ONONDAGA LAKE
PHOSPHORUS WHITE PAPER

Prepared for

Onondaga County Department of
Water Environment Protection

Prepared by

CRA Infrastructure & Engineering, Inc.
State Tower Building, Suite 220
109 South Warren Street
Syracuse, New York 13202

Anchor QEA, LLC
290 Elwood Davis Road, Suite 340
Liