2009-2010 led to a substantial amount and persistence of ice cover.

The lake's main sampling station, referred to as South Deep, is the deepest point in the southern basin; this has been the standard monitoring location on Onondaga Lake since the County initiated monitoring in 1970. In addition to the standard biweekly sampling at South Deep, WEP technicians collect samples from the deepest point of the lake's northern basin (North Deep) four times each year to confirm that water quality conditions measured at the South Deep station adequately characterize open water conditions. Results of North Deep and South Deep remained comparable in 2010.

During the summer, the AMP includes sampling at a network of nine near-shore locations for parameters indicative of the lake's suitability for water contact recreation. These parameters include Secchi disk transparency, turbidity and fecal coliform bacteria.

5.2 Compliance with AWQS

The 2010 monitoring results indicate that Onondaga Lake was generally in compliance with AWQS, with some exceptions, as noted in Table 5-1. The concentration of total dissolved solids (TDS), which primarily reflect the concentrations of the major cations and anions (calcium, sodium, magnesium, bicarbonate, potassium, chloride and sulfate), was above the AWQS of 500 mg/l. TDS concentrations consistently exceed this standard in Onondaga Lake.

In addition, the summer 2010 total phosphorus (TP) concentration in the lake's upper waters (25 µg/l) was above the state's guidance value. NYS has promulgated a narrative standard for phosphorus in water: "None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSCRR §703.2). For ponded waters, such as Onondaga Lake, the narrative standard is interpreted using a guidance value of 20 µg/l, which is calculated as the average TP concentration in the lake's upper waters, mid-lake station, between June 1 and September 30.

Onondaga County WEP collected water samples at two depths (3 m and 18 m) on three dates in 2010 and submitted the samples to Frontier Global Sciences Inc. for ultra-low level measurement of total mercury using EPA method 1631, and for methyl mercury using EPA Method 1669. The AWQS for total Hg in Class B and C waters is 0.7 ng/L. All six of the 2010 Onondaga Lake total Hg results exceeded this standard. The time series of total Hg and methyl Hg data measured in both the upper and lower waters of Onondaga Lake indicates a decline in the concentration of this heavy metal.

The AMP further documented that dissolved oxygen (DO) concentrations were not in 100% compliance with AWQS in 2012; DO in the lower waters were below the minimum 4 mg/l during the summer stratified period. During 2010 fall mixing, Onondaga Lake DO concentrations in the upper waters met the AWQS. Seasonal anoxia in stratified lakes is common; in NY, an estimated 70% of assessed lakes do not meet the minimum DO standards in the deep waters (NYSDEC Consolidated Assessment and Listing Methodology, May 2009). NYSDEC has not classified Onondaga Lake as trout water (T) or trout spawning water (TS). The DO concentration of Onondaga Lake's upper and lower waters is increasing, indicating a trend to improved water quality and habitat conditions.

New York State Dissolved Oxygen Aquatic Water Quality Standards

A-Special	In rivers and upper waters of lakes, not less than 6.0 mg/l at any time. In hypolimnetic waters, it should not be less than necessary for the support of fish life, particularly coldwater species.
AA, A, B, C, AA-Special	For trout spawning waters (TS), the DO concentration shall not be less than 7.0 mg/l from other than natural conditions. For trout waters (T), the minimum daily average shall not be less than 6.0 mg/l, and at no time shall the concentration be less than 5.0 mg/l. For non-trout waters, the minimum daily average shall not be less than 5.0 mg/l, and at no time shall the DO concentration be less than 4.0 mg/l.

In 2010, the measured fecal coliform bacteria counts at the Onondaga Lake monitoring stations did not exceed the ambient water quality standard (200 cfu/100mL) at offshore locations or at nearshore locations within the Class B water. For nearshore locations within the Class C water segment, monthly geometric mean concentrations of fecal coliform bacteria were within the ambient water quality standard of 200 cfu/100mL except at two locations (monthly standard not met 86% and 43% of the assessment period, refer to Figure 5-6).

Table 5-1. Onondaga Lake compliance with ambient water quality standards and guidance values, 2010. Dashed lines indicate that the parameter is not measured at this location. Parameters listed in **bold** are cited in the ACJ.

	South Deep		Nearshore Stations	
	Upper Mixed Layer	Lower Water Layer		
Parameter	**(0-6m)**	**(9-18m)**	**(Class B)**	**(Class C)**
Ammonia-N	100%	100%	-	-
Arsenic	100%	100%	-	-
Cadmium	100%	100%	-	-
Chromium	100%	100%	-	-
Copper	100%	100%	-	-
Dissolved Oxygen	100% >5 mg/l; 99.9% >4 mg/l	76% >5 mg/l; 82% >4 mg/l	-	-
Total Dissolved Solids	0%	0%	-	-
Fecal Coliform	(see note)	--	(see note)	(see note)
Lead	100%	100%	-	-
Mercury	0%	0%	-	-
Nickel	100%	100%	-	-
Nitrite	100%	79%	-	-
pH	100%	100%	-	-
Total Phosphorus (*guidance value*)	Not in compliance (*summer average guidance value)*	-	-	-
Zinc	100%	100%	-	-

Nearshore Class B stations in the vicinity of: Bloody Brook, Onondaga Lake Park, Willow Bay, Maple Bay and Westside Wastebeds.
Nearshore Class C stations in the vicinity of: Ley Creek, Metro, Onondaga Creek, Harbor Brook and Ninemile Creek.

Notes:

Ammonia-N compliance represented as average of discrete depth percent compliance.
Dissolved Oxygen compliance based on water quality buoy data at 2m and 12m depths.
Fecal Coliform bacteria data are assessed as monthly geometric means (GM) during the period of Metro disinfection (April –Oct).
Fecal Coliform concentrations (monthly geometric means) did not exceed the water quality standard at offshore locations [upper mixed layer (0-6 m)] or at nearshore Class B waters locations. For nearshore locations in Class C waters, GM concentrations were below the water quality standard, except at two locations (standard exceeded 86% and 43% of the time, see Figure 5-6).
Mercury samples collected at 3m and 18m depths, 3 dates, ultra low-level measurement.
Total Phosphorus compliance based on upper waters samples (0, 1 and 3 m depths) averaged June 1 to Sept 30

5.3 Trophic state

Onondaga Lake can be characterized by its trophic status, that is, how much sunlight it converts to organic matter through photosynthesis. Highly productive systems are termed **eutrophic**, while systems with low levels of productivity are termed **oligotrophic.** Those in between are called **mesotrophic**. Excessive productivity can result in conditions that impair a waterbody for a particular use, such as water supply or recreation.

The productivity of Onondaga Lake, like most lakes in the Northeast, is limited by the availability of phosphorus. Adding phosphorus induces eutrophication, and such over-productive waters support an abundant community of algae and cyanobacteria (blue-green algae). Approximately 50 species of cyanobacteria have been shown to produce toxins that are harmful to vertebrates (Codd 1995).

When algal biomass settles to the lower, unlighted areas of a productive lake, its decay robs the lower waters of dissolved oxygen, making them uninhabitable by fish or other oxygen-requiring organisms. Under these anaerobic or oxygen-free environments, undesirable compounds such as ammonia and soluble phosphorus may be released from the sediments.

Monitoring the trophic status of Onondaga Lake requires tracking several key parameters to assess the type and abundance of algae, and the chemistry of the deep waters. Three standard trophic state indicator parameters are used to evaluate the lake's trophic status and trends: total P, chlorophyll-*a* and Secchi disk transparency.

5.3.1 Total Phosphorus (TP)

Since the productivity of Onondaga Lake is limited by the availability of phosphorus in the water, total phosphorus concentration (TP) is an important indicator of trophic status. Phosphorus concentrations in the lake's upper waters have exhibited a four-fold decrease since 1990 (refer to Figure EX-5). Phosphorus concentrations in the lake's upper waters averaged 25 µg/l over the summer of 2010. Since 2007, summer TP concentrations in the upper waters of Onondaga Lake have been under 30 µg/l. With the advanced treatment system at Metro producing consistently low effluent TP, the year-to-year variability in lake phosphorus levels reflects changes in precipitation patterns and the resultant watershed loading as well as changes in the food web structure. NYSDEC is completing a Total Maximum Daily Load (TMDL) allocation for Onondaga Lake to define the appropriate in-lake target concentration and the loading reductions needed to ensure that the lake meets its designated uses.

5.3.2 Chlorophyll-a

One of the undesirable attributes of eutrophic lakes is their green-tinged water and turbidity, diminishing their suitability for water supply and recreational uses. Abundant phytoplankton are a primary factor affecting turbidity; in most lakes there is a strong correlation between phosphorus, chlorophyll-a (the primary photosynthetic pigment in algal cells) and water clarity. The EPA and NYSDEC are developing nutrient criteria for lakes to protect water supply and recreational use, as well as deriving numerical limits on response variables such as chlorophyll-a. In the absence of state or federal criteria, the AMP has used site-specific criteria of 15 µg/L (minor bloom) and 30 µg/L (major bloom) to screen algal bloom thresholds for Onondaga Lake.

In Onondaga Lake, chlorophyll-*a* concentrations above 15 µg/l are associated with green-tinged and turbid waters that are less appealing for recreational use. Nuisance bloom conditions are defined as chlorophyll-*a* concentrations greater than 30 µg/L. There were no algal blooms in Onondaga Lake during the summer recreational period of 2010 (Figure EX-7). The average and peak concentrations of this plant pigment have declined significantly (Figure 5-1). Summer data (June-September) are used to track suitability of the lake for recreational uses. The annual data provide additional information regarding peak concentrations of chlorophyll that may be associated with spring and/or fall algal blooms.

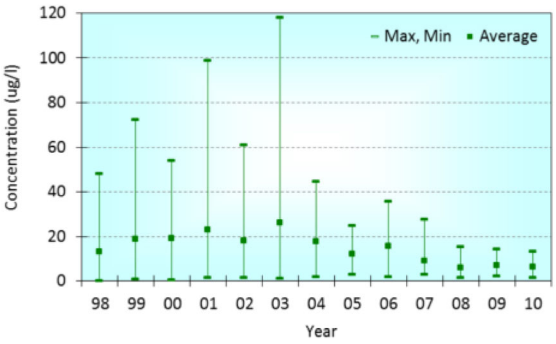


Figure 5-1. Chlorophyll-a concentration, January to December, 1998-2010.

There is also a strong correlation between the TP present in the lake during the spring, prior to the development of thermal stratification and the algal abundance in the summer months. In Onondaga Lake, Metro TP has represented a substantial portion of the annual phosphorus load to the lake; this is reflected in the correlation of Metro TP and summer chlorophyll-a.

In lakes where phytoplankton abundance is limited by phosphorus, the two trophic state parameters are highly correlated. Data from regional lakes (Figure 5-2) illustrate this relationship. Data for the Finger Lakes represent results of a NYSDEC survey conducted between 1996 and 1999. NYSDEC rejected their phosphorus data from 1998 for quality control reasons. The NYSDEC study design called for sampling each Finger Lake monthly between June and August at a single mid-lake station, with the exception of Cayuga Lake, which was sampled at three locations (Callinan 2001). Data for Onondaga and Oneida Lakes are averaged over this same time period, for data comparability. Oneida Lake data were provided by the Cornell Biological Field Station (Lars Rudstam, personal communication, June 2011). Oneida Lake is notably shallower than the Finger Lakes, has a larger proportion of the bottom suitable for zebra mussels, and does not develop stable thermal stratification during the summer.

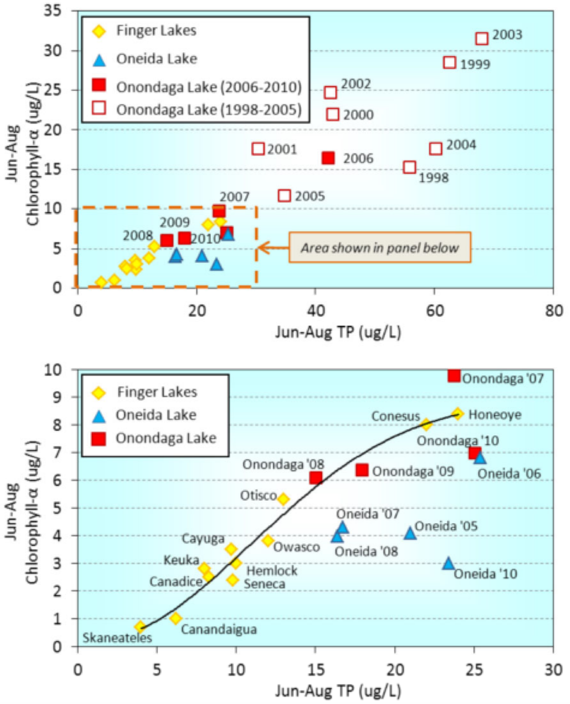


Figure 5-2. Summer (June- August) average TP and chlorophyll-a concentrations in Onondaga Lake compared with selected regional lakes. The top panel shows Onondaga Lake concentrations pre-Actiflo® (1998-2005) and post-Actiflo® (2006-2010). The bottom panel represents the same data, scaled to show the 2007-2010 Onondaga Lake data and a best-fit trendline ($R^2 = 0.97$) of the Finger Lakes concentrations (1996-1999).

5.3.3 Secchi Disk Transparency

Another—and more direct—indicator of turbidity of the water is the Secchi disk transparency. A Secchi disk is a 25 cm diameter disk with alternating black and white quadrants. It can be lowered into the lake, and the depth at which it can no longer be seen from the surface or from the deck of a boat, is known as the Secchi disk transparency. Greater depth indicates clearer and less productive waters. Highly productive waters may have Secchi disk measurements of less than one meter. Water clarity data are influenced by both bottom-up (nutrient levels) and top-down (food web) effects; the presence and abundance of grazing organisms has a major impact on the algal community.

To meet swimming safety guidance, Secchi disk transparency greater than 1.2 m is required at designated beaches. There is no NYS standard or guidance value for Secchi disk transparency of off-shore waters; most lake monitoring programs in the state monitor Secchi disk transparency at a mid-lake station overlying the deepest water, comparable to Onondaga Lake South Deep station. The Citizens Statewide Lake Assessment Program (CSLAP),a joint effort of NYSDEC and the NYS Federation of Lake Associations, considers summer average Secchi disk transparency greater than 2 m as indicative of mesotrophic conditions (Kishbaugh 2009). The water clarity of Onondaga Lake was slightly lower during the very wet summer of 2010, averaging 1.9 m and ranging from 0.8 m to 2.9 m over the June – September interval (Figure 5.3). Results in 2010 were comparable to the 2007 water clarity conditions.

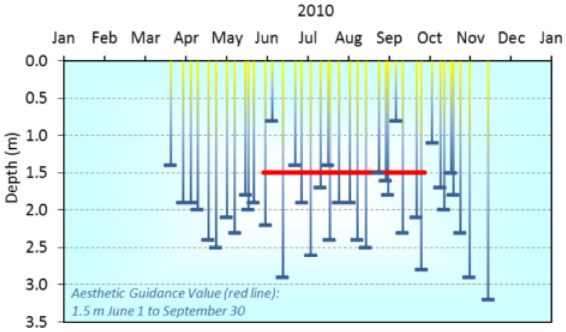


Figure 5-3. Secchi Disk transparency, Onondaga Lake South Deep, 2010.

In addition to Secchi disk transparency, the AMP includes measurements of light extinction using a LiCor instrument and data logger. These measurements correlate with Secchi disk transparency measurements.

5.3.4 Trophic State Index

The three trophic state indicator parameters can be expressed on a common scale, ranging from 1 to 100, with higher values indicating greater productivity (Carlson 1977). By all measures, the trophic state of Onondaga Lake has shifted dramatically, as demonstrated by reductions in the lake's trophic state index, or TSI, (Figure 5-4) calculated from summer (June 1 through September 30) average total P, chlorophyll-*a* and Secchi disk transparency. The 2010 results confirm that the productivity of Onondaga Lake has declined significantly since Onondaga County began monitoring in 1970; the lake is mesotrophic based on total P and chlorophyll. The 2010 Secchi disk transparency results were slightly depressed; this is attributed to the food web effects (alewife eliminating larger zooplankton) as well as the very wet summer and the influence of the Tully Valley mudboils.

The wet summer resulted in increased loading of suspended sediments. The mud boils on upper Onondaga Creek may have contributed to the diminished water clarity of the lake in 2010, and therefore to the slight divergence in TSI values calculated for chlorophyll and water clarity. According to USGS scientist William Kappel, a surge of mudboil activity began in early March 2010 (personal communication May 2011). This outbreak caused direct discharge of mudboil sediments to the creek, returning turbidity to early 1990 levels. Sediment loading to Onondaga Creek increased from approximately 0.1 metric tons per day between October 2009 and February 2010 to several metric tons per day later in 2010. On several occasions, the mud boils resulted in a sediment load to Onondaga Creek between 10 and 40 metric tons/day. Overall, Mr. Kappel estimated the average sediment load during the 2010 water year from mud boils at approximately 1 metric ton/day. However, during the critical March-September period, the mud boils likely contributed approximately six MT/day of fine-grained sediment to Onondaga Creek (William Kappel, USGS personal communication May 2011).

In addition to the increased suspended solids input from the watershed in 2010, food web effects also contributed to the loss of water clarity. The resurgence of a strong year-class of the alewife has dramatically affected the larger zooplankton species; these efficient grazers of phytoplankton are now essentially absent from the community, resulting in increased algal biomass and reduced light penetration in the water column. This topic is discussed further in Section 6.

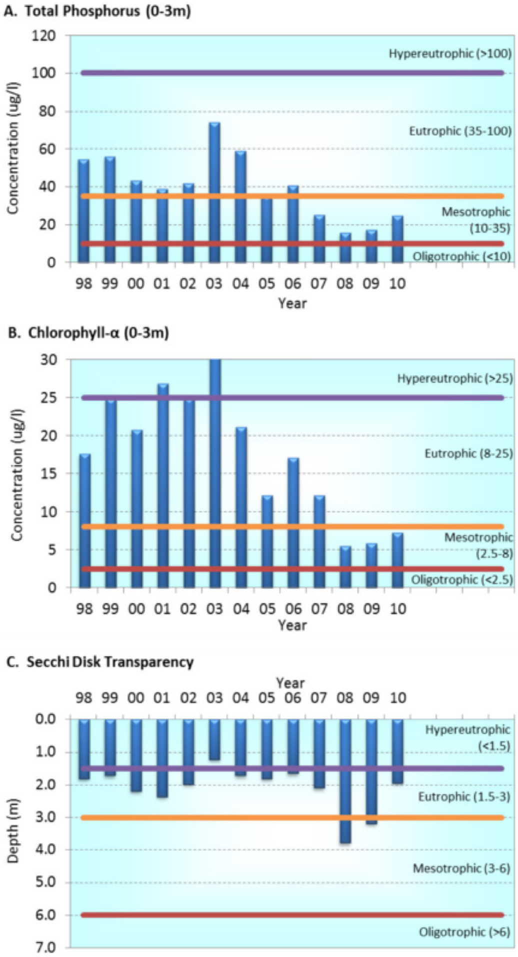


Figure 5-4. TSI conditions based on summer (June 1 – September 30) data, 1998-2010.

5.4 Dissolved Oxygen

A lake's dissolved oxygen (DO) content is a critical factor for aquatic life. As discussed in prior sections of this report, a restoration goal for Onondaga Lake was to meet the AWQS for DO during fall mixing. This goal has been met (refer to Figure EX-9). In addition, the reduction in nutrient loading has led to improved DO conditions throughout the water column. The improved DO status is evident from the reduction in the volume of affected water and the duration of anoxic conditions (refer to Figure EX- 8). One measure of the improving DO status of Onondaga Lake is the shift toward later onset of anoxia (Figure 5-5). Since the Actiflo® process came on line in 2005, anoxia has been delayed for a period of several weeks in the lower waters. The implications of this improved condition for the lake's fish community are discussed in Section 6.7.

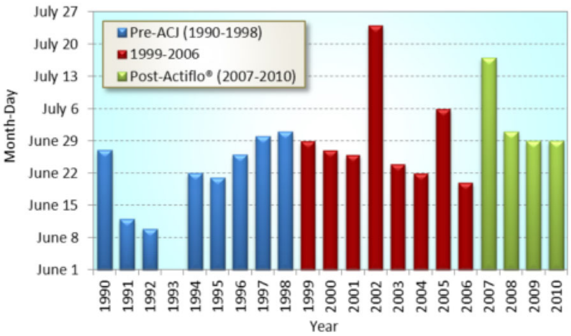


Figure 5-5. First date of measured anoxic conditions at 15m depth, Onondaga Lake, 1990 – 2010.

5.5 Ammonia N and nitrite N

Prior to the engineering improvements at Metro to bring about year-round nitrification of wastewater, Onondaga Lake was considered impaired by elevated concentrations of ammonia. Concentrations of this potentially harmful form of nitrogen exceeded the state ambient water quality standard for aquatic life protection (Table 5-2). The lake is now in full compliance with ambient water quality standards for ammonia, and in 2008 was officially removed from the State's 303(d) list of impaired waterbodies for this water quality parameter.

Table 5-2. Percent of Ammonia Measurements in Compliance with Ambient Water Quality Standards, Onondaga Lake, 1998-2010.

Depth (m)	*Percent measurements in compliance, NYS standard**												
	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
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

*6 NYCRR §703.5 Water quality standards for taste-, color- and odor-producing, toxic and other deleterious substances (http://www.dec.ny.gov/regs/4590.html#16130)

5.6 Recreational quality

The suitability of Onondaga Lake for water contact recreation is assessed using two parameters: fecal coliform bacteria and water clarity. In New York, fecal coliform bacteria are used to indicate the potential presence of raw or partially treated sewage in water. Although most strains of fecal coliform bacteria are not harmful, this class of bacteria is present in the intestinal tract of all mammals; the presence and abundance of fecal coliform bacteria in water is correlated with the risk of encountering pathogenic (disease-causing) microorganisms, including bacteria, viruses and parasites.

The applicable NYS ambient water quality standard for fecal coliform bacteria in surface water, as set forth in 6NYCRR Part 703.4, is as follows:

Fecal coliforms (number per 100 ml).

Classes	*Standard*
A, B, C, D, SB, SC	The monthly geometric mean, from a minimum of five examinations, shall not exceed 200

This standard is used to assess bacterial contamination at nearshore locations (Figure 5-6) as well as at the open water sites North Deep and South Deep (refer to Figure 1-2). Bacteria levels in portions of the lake typically increase following significant rainfall, and concentrations often vary by orders of magnitude due to the event-driven nature of the sources. Consequently, geometric means are best suited for examining spatial and temporal trends. The NY state standard for fecal coliform bacteria is assessed by taking frequent samples, a minimum of five per month, and calculating the geometric mean of the results. The ambient water quality standard for fecal coliform bacteria, designed to protect human health during water contact recreation, is set at 200 cfu (colony-forming units) per 100 ml of lake water. The standard applies during the period of Metro disinfection, which is April 1st – October 15th.

In 2010, bacteria counts at the monitoring stations were less than the fecal coliform bacteria standard at all but two nearshore monitoring locations within the Class C segment at the lake's southeastern shoreline (Figure 5-6). In addition, bacterial counts at the two offshore monitoring locations, North Deep and South Deep, were below the AWQS for fecal coliform bacteria during the 2010 assessment period.

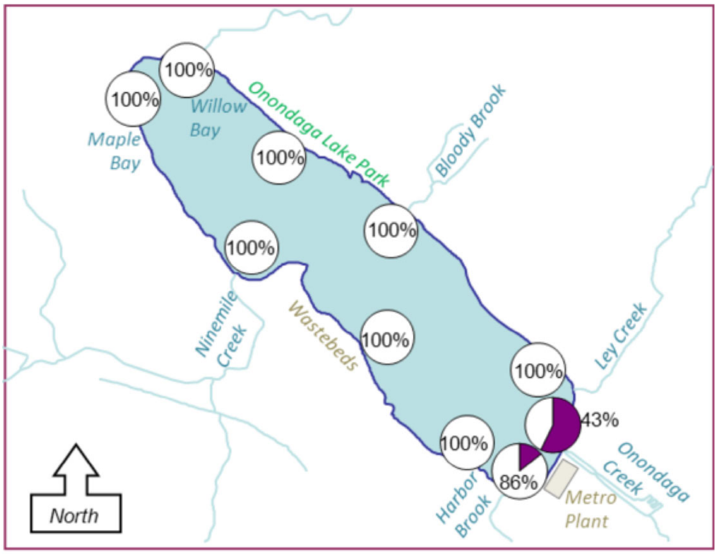


Figure 5-6. Fecal coliform bacteria results, Onondaga Lake nearshore stations, April – October 2010.

Note: Compliance is calculated for each location by comparing the monthly geometric mean of a minimum of five samples with the AWQS (200 cfu/100 mL). For October, the geometric mean includes three samples, as Metro disinfection ends October 15th in accordance with the facility's SPDES permit.

Water clarity is measured at the same network of nearshore stations. While there is no NYSDEC standard for water clarity, the NYS Department of Health (DOH) has a swimming safety guidance value for designated bathing beaches of 4 ft. (1.2 m). The 2010 results demonstrate that the DOH swimming safety guidance value was met throughout the summer recreational period (June 1st - Sept 30th) at all but two monitoring locations. These two nearshore areas - near the mouth of Onondaga Creek – met the swimming safety guidance value 90% and 5% of the time, respectively. The mud boils on upper Onondaga Creek may have contributed to the diminished water clarity of these two nearshore stations (see Section 5.3.4 for discussion of mudboils in 2010).

5.7 Nearshore conditions and trends

Onondaga County WEP has monitored nearshore water quality conditions as part of the AMP since 2000. The monitoring program includes both routine sampling and sampling following storm events. Dr. William Walker has completed a trend analysis of the water clarity and bacteria data through 2010. The analysis is included in the library. The significant findings of his analysis are summarized in this section.

Storm-driven discharges from urban and agricultural areas can trigger significant increases in turbidity and bacteria levels due to wash-off of pollutants from land surfaces and overflow of combined sewers. Evaluating long-term trends can be difficult due to high variability of these data and their dependence on antecedent hydrologic conditions. Dr. William Walker segregated the monitoring data into "wet" and "dry" weather events, using a 3-day antecedent rainfall of less than 0.5 inches of rainfall, as measured at Hancock Airport, over the three days prior to sample collection. The "dry" weather observations were those not affected by antecedent rainfall. Dr. Walker's analysis included evaluation of wet and dry weather results separately, all sample results together, individual nearshore sampling station results, and results grouped by station location in the lake:

- North end cluster, stations adjacent to: Ninemile Creek, Maple Bay, Willow Bay, Onondaga Lake Park, and Bloody Brook
- South end cluster, stations adjacent to: Ley Creek, Mid-South (near Metro outfall), and Harbor Brook.

In addition, Dr. Walker examined the trends from the South Deep station, to provide a basis for comparison to the nearshore stations.

5.7.1 Nearshore water clarity trends

Water clarity at the nearshore lake stations has increased over the AMP monitoring period. This increase is both statistically significant, and ecologically important as evident from the expansion of macrophyte growth into deeper waters and the cascading benefits on aquatic habitat and sediment stabilization. Turbidity is a far more robust indicator parameter for the statistical trend analysis, because many of the Secchi disk transparency data were recorded as greater than 1.2 m. This result indicates compliance with the NYS Department of Health swimming safety guidance value, but diminishes the power of the statistical analysis for trend detection. The only station not exhibiting a statistically significant decrease in turbidity was the Waste Beds, which was included in the AMP in 2007 and has a shorter period of record.

5.7.2 Fecal coliform bacteria trends

Fecal coliform levels are clearly higher during wet weather as compared to dry weather, especially at the southern nearshore stations (adjacent to Ley Creek, Onondaga Creek and Harbor Brook). Over time, there has been a decreasing trend in wet-weather bacterial abundance at the southern nearshore stations, as well as at the northern station adjacent to Bloody Brook. These patterns are generally consistent with reductions in storm-related bacteria sources (runoff, CSOs, Metro Bypass). In contrast, the dry weather data indicate increasing trends over time at southern nearshore stations near Harbor Brook and the Metro outfall. This increasing trend is consistent with the increasing trend in fecal coliform bacteria measured in Harbor Brook at the Hiawatha Blvd station, as well as the NYSDEC-mandated reduction in chlorine doses in the Metro Outfall 002 discharge. NYSDEC required this reduction to address concerns for potential adverse impacts of residual chlorine on aquatic life. In 2004, an ultraviolet (UV) disinfection system was installed to kill bacteria in the Metro 001 outfall. The Metro outfall 001 consistently meets its SPDES limit for fecal coliform bacteria.

Between 2003 and 2010, monthly geometric means exceeded the regulatory limit of 200 cfu/100 mL in three of 60 summer months in the nearshore station close to Metro and at the mouth of Onondaga Creek. For all other monitoring locations in the lake, summer monthly geometric means never exceeded the regulatory limit over this eight-year period.

5.8 Trends in Metro improvements and lake response

The improvements to the Metro treatment plant have resulted in significant reductions in ammonia and phosphorus loads to Onondaga Lake, and an associated steep decline in the concentrations of these nutrients in the lake water (Table 5-3; Figure 5-7; refer also to Figure EX-1 and Figure EX-3). Ammonia N met the AWQS at all depths throughout 2010. Productivity has declined, algal biomass is reduced, and the lake has exhibited mesotrophic conditions since 2007.

Table 5-3. Summary of trends in lake concentrations, 2001-2010.

Variable		**South Basin**		**North Basin**		**Lake Outlet**		**Nearshore****	
		Upper Waters	***Lower Waters***	***Upper Waters***	***Lower Waters***	***12 m***	***2 m***	***North Sites***	***South Sites***
Clarity	Secchi disk transparency	○	○	○	○	○	○	○	○
	Turbidity	○	-	-	-	-	-	↓	↓
Bacteria	Fecal coliforms	○	○	○	○	○	○	○	○
	E. Coli	○	-	-	-	-	-	↓	○
Nitrogen	Ammonia-Nitrogen as N (NH_3-N)	↓	↓	↓	↓	↓	↓	-	-
	Nitrite as N (NO_2-N)	↓	○	↓	○	↓	↓	-	-
	Nitrate as N (NO_3-N)	↑	↑	↑	↑	↑	↑	-	-
	Organic Nitrogen as N	↓	↓	↓	○	↓	↓	-	-
	Total Kjeldahl Nitrogen as N (TKN)	↓	↓	↓	↓	↓	↓	-	-
Phosphorus	Total Phosphorus (TP)	↓	↓	↓	↓	↓	↓	-	-
	Soluble Reactive Phosphorus (SRP)	↓	↓	↓	↓	↓	↓	-	-
Solids	Total solids (TS)	○	○	○	○	○	○	-	-
	Total suspended solids (TSS)	○	○	○	○	○	○	-	-
	Total dissolved solids (TDS)	○	○	○	○	↓	○	-	-
	Volatile suspended solids (VSS)	○	○	○	○	○	○	-	-
Chlorophyll	Chlorophyll-α	↓	○	○	○	○	○	-	-
	Phaeophytin-α	○	○	○	○	↓	○	-	-
Carbon	Total organic carbon (TOC)	↓	↓	↓	↓	↓	↓	-	-
	Total organic carbon, filtered (TOC-F)	↓	↓	↓	↓	↓	↓	-	-
	Total inorganic carbon (TIC)	○	↓	○	○	○	○	-	-
Other	Alkalinity as $CaCO_3$	○	○	○	○	○	○	-	-
	Bio. oxygen demand 5-day (BOD_5)*	-	-	-	-	-	-	-	-
	Calcium (Ca)	○	○	○	○	○	○	-	-
	Chloride (Cl)	○	○	○	○	↓	○	-	-
	Conductivity	○	○	○	○	○	↓	-	-
	Dissolved Oxygen (DO)***	○	↑	○	↑	↑	○	-	-
	Hardness	○	○	○	○	○	○	-	-
	Magnesium (Mg)	↓	○	○	○	○	○	-	-
	Sodium (Na)	○	○	○	○	○	○	-	-
	pH	○	○	○	○	↑	○	-	-
	Silica (SiO_2)	○	○	○	○	○	○	-	-
	Sulfate (SO_4)	↓	↓	○	○	↓	↓	-	-
	Temperature	○	○	○	○	○	○	-	-

Notes:

Significance level, two-tailed, seasonal Kendall test accounting for serial correlation.

↓ indicates decreasing trend ($p > 0.1$)
↑ indicates increasing trend ($p < 0.1$)
○ circle symbol indicates no trend ($p = 0.1$)
- Dash indicates parameter was not measured at this location, or trend analysis was not conducted.

* BOD_5 (Biochemical Oxygen Demand (5-day)) trend analysis results are not accurate because of the preponderance of data less than the MRL (PQL).

**Nearshore analyses conducted by Bill Walker on data from 1999-2010 (Walker, 2011). North sites include nearshore stations in the vicinity of Ninemile Creek, Maple Bay, Willow Bay, Onondaga Lake Park, and Bloody Brook. South sites include nearshore stations in the vicinity of Ley Creek, Metro (mid-South), and Harbor Brook.

*** Although Onondaga Lake continues to exhibit anoxic conditions in the deep water during summer stratification, the volume of the lake affected by low DO, and the duration of low DO conditions are both in decline. This is indicative of improved DO resources.

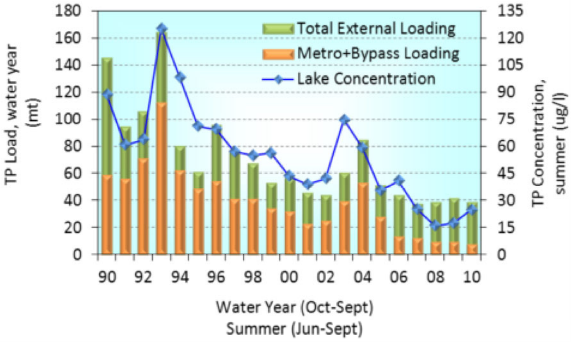
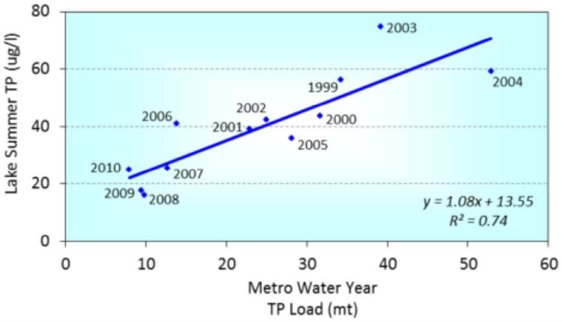


Figure 5-7. TP loading (water year), all external sources and summer TP concentration Onondaga Lake upper waters, 1990 – 2010.

The relationship between Metro TP load and lake response is illustrated in Figure 5-7. The loading calculations presented in this graph are based on water year (October 1- Sept 30). While a 12-month loading estimate is important to capture all the seasons, correlating summer water quality with the corresponding calendar year loads is not a reasonable approach, because October-December comes after June-September. The water year (October-September) interval is a rational approach, especially considering the lake's short water residence time, and has been widely used in other lake models. For additional discussion of the empirical mass-balance framework for Onondaga Lake, refer to previous reports prepared by Dr. William Walker and available on his web site http://www.wwwalker.net/onondaga

The annual loading is a less robust measure of summer average TP in the upper waters, due to the inclusion of the fall months. As illustrated in Figure 5-8(A), the TP input from Metro accounts for approximately 74% of the annual variation in the TP concentrations of the lake's upper waters. When watershed load is included (this source is more variable), the correlation is weaker, as displayed in Figure 5-8(B).


A. Lake TP Concentration vs Metro TP Load

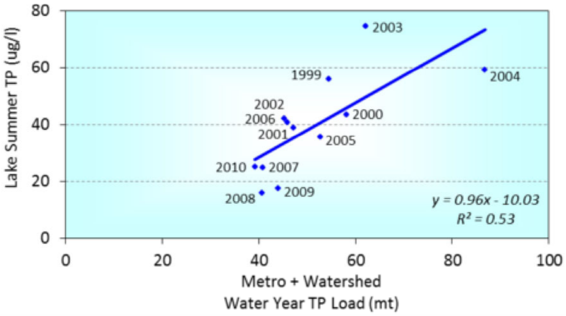

B. Lake TP Concentration vs Total TP Load

Figure 5-8. Relationship of Metro TP loading and lake summer TP (panel A-linear regression) and all sources TP loading and lake summer TP (panel B-linear regression).

Effluent total N has remained relatively constant as the total P has declined after 2005, resulting in a significant increase in the ratio of N:P in the lake's upper waters (Figure 5-9). The relative availability of these two nutrients affects the species composition and abundance of the phytoplankton community. Algal cells require both N and P for growth, and require these nutrients in a ratio that approximates their presence in the cellular protoplasm (the stoichiometric ratio). The stoichiometric ratio for algal cells is estimated as 16N:1P.

Nitrogen can become limiting to algal productivity when the available N:P supply ratio declines below a critical value, variously cited as in the range of 29:1 or lower (the red line on Figure 5-8 is drawn at 16, with a band around it reflecting the range of values cited in the literature). When the ratio of total N to total P in the water column declines to low values, P is present in abundance relative to the stoichiometric needs of the algal cells, and N may become limiting (Hall et al. 2005). Once N is limiting, several species of cyanobacteria, which can utilize atmospheric nitrogen, have a competitive advantage over other algal groups. In productive lakes, this leads to blooms of cyanobacteria and associated water quality problems. Cyanobacteria, once common, have comprised only a small fraction of the phytoplankton community since 2006.

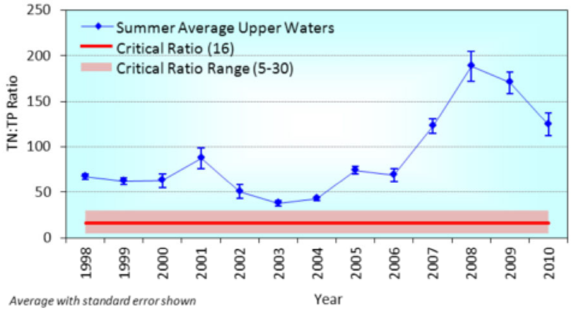


Figure 5-9. Onondaga Lake upper waters total nitrogen to total phosphorus (N:P) ratio, 1998-2010.

The ratio is concentration-based, where the ratio for each sample date was calculated, then the ratios were averaged to represent summer for each year. The summer average represents the period June 1 to September 30. Total N was calculated as the sum of Total Kjeldahl Nitrogen (TKN), nitrite-N and nitrate-N concentrations; TP was reported by the laboratory. Nitrite-N and nitrate-N samples were collected as composites of the upper mixed layer (UML); TKN and TP were collected at discrete depths, and the results were averaged for 0m and 3m depths to represent upper waters.

The transformation in the quality of Metro effluent has effected a fundamental change in the lake ecosystem. A reduced phosphorus supply has resulted in lower algal biomass, since phosphorus is now firmly established as the limiting nutrient for algal growth in Onondaga Lake. Reduced algal biomass results in less organic material to be decomposed in the lower waters, and a reduced demand on hypolimnetic oxygen resources. The result is a decrease in volume-days of anoxia and increased dissolved oxygen levels during fall mixing.

The AMP results document improved DO in the lake's upper and lower waters. The water quality monitoring buoy deployed at South Deep provides frequent measurements of the DO at 2 m and 12 m depths. Despite the year-to year variability in the onset of thermal stratification, the diminished mass of algae reaching the sediment surface has contributed to a later onset of anoxia and improved DO in the lake's lower waters.

The oxidation of ammonia to nitrate in Metro's biological treatment system has resulted in a statistically significant increase in nitrate concentrations in the lake's upper and lower waters. The increased nitrogen concentrations are also a consequence of the lower phosphorus loading. As phosphorus and algal productivity have declined, there is diminished uptake of all forms of nitrogen from the water column.

The presence of nitrate in the lower waters has affected the redox status of the lower waters, and modified the dynamics of sediment phosphorus release. As oxygen is depleted from the deep waters (Figure 5-10A), nitrate serves as an alternate electron acceptor for the microorganisms actively decomposing organic material settling out of the photic zone. Nitrate in the deep waters (Figure 5-10B) delays the reduction of iron and manganese, and phosphorus bound to these minerals remains trapped in the lake sediments.

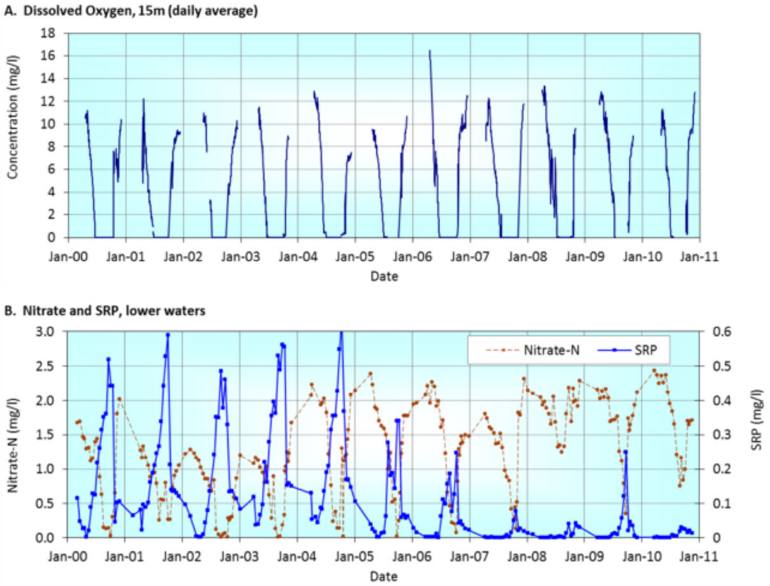


Figure 5-10. LWL concentrations of SRP, NO3-N and DO, 2006-2010.

Comparing the 2010 results to those of previous years highlights the effect the increasing nitrate levels have had on the redox status of the lake's hypolimnion, as reflected in the diminished accumulation of SRP in the lower waters during the summer period of thermal stratification (Figure 5-10B). Once iron and manganese are reduced, phosphorus is released to the overlying waters and the SRP concentrations in the hypolimnion increase. If the phosphorus released to the upper waters includes more than that represented by decomposition of algae from the current year, it may be considered as an internal load (recycle). During 2010, the redox status of the lake's lower waters (15 m and deeper) ranged from a low value of 50 mv on 8/10/11 to values greater than 300 mv (late June and again in November).

An estimate of the mass of phosphorus released from the lake sediments during the stratified period each year indicates that there is a great deal of variability; some change may be a result of improving redox status of the hypolimnion. However, variations in algal production and the duration of stratification also affect the magnitude of the internal phosphorus recycling.

A summary of the 2010 results of all parameters measured in Onondaga Lake is included in the library.

Section 6. Biology and Food Web: 2010 Results and Trends

This section of the Annual Report reviews the extensive AMP data describing the phytoplankton, macrophyte, zooplankton, macroinvertebrates, dreissenid mussel and fish communities that comprise the Onondaga Lake food web.

As phosphorus concentrations in Onondaga Lake have declined to mesotrophic levels, biological conditions have responded. Improved light penetration, a consequence of lower algal abundance has led to expansion of macrophyte beds. The expanded cover of macrophytes throughout the littoral zone has improved habitat and shelter for fish and other aquatic organisms.

6.1 Primary producers- Algae and Macrophytes

Since the late 1990s, the biomass of phytoplankton, which includes algae and cyanobacteria, in Onondaga Lake has declined rapidly, from a standing crop around 8 mg/l in 1998-99 to around 1 mg/l after 2007. Although algal biomass increased slightly in 2010 from 2008 and 2009 levels, the results for 2010 (April-October) are the third lowest since 1998 at 1.25 mg/l (Figure 6-1). These results are consistent with the discussion of trends in chlorophyll-a and water clarity presented in Section 5. There is a strong correlation between spring total P and algal abundance (as measured by chlorophyll-a) in the summer months that follow.

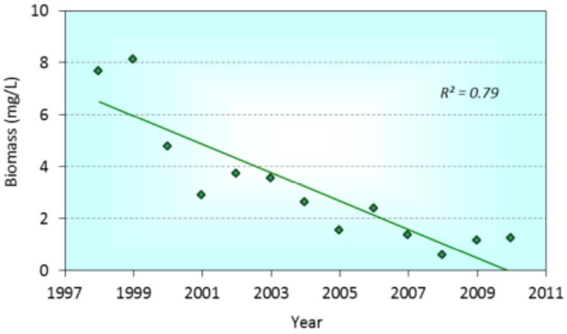


Figure 6-1. Reduction in the Onondaga Lake phytoplankton standing crop, 1998-2010.

The composition of the phytoplankton community has changed from one dominated by undesirable cyanobacteria (blue-greens) and pyrrhophytes (dinoflagellates) to one dominated by more desirable diatoms and chlorophytes (green algae) (Figure 6-2). Moreover, among the cyanobacteria that appeared briefly in the lake in the fall of 2010, the large nitrogen-fixing and often toxic colonial cyanobacteria (*Microcystis*, *Anabaena,* and *Oscillatoria*) were essentially absent.

The improved water clarity, allowing more light to penetrate to the bottom in inshore areas, has led to a trend of increasing colonization by macrophytes, and the littoral zone is covered with plants (refer to Figure EX-10). The diversity of this aquatic plant community has also increased dramatically from a low of 5 or 6 species in the early 1990s to 23 species in 2010 (refer to Figure EX-11).

Although phytoplankton abundance in 2010 was slightly higher than measured in 2009, the average algal biomass for April-October remained well below that expected for a meso-eutrophic lake (3-5 mg/l, Wetzel 2001) and is similar to that of 2007, at 1.3 mg/l (refer to Figure 6-1). Peak algal biomass did not exceed 3.0 mg/l in 2010, confirming the lake's mesotrophic status. Over the last decade, phytoplankton biomass has declined significantly, and the years from 2007 to 2010 were the four lowest years on record. This decline is likely due both to the improved removal of phosphorus from the Metro effluent and to increased grazing by dreissenid mussels. Large zooplankton were extremely rare in 2010 and algal biomass increased marginally compared to 2008 and 2009. Interestingly, quagga and zebra mussels also declined in 2010 compared to 2009.

Diatoms (Bacillariophyta) continued to dominate the phytoplankton community, and showed three peaks, an early spring peak, a mid-spring peak, and a fall peak (Figure 6-2 and Figure 6-3). In 2009, an exotic diatom species not previously identified from Onondaga Lake (*Actinocyclus normani*) was the most abundant phytoplankton species in the lake. This species has been in Lake Ontario since 1938 (Stoermer et al. 1985, Mills et al. 1993). In 2010, this diatom was rare and the most abundant phytoplankton species was the diatom *Fragilaria crotonensis,* which dominated the fall bloom. Diatoms have an elevated requirement for silica compared with other phytoplankton taxa, due to their frustules, and the effect of the spring diatom blooms is evident in the annual cycle of this nutrient. The other genera of phytoplankton dominant in 2009 remained common in the 2010 assemblage.

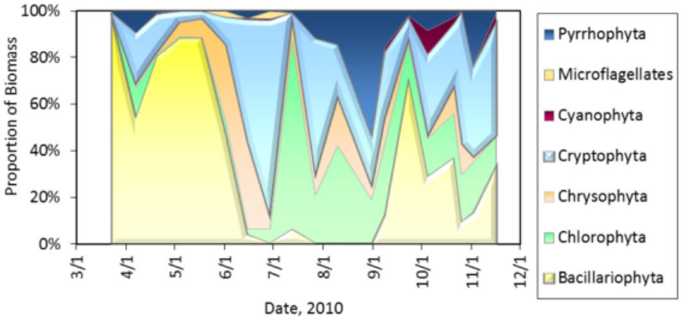


Figure 6-2. Proportional biomass of phytoplankton divisions, 2010.

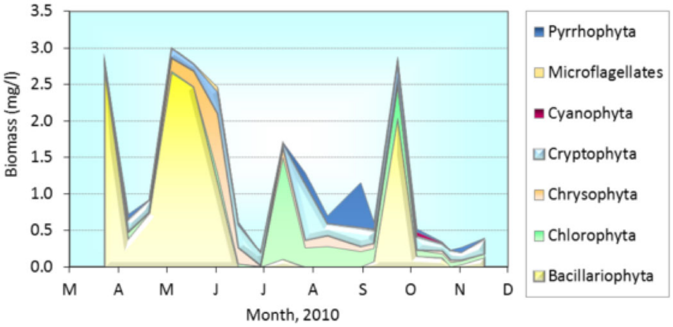


Figure 6-3. Phytoplankton community structure and biomass, 2010.

Cyanobacteria and dinoflagellates, which dominated the phytoplankton community in Onondaga Lake until 2001, have now nearly disappeared from the lake, and nuisance blooms of *Aphanizomenon* (*A. gracile* and *A. flos-aquae*), which were typical of summers before 2000, no longer occur. The species of cyanobacteria remaining in the lake are smaller in size, and peak cyanobacteria abundance reached only 0.05 mg/l in 2010, just slightly higher than in 2009 (0.03 mg/l).

Along with phytoplankton, aquatic macrophytes (plants) are also an important component of lake ecology; the rooted plants and algae have major effects on productivity and biogeochemical cycles. Macrophytes produce food for other organisms and provide habitat for aquatic invertebrates, fish, and wildlife, and help to stabilize sediments. As part of the ACJ, the AMP included extensive sampling of the lake's macrophyte community in 2000, 2005, and 2010 to complete a species list and document changes in biomass. Aerial photographs of the littoral zone are collected annually (when water clarity allows) to determine plant distribution.

The macrophyte community continued its expansion within the lake's littoral zone in 2010. Based on annual aerial photographs, coverage has expanded from 85 acres in 2000 to 409 acres in 2010 (Figure 6-4). The aerial photos do not enable species identification, only percent cover.

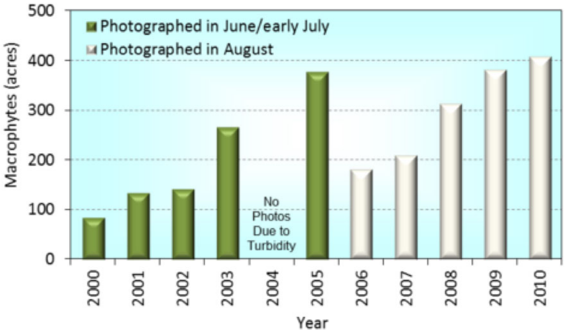


Figure 6-4. Macrophyte distribution, 2000 – 2010.

The detailed survey completed in 2010 documented 23 unique macrophyte species in the lake, compared with 17 species in 2005 and 10 species in 2000. This increase in species richness is due nearly entirely to establishment of native species; only two of the 13 new species documented since 2000 are non-native. The most abundant species were submersed macrophytes (Table 6-1). Seven of the species documented in the 2010 survey had not been observed in the lake previously. These new species were relatively rare in the lake, each accounting for less than 4% of the total plant coverage and biomass in the lake. Straight-leaf pondweed, designated as endangered within New York, was first reported in Onondaga Lake in 2005 and remained present in 2010. Community and species metrics all showed significant improvements since the 2000 survey. These improvements reflect the increased number of species in the lake and the increasing contribution of each species to the overall macrophyte community over time.

Table 6-1. Species list of aquatic macrophytes observed in Onondaga Lake in current (2010) survey, past studies, and documented historical observations.

Species	2010	2005	2000	1995	1993	1992	1991	Historical
Ceratophyllum demersum	X	X	X	X	X	X	X	1
Chara sp.	--	--	--	--	--	--	--	3
Chara vulgaris	X	--	--	--	--	--	--	--
Elodea canadensis	X	X	X	--	--	--	--	--
Fontinalis sp.	X	--	--	--	--	--	--	--
Lemna minor	X	X	--	--	xx	--	--	--
Lemna trisulca	X	X	--	--	--	--	--	--
Myriophyllum spicatum	X	X	X	X	X	X	X	--
Najas flexilis	X	X	--	--	--	--	--	--
Najas guadalupensis	X	X	--	--	--	--	--	--
Najas marina	--	--	--	--	--	--	--	1,2,4
Nitella flexilis	X	--	--	--	--	--	--	--
Nitella sp.	--	--	--	--	--	--	--	5
Nitellopsis obtusa	X	--	--	--	--	--	--	--
Polygonum amphibium	X	--	--	--	--	--	--	3
Potamogeton crispus	X	X	X	X	X	X	X	2
Potamogeton diversifolius	--	--	--	--	xx	--	--	--
Potamogeton pusillus	X	X	X	--	--	--	--	--
*Potamogeton strictifolius**	X	X	--	--	--	--	--	--
Ranunculus longirostris	X	--	--	--	--	--	--	--
Ranunculus sp.	--	--	X	--	--	--	--	--
Ruppia maritima	X	X	--	--	--	--	--	--
Sagittaria latifolia	--	X	X	--	--	--	--	--
Sparganium sp.	--	--	--	--	xx	--	--	--
Spirodela polyrhiza	X	X	--	--	--	--	--	--
Stuckenia pectinata	X	X	X	X	X	X	X	1,2,3
Stuckenia vaginata	X	--	--	--	--	--	--	--
Trapa natans	X	X	--	--	--	--	--	--
Vallisneria americana	X	X	X	--	--	--	--	--
Zannichellia palustris	--	--	--	--	xx	--	--	5
Zosterella dubia	X	X	X	X	X	X	X	1,2,3,4
Total Number	**23**	**17**	**10**	**6**	**10**	**6**	**5**	**9**

*Notes: * indicates endangered species; "X" indicates presence; "--" indicates absence; "xx" only a few plants found behind experimental wave breaks.*
Historical presence indicated by note number.

Sources for surveys by years:
2010 Survey (OCDWEP 2011)
2005 Survey (OCDWEP 2006)
2000 Survey (OCDWEP 2001)
1995 Survey (Arrigo 1995)
1993 Survey (Madsen et al. 1996b)
1992 Survey (Exponent 1998 and Madsen et al. 1996b)
1991 Survey (Madsen et al. 1996a)

Historical Sources:
1. Paine (1865)
2. Bye and Oettinger (1969)
3. NYS Museum voucher specimen (Madsen et al. 1996a)
4. Goodrich (1912)
5. Dean and Eggleston (1984)

6.2 Zooplankton and dreissenid mussels

The zooplankton community is a pivotal component of the lake ecosystem; these grazing aquatic animals affect the abundance and species composition of the phytoplankton community, and are, in turn, affected by the fish community. The size structure and abundance of the Onondaga Lake zooplankton community is tracked annually as part of the AMP. In Onondaga Lake, the zooplankton and benthic mussels are the most important grazers of phytoplankton.

The size structure of the zooplankton community, i.e., the relative abundance of small and large species, is a consequence of the grazing pressure exerted on zooplankton by fish. The temporal changes in the zooplankton community are linked to changes in predation by the dominant fish planktivore in the lake, the alewife (*Alosa pseudoharengus*) (Wang et al. 2010). In general, the alewife tend to feed on larger zooplankton species leaving smaller zooplankton alone. When alewife populations are high, the population of larger zooplankton species declines. In the absence of alewife predation, the population of larger zooplankton species increases, as illustrated in Figure EX-13. This in turn affects the phytoplankton community, as larger zooplankton are far more efficient grazers than the smaller zooplankton; the presence of larger organisms results in less algae and clearer waters (refer to Figure EX-14).

The average biomass of all zooplankton in the lake (as measured in dry weight) was lower during April-October 2010 (143 µg/l) than it was for the same period in 2009 (236 µg/l). The peak zooplankton biomass, evident in late-June 2010, was 884 µg/l. During this period of peak abundance, the zooplankton community was dominated by taxa in the family Bosminidae, which are small crustacean species (Figure 6-5). The low biomass of *Daphnia* – larger zooplankton - in the years between 2003 and 2007 and then again in 2010 (Figure 6-6) is attributed to the presence of abundant alewife during these time periods.

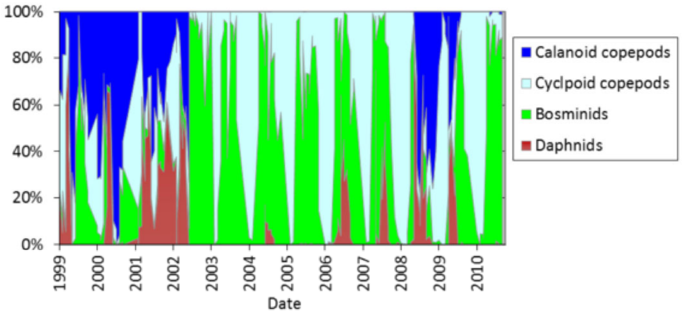


Figure 6-5. Average biomass of zooplankton, proportion of major groups.

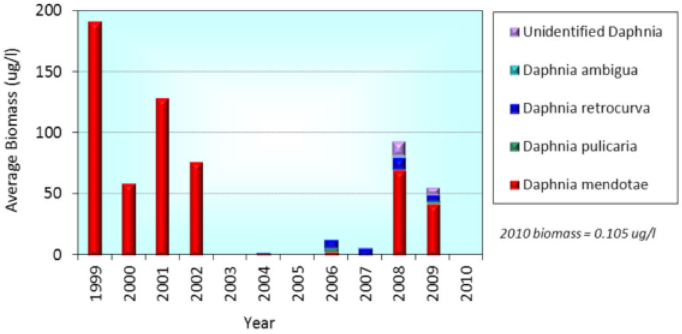


Figure 6-6. Biomass of various Daphnia species in Onondaga Lake.

The data from Onondaga Lake clearly indicate that selective predation of larger zooplankton by fish has a direct effect on the species composition and size structure of the zooplankton community. The significance of the alewife on this process is striking. The average size of the total zooplankton community in Onondaga Lake during periods of higher alewife abundance (2003-2007) was 0.35 mm (Figure 6-7). In 2010, the average size of the zooplankton community was 0.28 mm, which is the smallest average size in the dataset (Figure 6-7). The decline in zooplankton length in the fall of 2009 is a typical effect of a large number of fish hatched that year. Young fish affect zooplankton in the late summer as their total biomass increase and individual size increase. This age group and addition fish from the 2010 year class caused the small size of zooplankton observed throughout 2010 (Figure 6-8).The zooplankton data from 2010 confirm the fisheries analysis; alewife had another strong year class in 2009 and are having a dramatic effect on the lake food web.

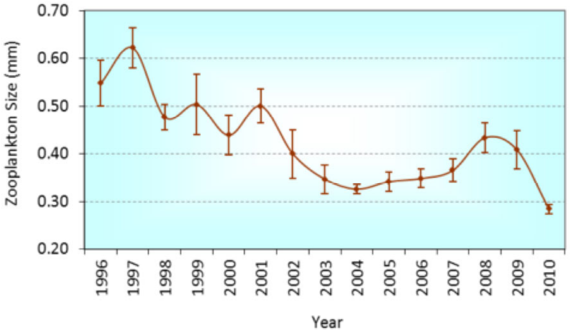


Figure 6-7. Average size of all crustacean zooplankton in Onondaga Lake, 1996 – 2010.

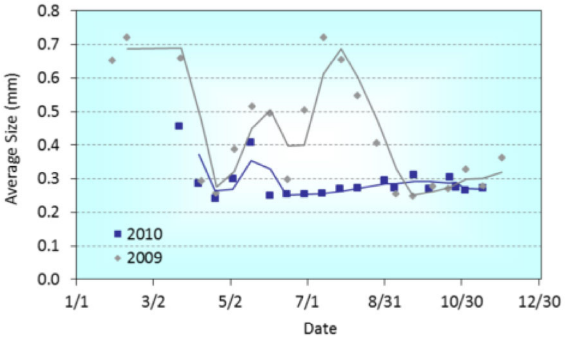


Figure 6-8. Average crustacean zooplankton length (mm), 2009 and 2010.

Increased alewife abundance had an important cascading effect on lower levels of the food web. At the level of the zooplankton, alewife feeding selectively on larger zooplankton leads to lower biomass and smaller average size of the crustacean zooplankton (refer to Figure EX-13). Smaller zooplankton are less efficient than larger ones in harvesting phytoplankton, and phytoplankton abundance increases as a result. More abundant phytoplankton results in increased primary production and decreased water clarity, typically measured as Secchi disk transparency. The relationship between zooplankton size and water clarity was illustrated in Figure EX-14. These top-down effects are often referred to as a "trophic cascade", with alternating increases and decreases between adjacent levels of the food web. The strong year-class of alewife in 2009 precipitated such a trophic cascade with noticeably reduced Secchi disk transparency measurements and increased chlorophyll-a and total P levels in summer 2010. Note that total P loading did not increase from 2009 to 2010 although a wet summer led to higher P loading from the watershed (refer to Figure 5-6).

Zebra mussels (*Dreissena polymorpha*) were introduced into the Great Lakes from Eurasia in ballast water from international shipping. They were first recorded in Onondaga Lake in 1992 although they did not become abundant until 2000 (Spada et al. 2002). A second related species—the quagga mussel (*Dreissena bugensis*) - appeared in Onondaga Lake in 2005. The Annual Monitoring Program has followed their abundance and distribution using consistent methods since 2005. Both species increased in abundance since 2005, reaching peak average density in 2007 of over 10,000 mussels/m^2. Quagga mussels increased in 2008 and reached higher abundances than zebra mussels by 2009, although zebra mussels were again more abundant (55% by number) than quagga mussels (45% by number) in 2010. Average annual mussel biomass in the lake increased to around 1017 g/m^2 in the 0-4.5 m depth range by 2007 and has decreased since then (741 g/m^2 in 2008, 736 g/m^2 in 2009 and 544 g/m^2 in 2010). Quagga mussels dominated mussel biomass in both 2009 (84%) and 2010 (87%) due to their larger average size (Figures 6-9 and 6-10). Due to the high variability in mussel densities, the declines in density and biomass from 2009 to 2010 were not significant (two-tailed t-test, P=0.25 for density and p=0.52 for biomass).

These benthic mussels are filter feeders, and, as such, exercise a top-down effect on phytoplankton abundance similar to that of the zooplankton. The high mussel biomass since 2007 suggest continued high grazing pressure from these mussels on phytoplankton. However, the littoral zone is relatively small in Onondaga Lake and the large effects of mussels observed in the nearby Oneida Lake may not materialize.

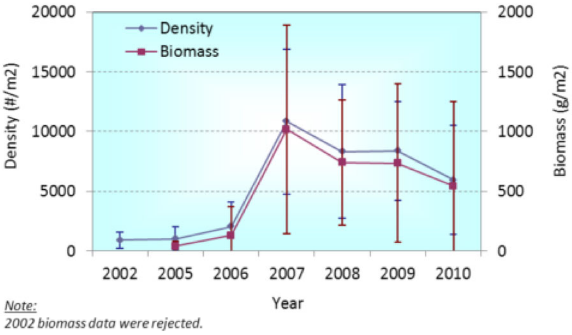


Figure 6-9. Dreissenid mussel average density and biomass with standard deviation, 2002-2010.

(Note: where average quagga and zebra mussel biomass by zone were reported separately (2009 and 2010), the biomasses of each species in each zone were averaged to obtain total average mussel biomass by zone. Average zone biomasses were then averaged, and standard deviation calculated, for the lake biomass as presented in this graphic.)

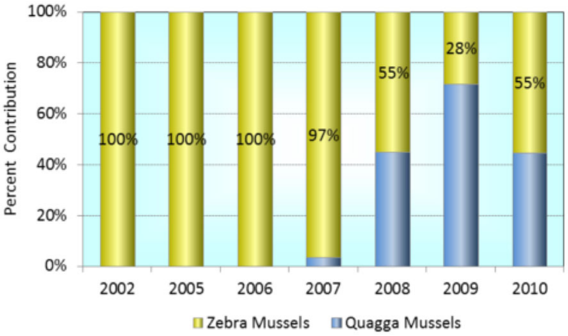


Figure 6-10. Relative abundance of dreissenid mussels, 2002-2010.

6.3 Littoral macroinvertebrates

In addition to the biennial tributary macroinvertebrate monitoring, Onondaga County WEP samples and analyzes the macroinvertebrate community of the lake's littoral zone every five years. Samples are collected at five reference locations around the littoral zone. Macroinvertebrate organisms are separated from the lake sediments, identified, and enumerated. These data are used to calculate NYSDEC standard benthic community indices, indicating the existence and severity of impairment. In addition, chironomids in the littoral samples were examined for deformities. The complete report and data files from the 2010 investigation, including detailed comparisons with results from 2000 and 2005, are included in the Library (reference L08.7). Highlights of the report are included in this section of the annual report.

The macroinvertebrate community of the littoral zone has shown considerable improvement since 2000, as displayed in Figure 6-11. The designation of low and high energy regions refers to wave energy, and is a result of the lake's orientation and prevailing winds. The lake's littoral zone is affected by many factors including substrate texture and organic matter. The improvement in the macroinvertebrate community metrics is most pronounced at those stations (Site 3 – Metro, and Site 4 –Ley Creek) that were in the poorest condition in 2000. Although the community at Site 3 was still categorized as *severely impacted* in 2010, it has improved steadily since 2000 and is approaching a *moderately impacted* condition. Three (Sites 2, 4, and 5) of the five sites are now categorized as *slightly impacted*. Changes in macroinvertebrate community composition are evident throughout much of the lake in the form of higher species richness and diversity, which have resulted in improved scores for Biological Assessment Profile (BAP), Hilsenhoff Biotic Index (HBI), and Percent Model Affinity (PMA). These changes are likely a response to improvements in water quality, decreased organic loading, improved dissolved oxygen conditions in littoral sediments, and increases in macrophyte abundance and coverage.

Despite the noted improvements, the littoral macroinvertebrate community of Onondaga Lake still exhibits signs of stress, especially at the southern end (Table 6-2). This is the area of the lake that was the most impaired and will take the longest time to recover from decades of impacts from municipal and industrial influences. Full recovery at the southern end of the lake may take many years, and the diversity and richness of the macroinvertebrate community at this location may never equal that seen in other areas of the lake due to the poorer habitat quality of the predominantly fine sediments in this region of the lake. On the other hand, the Honeywell projects to address legacy pollution of the sediments may affect the macroinvertebrate community in these areas.

The improving trends in littoral macroinvertebrate community metrics since 2000 should continue as the lake responds to improvements in wastewater collection and treatment, both at Metro and the combined sewer overflows, and other remediation efforts occurring within the lake and surrounding watershed. The ongoing expansion and diversification of the aquatic macrophyte community throughout the lake's littoral zone will also contribute to changes and likely improvements to the littoral macroinvertebrate community.

Table 6-2. Mean index value and corresponding NYSDEC water quality assessment score from petite Ponar samples (with dreissenid mussels included in the sample) for sites in Onondaga Lake in 2010.

Benthic Community Indices	Site 1 Maple Bay		Site 2 Wastebeds		Site 3 Metro		Site 4 Ley Creek		Site 5 Hiawatha Point	
	Index Mean	*NYSDEC WQ Scale Mean*	*Index Mean*	*NYSDEC WQ Scale Mean*	*Index Mean*	*NYSDEC WQ Scale Mean*	*Index Mean*	*NYSDEC WQ Scale Mean*	*Index Mean*	*NYSDEC WQ Scale Mean*
Richness	13.6	4.41	11.7	3.48	9.94	2.44	12.6	3.91	14.9	5.22
Diversity	2.45	4.56	2.65	5.78	2.26	3.81	2.86	6.65	3.02	7.29
Dominance-3	0.722	5.40	0.702	5.77	0.805	4.08	0.641	6.82	0.608	7.37
PMA	45.0	3.04	59.1	5.82	28.4	0.433	59.6	5.92	57.4	5.49
HBI	8.12	4.71	7.27	6.82	9.70	0.744	7.52	6.20	7.80	5.51
NYSDEC Site Mean Water Quality Value	**4.4**		**5.5**		**2.3**		**5.9**		**6.2**	
Level of Impact	**Moderate**		**Slight**		**Severe**		**Slight**		**Slight**	

Notes:

NYSDEC WQ Scale Mean refers to the water quality score resulting from a calculation based on the benthic community index. The calculations are found in the NYSDEC report "Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State" (2009). The Level of Impact is obtained from a scale provided in the NYSDEC 2009 document, using the NYSDEC Site Mean Water Quality Value.

Indices: Richness = a measure of the number of species present; Diversity = a measure of species diversity; Dominance-3 = combined percent contribution of three most numerous species; PMA = Percent Model Affinity, a measure of similarity to a model non-impacted community; HBI = Hilsenhoff Biotic Index, a measure of community tolerance to pollution.

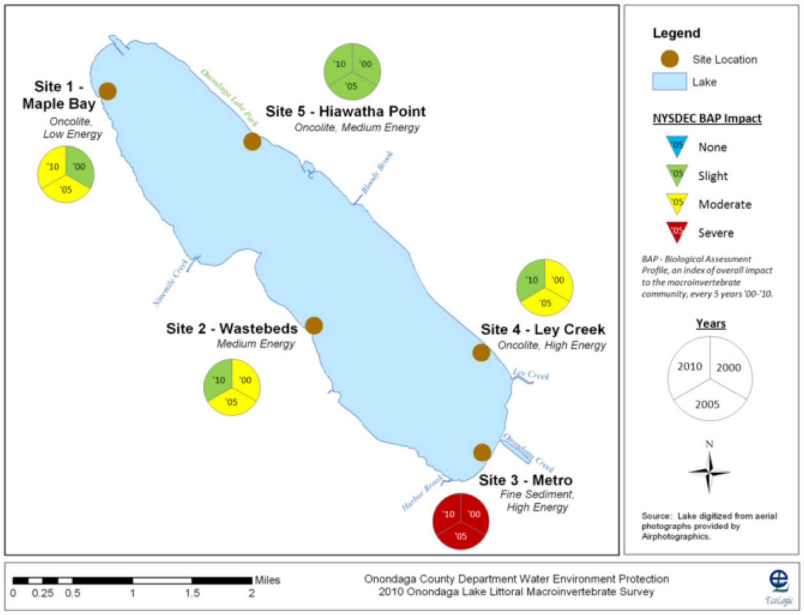


Figure 6-11. Spatial depiction of littoral macroinvertebrate community data.

6.4 Fish

Changes in the fish community of Onondaga Lake are anticipated as water quality and habitat conditions improve. The significant reduction in ammonia and phosphorus input, and the consequent shift from eutrophic to mesotrophic conditions over the past several years are expected to expand available fish habitat within both the littoral zone and the pelagic zone. Since 2000, the AMP has included an extensive fisheries monitoring program, incorporating different types of sampling gear to asses nesting, larval, juvenile, and adult stages of numerous species. The challenge in data analysis and interpretation lies with the multitude of abiotic and biotic factors affecting the fish community, including weather and climate, interactions among species, food web effects, and invasive species. The following section provides an overview of the lake's fish community in 2010 and includes assessment of trends observed since the AMP biological program began in 2000. The species identified in Onondaga Lake from 2000 through 2010 are listed in Table 6-3.

Table 6-3. Fish species identified in Onondaga Lake, 2000-2010.

Abundant Species		Common Species		Uncommon Species	
Alewife	Largemouth bass	Black crappie	Fathead minnow	Black bullhead	Quillback
Banded killifish	Pumpkinseed	Bluntnose minnow	Freshwater drum	Chain pickerel	Rainbow smelt
Bluegill	Smallmouth bass	Bowfin	Longnose gar	Goldfish	Rainbow trout
Brown bullhead	Walleye	Brook silverside	Logperch	Greater redhorse	Round goby
Carp	White perch	Brook stickleback	Northern pike		Rudd
Gizzard shad	White sucker	Brown trout	Rock bass	Green sunfish	Silver redhorse
Golden shiner	Yellow perch	Channel catfish	Tessellated darter	Johnny darter	Spotfin shiner
		Emerald shiner	Shorthead redhorse	Lake sturgeon	Tiger muskie
				Longnose dace	Trout perch
				Northern hogsucker	White bass
					Yellow bullhead

6.4.1 Richness and Diversity

Several important metrics of the fish community are based on measured diversity and richness of the adult fish community, both littoral (near-shore) and pelagic (open water). Richness is a count of the number of species within a community, while diversity considers both the number of species present and their relative abundance. In Onondaga Lake, richness has generally increased over the decade of AMP monitoring, from 24 species in 2000 to 28 species in 2010 captured during spring and fall electrofishing surveys. Onondaga Lake is part of the Seneca River system, which provides a corridor for fish movement between the lake and the waterways connected to the Seneca River. Over the last decade, 45 fish species have been documented in the lake, comparable to regional waters.

The diversity of fish communities fluctuates in response to changes in seasonal and environmental variables, and inter-species competition. In Onondaga Lake, changes in diversity are highly influenced by the periodic peaks and crashes of two species of clupeid, alewife (*Alosa pseudoharengus*) and gizzard shad (*Dorosoma cepedianum*). Abundance of these two species of the herring family is highly variable, as Onondaga Lake is near the northern edge of their range, and both species periodically exhibit significant winter mortality. Extremes in recruitment are seen as well; both species periodically produce very strong year classes that dominate the catch for years, as individual fish can live 10 years or longer. Shannon-Wiener diversity (an index that considers richness and relative abundance) has fluctuated over the past 10 years; however, when calculating this index without clupeids there is a much more consistent trend. In 2010, abundance was dominated by clupeids with alewife comprising almost 74% of the entire catch; yellow perch and pumpkinseed sunfish were the next dominant species.

6.4.2 Reproductive Success

The AMP employs several methods to assess fish reproduction, including nesting surveys, sampling of larval fish, and sampling of young of year fish. Evaluation of the young fish provides information on the overall health of the fish community within the lake and success of reproduction from year to year. Factors other than water quality, including water temperature during and after spawning, water levels, and trophic dynamics, can affect reproductive success and need to be considered as well.

The centrarchid species in the lake (largemouth and smallmouth bass, pumpkinseed and bluegill sunfish, rock bass) and bullhead construct nests in the littoral zone. Each year, the AMP team conducts nesting surveys to estimate the number and spatial distribution of the nests. In 2010, 2,050 nests were observed (Figure 6-12), with a slightly skewed distribution between the north and south basins, (60% and 39%, respectively).

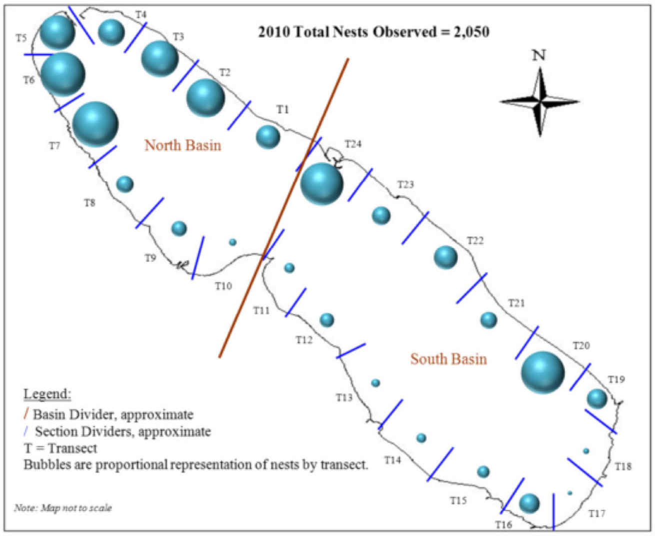


Figure 6-12. Nesting survey map and comparison of north vs. south-2010.

This represents a slightly less even distribution than in the past two years, although not as skewed as earlier years, for example, in 2007, 84% of the nests were located in the northern basin. Approximately one third of the nests supported pumpkinseed sunfish.

During sampling in 2010, larval stages of alewife, bluegill, and pumpkinseed were collected in Onondaga Lake, documenting successful reproduction of these species. In addition, the 2010 field effort captured young-of-year smallmouth and largemouth bass, brown bullhead, common carp, and *Lepomis* spp (bluegill and pumpkinseed sunfish), as displayed in Figure 6-13. Larval samples were dominated by alewife, indicating the potential for another strong year class for this clupeid species. Both the diversity and richness of young-of-year have increased over the decade of Onondaga County biological monitoring, indicating more species reproducing as well as a more balanced community.

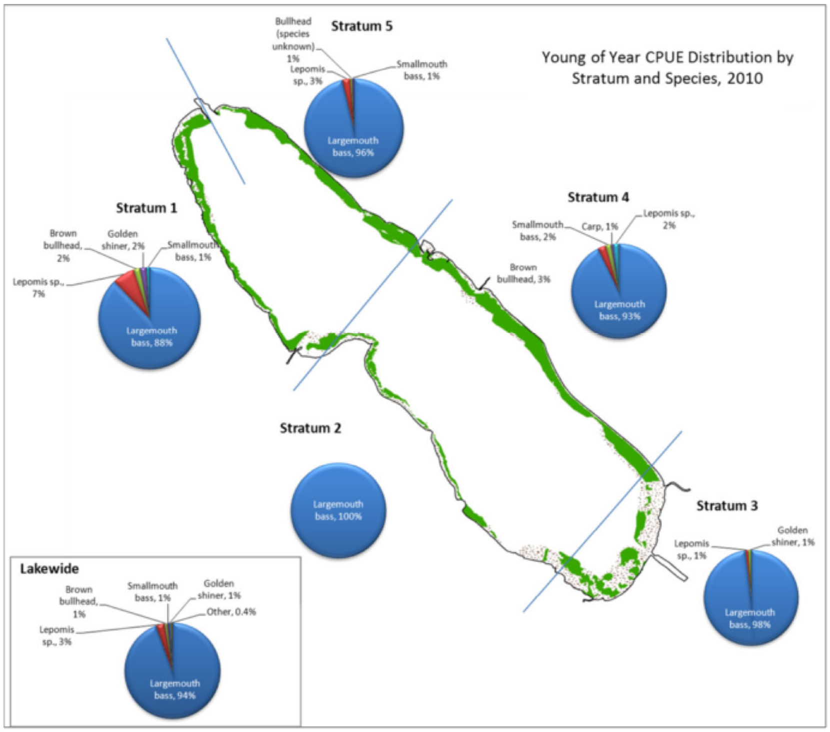


Figure 6-13. 2010 Young-of-year Catch per Unit Effort (CPU) distribution by stratum and species.
Data indicate where young-of-year fish were caught in the lake during 2010, as well as the percent of species caught in each stratum.

6.4.3 Recreational Fishery

Onondaga Lake supports a varied recreational fishery, with largemouth bass, smallmouth bass, bluegill and pumpkinseed (*Lepomis* or sunfish species), yellow perch, and brown bullhead examples of the more common sport fish. Population characteristics of these species are monitored to assess changes in the quality of the lake's sport fishery. Specifically, the relative abundance of fish in various size classes available to anglers, the general condition of fish with regard to the relative weight of individuals of each species, and angler catch rates for largemouth and smallmouth bass are analyzed to determine the quality of the fishery and identify any changes that may be occurring. The estimated abundance of two important gamefish, largemouth and smallmouth bass, over the last decade of the AMP is illustrated in Figure EX-12.

6.4.4 Fish Size – Largemouth Bass

Electrofishing and gill net catches of largemouth bass in fall 2010 indicated that the majority (69%) of angling-size largemouth bass in the lake are 8-15 inches in length. The proportion of the population from 15-20 inches increased by nearly 20% from 2009 to 2010 and now represents nearly a third of the angling-size population. Largemouth bass exceeding 20 inches are rarely collected during AMP sampling efforts. This suggests that fish of this size are rare in Onondaga Lake, since they would be susceptible to capture by electrofishing. The current size structure of the largemouth bass population in the lake provides anglers with a large proportion of catchable-size largemouth bass of small to moderate length (8-15 inches) and a moderate proportion of fish of relatively large size (>15 inches). Analysis of largemouth bass weight by size class in 2010 indicates that fish continue to be relatively heavy for their length and suggests that forage is not limiting. Onondaga Lake provides anglers an opportunity to catch largemouth bass that will generally be heavier for their length than average for this species.

6.4.5 Fish Size – Smallmouth Bass

The size distribution of smallmouth bass in the fall 2010 electrofishing and gill net catches was distinctly different from that of largemouth bass, with the majority (60%) of angling-size fish being 7-11 inches in length. However, the proportion (40%) of smallmouth bass greater than 11 inches in fall 2010 was the highest it has been since 2003. This increase was due primarily to an increase in the number of 11-14-inch fish. The overall number of smallmouth bass captured during fall sampling efforts has shown a steady decline since 2007, but in 2010, the proportion of larger fish in this population increased considerably. The current abundance and size structure of the smallmouth bass population in Onondaga Lake provides somewhat limited availability of smallmouth bass to anglers, but those fish that are available provide relatively high angling quality. Analysis of smallmouth bass weight by size class in 2010 indicates that smallmouth bass are in generally good condition and above average in weight for their length. Though not as abundant as largemouth bass, Onondaga Lake provides anglers the opportunity to catch smallmouth bass that are of desirable weight for their length.

6.4.6 Fish Size – Sunfish

The fall 2010 electrofishing and gill net catches of sunfish (bluegill and pumpkinseed) indicated that the population is dominated (99%) by fish of 3-8 inches in length. This has been the case since the AMP began in 2000. The fall 2010 data showed that the proportion of sunfish 6-8 inches increased from 13% in fall 2009 to 22% in fall 2010. This means that currently a greater proportion of quality-size sunfish are available to anglers than in the previous year. This proportion may increase further in 2011 as the large proportion (77%) of angling-size sunfish less than 6 inches grow to quality size.

Sunfish greater than 8 inches in the catch have been scarce. Several factors may be contributing to this. It is possible that the selected gear does not capture larger sunfish in proportion to their abundance. Larger adult sunfish tend to be more pelagic than juveniles and smaller adults and may be captured disproportionately less than these other groups when electrofishing littoral habitats. Slow growth of fish after reaching reproductive age and competition for food with other species such as alewife and gizzard shad may also be contributing to low abundance of larger sunfish in Onondaga Lake. Weight analysis of adult-size fish indicates that forage is not limiting for sunfish in Onondaga Lake and energy reserves of individual fish are relatively high, so it is possible that this energy goes to reproduction rather than growth. Despite the scarcity of sunfish longer than 8 inches, sunfish up to that size are readily available to anglers and are increasing in abundance in recent years.

6.4.7 Fish Size – Yellow Perch and Brown Bullhead

Size distribution of yellow perch in the fall 2010 electrofishing and gill net catch indicated that the angling-size population is dominated (88%) by fish 5-8 inches long. Yellow perch from 8-10 inches long comprise 10% of the angling-size population, and fish larger than 10 inches are rare. We measured a similar size structure of the yellow perch population in 2006. This was followed by two years of increasing proportions of fish 8-10 inches long and 10-12 inches long as the dominant year class of smaller fish grew to maturity. Increases in the proportion of yellow perch in the larger size classes in 2011 and 2012 can be expected as the abundant year-class representing fish 5-8 inches ages. The overall abundance of yellow perch has been increasing. This coupled with a strong year-class that is approaching quality size should translate to more and larger yellow perch being available to anglers in the near future.

Electrofishing and gill net catches of brown bullhead in fall 2010 indicated that there is a relatively even distribution of angling-size fish among the 6-9 inch (31%), 9-12 inch (40%), and 12-15 inch (28%) size classes. Nearly 70% of the angling-size fish are of quality size (9 inches) or greater. This affords anglers an opportunity to catch relatively large brown bullhead. Analysis of brown bullhead weight for various size classes indicated that brown bullhead in Onondaga Lake are in generally good condition, and their weight for a given length has shown an increasing trend since 2008. The increasing overall number and individual relative weight of brown bullhead in recent years has created the potential for a high-quality brown bullhead fishery in Onondaga Lake.

6.4.8 Angler Catch Rates of Bass

Largemouth and smallmouth bass are the most popular game species in Onondaga Lake. Data on angler catch rates are obtained through a volunteer angler diary program. Participating anglers record and submit standardized information on the number and species of fish caught, amount of angling effort expended, and area fished for Onondaga Lake, the Seneca River upstream of Onondaga Lake, the Seneca River downstream of Onondaga Lake, and the Oneida River. This information is used to characterize angler success in these waters and allow for assessment of how angler success in Onondaga Lake compares with other connected waters.

Largemouth bass angler catch rates in Onondaga Lake from 2001 through 2010 have ranged from 0.23 fish/hr to 0.83 fish/hr. The five highest annual catch rates have occurred during the last five years, with the 2010 catch rate of 0.49 fish/hr below the 2009 rate of 0.69 fish/hr, but similar to the rate of 0.48 fish/hr in 2007 and 2008. Prior to 2006, largemouth bass catch rates in Onondaga Lake were typically below the connecting waters. Since 2006, Onondaga Lake catch rates of largemouth bass have consistently ranked first or second among the diaries collected on the Oneida River, Onondaga Lake and the Seneca River.

Conversely, smallmouth bass angler catch rates in Onondaga Lake have shown a general decline from an initial high value of 2.80 fish/hr in 2001 to a low of 0.17 fish/hr in 2009. The 2010 value of 0.36 fish/hr was more than double the 2009 catch rate but still the second lowest rate recorded since the angler diary program began. Smallmouth bass angler catch rates from Onondaga Lake have been well below those of the Seneca River (upstream and downstream) and the Oneida River for the past three years.

The general lower angler catch rates of smallmouth bass from Onondaga Lake, particularly in the past three years, are likely a result of changing littoral habitat (e.g., increased distribution and abundance of aquatic macrophytes) and a subsequent increase in largemouth bass abundance. Black bass (largemouth and smallmouth combined) angler catch rates in Onondaga Lake have remained relatively consistent since 2002, ranging from 0.69 to 1.40 fish/hr. This compares favorably with the mean angler catch rate of black bass from nearby Oneida Lake (0.69 fish/hr) for the period of 2002 through 2007. Angler catch of largemouth bass has exceeded that of smallmouth bass in Onondaga Lake, reflecting the shifts in abundance of these two species identified through other fish sampling programs of the AMP.

6.5 Fish Abnormalities

The occurrence of physical abnormalities in fish captured during AMP sampling is monitored using a standardized protocol known as DELTFM. DELTFM abnormalities are defined as Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies. Data are used for trend analysis and to compare fish collected from Onondaga Lake to those collected in other areas. Fish abnormalities can result from chemical contamination, biological agents such as bacteria, viruses or fungi, or interactions among multiple stressors.

DELTFM abnormalities showed an overall increase from 2003 to 2009, but decreased in frequency in 2010. DELTFM abnormalities were found in 0.6% of adult fish from Onondaga Lake in 2003, increased to 4.1% in 2005, decreased slightly to about 3% in 2006 and 2007, and then increased steadily to 7.7% in 2009. DELTFM abnormalities showed a decline in 2010, occurring in 6.1% of adult fish. The majority of abnormalities in the Onondaga Lake fish community in 2010 were lesions (73%), followed by deformities (18%), and erosions (7%). Tumors, malignancies, and fungal infections were rare (<2% combined).

Nineteen species of adult fish were found with DELTFM abnormalities in 2010, exceeding the previous high of 17 species in 2009. One of these species was common carp, which had not previously been included in fish examined for DELTFM abnormalities. The species contributing the most to the DELTFM total in 2010 were brown bullhead (22% of total), largemouth bass (16%), gizzard shad (12%), pumpkinseed (10%), and white sucker (10%). The decline in DELTFM abnormalities observed in 2010 is due primarily to a decline in occurrence of abnormalities in brown bullhead from 2009 to 2010 (Figure 6-14). This continues a decline in abnormalities in this species that began in 2009.

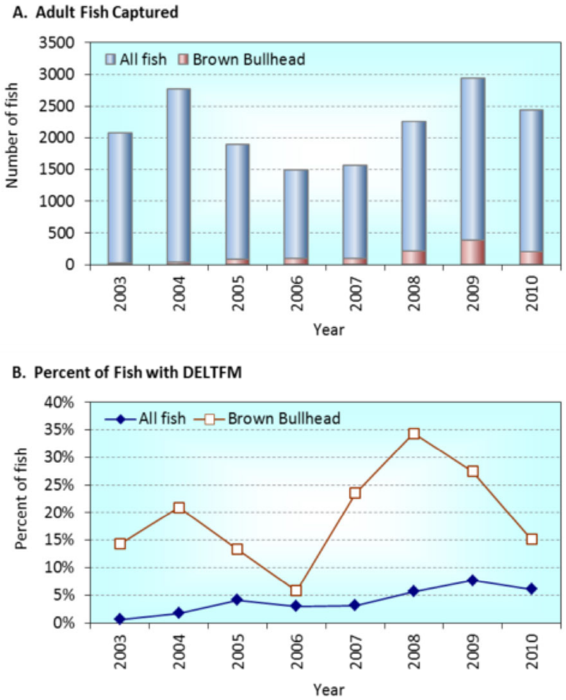


Figure 6-14. Relative importance of brown bullhead in characterizing DELTFM abnormalities in Onondaga Lake fishes, 2003-2010.

The incidence of lesions and tumors in brown bullhead in Onondaga Lake from 2000 to 2010 was compared with similar data from waters in the Chesapeake Bay watershed, Great Lakes, and Cape Cod area. Prior to 2007, occurrences of lesions and tumors in Onondaga Lake brown bullhead were within the range associated with reference sites (typically <5% incidence) from this larger regional set of waters. Data from 2007-2009 indicated a shift in occurrence to levels associated with contaminated sites from regional waters. The cause of this shift is not known, but may have been due to several recently identified pathogens affecting brown bullhead in Onondaga Lake. The incidence of lesions and tumors in brown bullhead in Onondaga Lake declined in 2009 and again in 2010, suggesting a recovery of the population from these pathogens. The incidence of lesions and tumors in brown bullhead in Onondaga Lake in 2010 fell to 10% and is again approaching the range associated with regional reference sites.

6.6 Additional information regarding the fish community

The AMP collects a large amount of data each year related to the lake's fish community; lake managers, local scientists, university professors and others use these data for teaching and research purposes. Onondaga County maintains a custom database to manage these extensive data sets and facilitate their retrieval. In addition to the topics discussed in the 2010 Annual AMP report, the Library includes an additional 24 figures and tables of data related to the lake's fish community, as well as a report on growth and survival of largemouth bass. Interested parties are encouraged to explore the additional resources archived in Library Section L09.

6.7 Integrated assessment of the food web

The Onondaga Lake ecosystem is changing. The improvements made at the Metro wastewater treatment facility reduced the input of phosphorus and ammonia N, resulting in decreased algal productivity and biomass in Onondaga Lake. Along with this shift toward mesotrophic conditions, the zebra mussel and quagga mussel have been able to thrive in the lake. Rooted aquatic plants have returned to the littoral zone, providing expanded nearshore habitat for fish and other aquatic animals.

The story of Onondaga Lake's recovery is complex; the reductions in nutrients and phytoplankton do not account for all of the changes observed in recent years. The AMP long-term data set allows scientists to document the details of the water quality changes and to integrate the role of food-web dynamics in an understanding of water quality changes. Clearly, phytoplankton biomass in the lake has declined as a result of reduced phosphorus loading from Metro, but differences between years are also affected by changes in the lake's trophic conditions- notably the abundance and efficiency of grazing organisms. From this perspective, large zooplankton, which are efficient grazers of phytoplankton, and dreissenid mussels play an important role in moderating summer phytoplankton biomass and water clarity.

The size structure of the zooplankton community is directly affected by the alewife. The decrease in alewife biomass in 2008 and the first part of 2009 allowed for the return of larger species of zooplankton, and had subsequent effects on the structure of the phytoplankton community. Analysis of the 2010 data has indicated another strong year class for alewife (2009 year class) that virtually eliminated large zooplankton in 2010; the average size zooplankton in Onondaga Lake was the lowest measured since monitoring of lower trophic levels began. Water clarity was lower in 2010 compared to 2008 and 2009; total phosphorus was up slightly, although loading from Metro was unchanged, and chlorophyll-a was higher. This is consistent with a cascading effect of alewife on phytoplankton through the elimination of large zooplankton. However, there are confounding patterns in nutrient and sediment loading associated with the wet summer of 2010 that also need to be considered. Mussel populations remain high in the littoral zone, and macrophyte coverage of the littoral zone was the highest recorded.

Macrophyte coverage and abundance in Onondaga Lake has been increasing in response to water-quality improvements, particularly those resulting in increased water clarity. Increased macrophyte abundance presumably has resulted in a substantial increase in production of macroinvertebrates in the littoral zone. This promotes the observed increase in abundance of several littoral fish species, such as largemouth bass, pumpkinseed, yellow perch, and brown bullhead among others, that use macrophyte beds for foraging areas. Young-of-the-year sport fish and forage fish species, such as golden shiner, that prefer vegetated habitats are increasing in number as a result of expanded habitat. These small fish, in turn, provide additional forage for larger fish-eating species such as largemouth bass.

Of importance to anglers is the increase in largemouth bass in the electrofishing surveys and the decline in smallmouth bass in the littoral zone. Macrophyte coverage in 2010 appears to be reaching a density that is higher than the preferred range for largemouth bass, which may eventually lead to a reduction in the population of this gamefish.

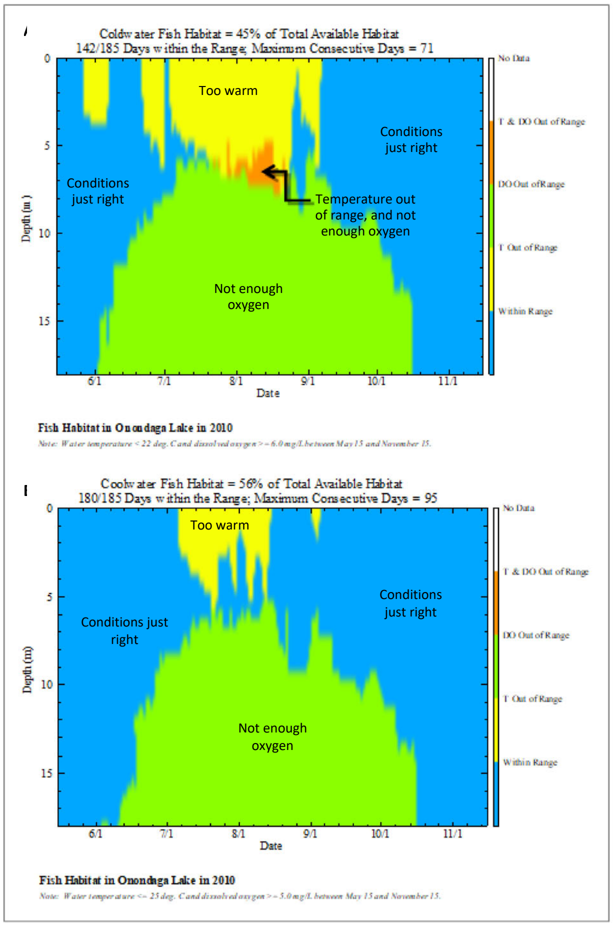
In years of high alewife abundance, fish with pelagic larvae (such as pumpkinseed, bluegill, yellow perch and white perch) have shown reduced recruitment, which is likely due to predation of larvae by alewife when alewife abundance is relatively high. Analysis of larval trawl data indicate that only three species were collected throughout 2010, with the alewife dominant. Pumpkinseed larvae were collected in early June; bluegill larvae were collected in mid- and late-July, and larval alewife from early June to late July. The alewife, in turn, serve as forage for larger, fish-eating species such as smallmouth and largemouth bass, yellow perch, white perch, and walleye. Changes in the size distribution of smallmouth bass - in particular since 2000 - suggest that larger adults of this species may have shifted to deeper, offshore habitat from shallower, littoral habitat. The availability of alewife as forage in pelagic habitats may be facilitating this shift. If such a shift has occurred, this would reflect a change in adult smallmouth bass foraging from a littoral-based food web to a pelagic-based food web.

The proliferation of zebra and quagga mussels in the lake after reductions in ammonia levels may be helping to support the increased abundance of species like pumpkinseed by providing an abundant food source. Other species such as freshwater drum, yellow perch, and common carp that feed on mussels are also likely benefitting from the increasing abundance of these mussels. All three species utilize both littoral and pelagic areas; fishbase.org identifies yellow perch and common carp as benthopelagic and freshwater drum as demersal. The AMP monitoring results confirm this trophic classification; the three species are captured by electroshocking in the littoral zone as well as by gill netting in the pelagic zone Consumption of mussels by multiple fish species provides another connection between the littoral-based food web and the pelagic-based food web. The increasing complexity of the overall food web in Onondaga Lake is an important sign that the lake is recovering from past environmental perturbations.

In addition to the food web effects, dissolved oxygen (DO) and temperature affect habitat availability for different species of fish, which shapes the fish community structure of Onondaga Lake. The Data Visualization Tool (DVT) provides insight into the habitat available for coolwater and coldwater fish communities, or "fish space". The fish space metric is useful for tracking changes in habitat based on DO and temperature, two variables that are necessary, but not sufficient to maintain a population. Optimal DO and temperature requirements differ for coolwater and coldwater fish species.

Two metrics illustrate this approach:
(1) coldwater fish habitat (Figure 6-15(a)), and
(2) coolwater fish habitat (Figure 6-15(b)).

In both graphics, the blue color represents depth and temporal location of water temperatures and dissolved oxygen concentrations suitable for cold- and coolwater fish habitat, respectively. Yellow shows where and when temperatures are out of range, while green shows where and when dissolved oxygen is out of range. Orange represents conditions where both temperature and dissolved oxygen are out of the range suitable for fish habitat.



Fish Habitat in Onondaga Lake in 2010

Note: Water temperature < 22 deg. C and dissolved oxygen >= 6.0 mg/L between May 15 and November 15.

Fish Habitat in Onondaga Lake in 2010

Note: Water temperature <= 25 deg. C and dissolved oxygen >= 5.0 mg/L between May 15 and November 15.

Figure 6-15. Fish space metric, 2010, for coldwater and coolwater species.

Overall, there has been an increase in the quantity and quality of habitat available to fish species in Onondaga Lake. This has resulted in a slight increase in fish species richness with a more even distribution of fish throughout the lake. Many fish species, particularly those associated with vegetated habitats, are also increasing in abundance, while others may decline. This increasing complexity with regard to energy sources and energy flow results in an ecosystem that may be more resilient to environmental stress. The 2010 AMP findings indicate that this is an ongoing process and that more changes are likely to occur. As water quality continues to improve, and more diverse and higher quality habitats become established, further increases in aquatic species diversity, abundance and interrelatedness are expected.

Section 7. Seneca River: 2010 Conditions and Trends

The ACJ includes requirements for monitoring and modeling the water quality conditions in the Seneca River as part of a regional approach to wastewater management. The Seneca River is included on New York State's compendium of impaired waters, due to low dissolved oxygen concentrations during warm water and low flow conditions, which typically occur in the mid to late summer in Syracuse. The outlet of Onondaga Lake joins the Seneca River as it flows north to Lake Ontario. The quality of Onondaga Lake waters clearly affects water quality of the river in the vicinity of the outlet.

As part of the annual AMP, water quality conditions are monitored at Buoy 316 in the Seneca River during summer low flow conditions (Figure 7-1); data are collected from other buoy locations to support the Three Rivers Water Quality Model. Results of the 2010 Three Rivers water quality monitoring program are archived in the library; the 2010 findings are summarized in this section of the Annual Report.

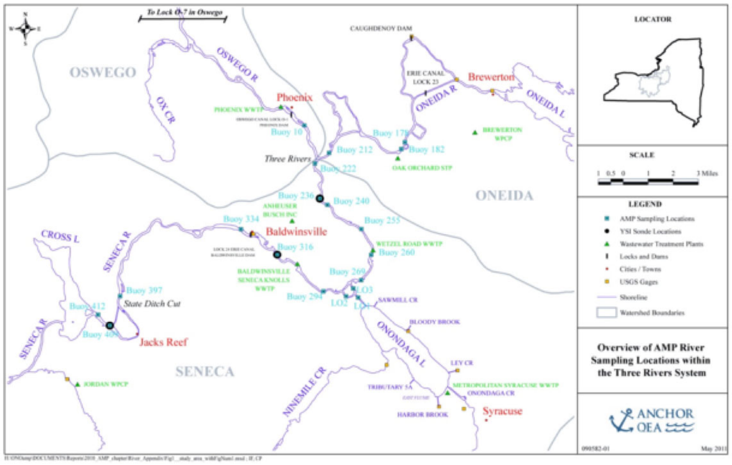


Figure 7-1. Three Rivers system study area.

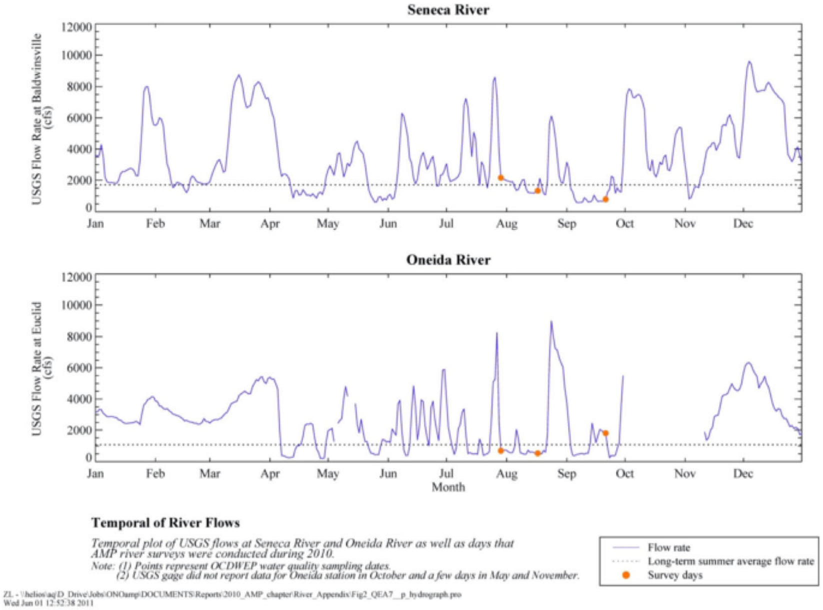
Between late May and early November, 2010, water-quality recording devices (YSI sondes) were deployed at Buoys 316, 236 and 409 to measure in-situ dissolved oxygen, pH, salinity and temperature at 15-minute intervals. Data from these locations document ambient water quality conditions upstream of the "state cut", an area of prolific dreissenid mussels (Buoy 409), upstream of the Baldwinsville-Seneca Knolls WWTP outfall and outlet of Onondaga Lake (Buoy 316), and downstream of the lake outlet and Wetzel Rd WWTP outfall (Buoy 236). In addition to the high-frequency sonde monitoring, three full water quality surveys were conducted in 2010 on July 29, August 17 and September 21. Taken together, these data portray water quality conditions in the Seneca River in response to point source discharges, biological conditions and changes in quality of the outflow.

The higher salinity of Onondaga Lake waters compared to the Seneca River affects stratification and mixing of the outflow. Particularly when flow and velocity in the Seneca River are low, the more saline, denser water entering from Onondaga Lake forms a discrete lower water layer that is detectable at nearby locations. Consistent with past years, stratification downstream of the outlet was observed for salinity, DO (August and September, but not in July), and to a much lesser extent, temperature. These observations were likely due to the influx of Onondaga Lake water, limited vertical mixing, and potential inflow of groundwater in the area of the "Deep Hole", located in the Seneca River near Buoy 269, which is adjacent to the Onondaga Lake outlet.

The Onondaga Lake outlet is not the only factor affecting water quality of the Seneca River. In the early 1990s, the invasive dreissenid mussels (zebra and quagga mussels) began to colonize sections of the Seneca River as they migrated eastward from the Great Lakes through the NYS Barge Canal system. Proliferation of the mussels along the river bed has profoundly affected the cycling of nutrients and organic material, and, consequently, the quality of the river water. Respiration of the benthic organisms depletes dissolved oxygen, and the river water has become notably clearer as phytoplankton and other particles are filtered out. Greater light penetration has allowed macrophyte growth to expand.

The year 2010 can be characterized as a relatively higher flow year. Flow conditions in the Seneca River in 2010 exhibited a pattern of generally variable flows. Compared to the past two years, the summer flow conditions were higher and more variable. Flows ranged from 1,000 to 8,000 cubic feet per second (cfs), with a relatively short low flow period in mid-September. The average summer flow rate in 2010 was approximately 2,400 cfs, which is higher than the long-term summer average of 1,700 cfs (average of summer values since 1950).

As a reference, the seven-day average low flow condition for the Seneca River at the Baldwinsville monitoring site with a probability of recurring once in 10 years (the 7q10 flow) is approximately 350 cfs. This figure is based on 55 years of record. During 2010, none of the reported daily average flows for the Seneca River dropped below the 7q10 flow (Figure 7-2).



Temporal of River Flows

Temporal plot of USGS flows at Seneca River and Oneida River as well as days that AMP river surveys were conducted during 2010.

Note: (1) Points represent OCDWEP water quality sampling dates.
(2) USGS gage did not report data for Oneida station in October and a few days in May and November.

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Figure 7-2. 2010 Seneca River hydrograph with sampling dates.

WEP personnel completed three water quality surveys of the Seneca River in the summer of 2010. Sampling locations are upstream and downstream of the inflow of Onondaga Lake. The 2010 water quality conditions were generally similar to those documented in previous years. The data measured during the individual surveys were reflective of the predominant processes occurring in the river at that time of the year, including varying flow conditions, zebra mussel activities, inflow from Onondaga Lake, and vertical mixing within the water column.

The 2010 summer discharge of the Seneca River was slightly higher than the long-term summer average, but it was much higher than what might be considered a summer low flow condition. As a result, the spatial trends of water quality parameters during the July and August surveys were similar in surface and bottom waters and, overall, less pronounced than those typically observed under the lower flow conditions sampled in the past.

Similar to 2009, there were seasonal differences between the July/August surveys and the September survey. The spatial patterns for the water quality parameters were more pronounced during the July and August surveys than they were during the September survey. The seasonal differences can be attributed to the changes in flow regime and the higher respiration rate of dreissenid mussels during the warmer July and August surveys.

Twelve violations of the NYSDEC instantaneous minimum DO standard of 4 mg/l were measured during the August 2010 survey (Table 7-1). There were no measured violations of the NH_3-N or NO_2 standards during the 2010 field program.

Table 7-1. Summary of non-compliance with selected AWQS, Three Rivers, 2010.

Parameter	Sampling Date	Location	Depth	Values Out of Compliance (mg/l)
Dissolved Oxygen (*Instantaneous Compliance Criteria = 4 mg/l*)	8/17/2010	Buoy-10	Bottom	3.52
		Buoy -222	Bottom	3.28
		Buoy -240	Bottom	1.54
		Buoy -255	Bottom	3.16
		Buoy -260	Bottom	2.32
		Buoy -269	Bottom	3.18
		Buoy -294	Surface	3.97
			Bottom	1.79
		Buoy -316	Surface	2.99
			Bottom	2.78
		Buoy -334	Surface	3.69
			Bottom	3.19
Parameter	**Sampling Date**	**Location**	**Depth**	**Values Out of Compliance (mgN/L)**
NO2-N (*AWQS = 0.1 mg N/L*)	All dates	All locations	All depths	None
Total NH3-N *AWQS calculated from pH and Temperature**	All dates	All locations	All depths	None

*The median value for NH3-N ambient water quality standard in 2010 was approximately 1.2 mg N/L, ranged from 0.25 mg N/L to 1.8 mg N/L.

In addition to the three extensive surveys in 2010, data from the in-situ sondes deployed in the Three Rivers indicate the frequency, magnitude and duration of low DO conditions. For days during which the sondes were in operation, the daily instantaneous standard of 4 mg/l was not met in 18%, 17%, and 28% of those days at Buoys 409, 316, and 236, respectively. Likewise, the daily average DO standard of 5 mg/l was not met in 14%, 22%, and 28% of those days. The frequency of such violations in 2010 was slightly less than that from 2009 at Buoys 409 and 316, but slightly higher at Buoy 236, due to low DO concentrations at the bottom layer measured during mid-August in 2010. Overall, the water quality conditions in 2010 exhibited an improvement in terms of regulatory compliance when compared with previous lower flow years (e.g., 2007).

Section 8. Progress with related initiatives

Onondaga Lake continues to be a focal point of community revitalization efforts. In 1990, the U.S. Congress created the Onondaga Lake Management Conference under Public Law 101-596, section 401 to meet two objectives:

(1) Develop a comprehensive revitalization, conservation and management plan for Onondaga Lake that recommends priority corrective actions and compliance schedules for the cleanup of Onondaga Lake; and

(2) Coordinate the implementation of the plan by the State of New York, the Army Corps of Engineers, USEPA, and all local agencies, governments and other groups participating in such management conference.

The plan for restoring Onondaga Lake http://www.onlakepartners.org/ppdf/p1301a.pdf was released in December 1993. Among its recommendations was creation of an institutional framework to coordinate implementation of the remedial actions, which led to the 1999 formation of the Onondaga Lake Partnership (OLP). The OLP has six members: the U.S. Army Corps of Engineers, Environmental Protection Agency, NYSDEC, the NYS Attorney General's Office, Onondaga County and the City of Syracuse. Other community groups and volunteers participate through two standing committees. The OLP website www.onlakepartners.org summarizes ongoing efforts.

Honeywell International, Inc. is proceeding with remediation of legacy industrial pollution under regulatory oversight. To date, efforts have focused on identification and removal of sources to prevent additional contamination from reaching the lake. Now, the remedial project effort is addressing contaminated lake sediments. Plans for sediment dredging and capping in certain areas, mostly in the southern littoral zone, are complete and dredging will begin in 2012. Information on the Honeywell project submittals is available online at www.dec.ny.gov/chemical/37558.html on the NYSDEC website.

Three inter-related water quality models, Onondaga Lake Water Quality Model (OLWQM), Onondaga Lake Basin Model, and Three Rivers Water Quality Model (TRWQM), are being used to evaluate the effectiveness of restoration alternatives. The ACJ required development, calibration and confirmation of these models using AMP data. These models quantify the response of Onondaga Lake and the Seneca River to improvements in wastewater treatment and non-point source pollution control measures within the watershed. The three models are integrated, with output from one providing input to the next. The Onondaga Lake Basin Model, developed by the US Geological Survey (USGS) in cooperation with the OLP, is designed to simulate the flow of water and materials (nutrients and sediment) to the lake. The OLWQM, developed by Anchor QEA, is a mechanistic model focusing on eutrophication. Anchor QEA also developed the TRWQM, a mechanistic model focusing on dissolved oxygen conditions in the Seneca River.

The Onondaga Lake Basin Model http://pubs.usgs.gov/sir/2008/5013/SIR2008-5013.pdf is being used to analyze the effects that proposed best management practices (BMPs) are likely to have on the loads of phosphorus and nitrogen entering the lake. These BMPs will include both actions on the landscape (for example, guiding land use changes) and actions to manage hydrology (for example, through enhanced detention and storage). The link to reports related to the Onondaga Lake Basin Model is http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-AF3-1.html.

WEP and the Onondaga Environmental Institute (OEI) www.onondagaenvironmentalinstitute.org collaborated on an extensive monitoring and surveillance program designed to identify and, ultimately, remediate dry weather sources of bacteria to the lower reaches of Onondaga Creek and Harbor Brook. Two phases of the investigation have been completed, and additional monitoring is planned. Samples were collected from seven sites along a five mile segment of Harbor Brook, and 22 sites along a 24-mile segment of Onondaga Creek. Results have pinpointed specific areas where bacteria are entering the creeks, and helped direct remedial work on the aging wastewater collection infrastructure within the City of Syracuse.

A conceptual design and plan for revitalization of Onondaga Creek has been developed by representatives of the City of Syracuse, Onondaga Environmental Institute, Cornell Cooperative Extension of Onondaga County, Atlantic States Legal Foundation, the SUNY College of Environmental Science and Forestry, and Canopy, a coalition of parks associations and community gardens in the City of Syracuse. Project information is available at www.esf.edu/onondagacreek/project.htm. The City of Syracuse has received a matching Local Waterfront Revitalization Program (LWRP) grant from the NY Department of State to construct improvements on Onondaga Creek that will enhance public access and aquatic habitat.

The engineering improvements to the wastewater collection and treatment infrastructure continue to be the subject of professional and trade publications and presentations. In addition, scientists and academics continue to analyze this unique case study of rehabilitation of a once-degraded lake. The human health impacts and ecological analysis of the contaminant issues are of interest to academic and agency scientists, public policy specialists, economists, and engineers. An Onondaga Lake Symposium is convened each November by Upstate Freshwater Institute to discuss recent findings http://www.upstatefreshwater.org/html/annual_olsf.html.

Exploration of green technology solutions to the challenges facing Onondaga Lake is underway from multiple perspectives. In addition to investigating green solutions to urban storm runoff, the OLP is exploring alternative green technologies for mitigating the Tully Valley mudboils, a source of sedimentation to Onondaga Creek. Onondaga County's "Save the Rain" initiative is an effort to educate the watershed community on effective measures to reduce runoff from the urban landscape. Information on porous pavement, tree planting, rain gardens, rain barrels and more are available at http://savetherain.us/.

As efforts continue to reduce point and nonpoint sources of pollution to the lake, other projects are underway to enhance recreational access and opportunities for community involvement with the lake and its shoreline. Planning and design of Phase 1 of the Creekwalk to connect Onondaga Lake to Armory Square are complete and construction has begun. Phase two of the Creekwalk, connecting Armory Square to Kirk Park, is under construction. Future phases await funding. The City of Syracuse has collaborated with Onondaga County to incorporate green infrastructure technologies as part of this project.

Section 9. Emerging issues and recommendations

The AMP is not static; Onondaga County, NYSDEC, ASLF and members of OLTAC review the monitoring program design each year in light of new information and emerging issues affecting the lake ecosystem. Maintaining the integrity of the long-term monitoring program is important for trend analysis; consequently, most program changes build on the current monitoring framework.

Onondaga County is working with NYSDEC and ASLF to modify the tributary monitoring program to address the requirements of the fourth stipulation amending the ACJ; the stipulation directs the County to evaluate the effectiveness of the green and gray infrastructure improvements. The enhanced tributary monitoring will include additional storm event sampling on Onondaga Creek and Harbor Brook, following completion of the gray infrastructure, such as the storage facilities planned for Clinton and lower Harbor Brook. The enhanced tributary monitoring program may also include limited testing for the presence and concentration of priority pollutants, such as heavy metals, pesticides, and other compounds. The additional monitoring will begin in 2012, pending NYSDEC approval of the workplan.

As first noted in the 2009 AMP report, the significance of observed abnormalities on captured fish merits additional investigation and documentation. Several research and monitoring efforts to characterize the fish community are currently underway on behalf of Honeywell International and the State University of NY College of Environmental Science and Forestry. Noting likely capture injuries, such as erosion of a dorsal fin, may help differentiate potential impacts of exposure to sediment contaminants. Currently, Onondaga County WEP field technicians do not examine common carp for DELTFM abnormalities, due to the difficulty of examining these large fish on board the monitoring boat. As benthic feeders, the condition of carp in the lake may provide useful information, and it is recommended that a few (2-4) carp be examined in each of the electrofishing transects.

Remedial measures to mitigate legacy pollutants are underway. Nitrate additions to the lake's lower waters began in 2011, in an effort to modify the oxidation-reduction potential at the sediment water interface and delay mercury methylation. Plans to dredge sediments from the lake and restore aquatic habitat are proceeding, and will begin to affect the lake in 2011-2012. The restoration efforts will inevitably affect analysis and interpretation of the AMP biological and habitat data. The County will integrate the results of the Honeywell activities into the overall evaluation of the lake's ecosystem, to the extent that data are made available. Any change to the County's approach to data evaluation brought about by the Honeywell program will be documented in the Data Analysis and Interpretation Plan, which is part of the annual workplan submittal and included in the library of the Annual Report.

The Onondaga Lake Water Quality Model was developed and calibrated using data from the AMP, and has been subject to outside expert peer review. This model will serve the entire community by defining the water quality and aquatic habitat benefits, if any, realized by further reducing nutrient and sediment inputs from point and nonpoint sources. NYSDEC will use this model to evaluate the environmental benefits, if any, associated with additional phosphorus removal from Metro and watershed sources. This analysis will support a TMDL allocation for phosphorus inputs to Onondaga Lake.

Section 10. Acknowledgements

In addition to the authors of the Annual Report, several other individuals and professional service firms contribute their expertise to the data collection and interpretation effort. We wish to acknowledge the contribution of the following specialists for their ongoing commitment to investigating the Onondaga Lake ecosystem.

(1) *AirPhotographics Inc.* of Martinsburg WV. This firm obtains the aerial photographs of the lake's nearshore zone each summer and provides high-quality images for interpretation of the amount of the littoral zone covered with macrophytes. They have been working with the AMP team since 2000.

(2) *Aquatic Resources Center* of Nashville TN. Todd Askegaard is responsible for the identification and enumeration of the macroinvertebrate community of both the tributaries and lake's littoral zone. Mr. Askegaard has been working with the AMP since sampling of the macrobenthic community began in 1999.

(3) *PhycoTech Inc*. of St. Josephs MI. Dr. Ann L. St. Amand has been identifying the Onondaga Lake phytoplankton community since 1990. Each year, Dr. St. Amand and her staff at PhycoTech provide the detailed taxonomic information needed to characterize this ecosystem in flux.

(4) *Racine-Johnson Aquatic Ecologists* of Ithaca NY. Bob Johnson has completed all three of the detailed Onondaga Lake macrophyte surveys in 2000, 2005 and 2010.

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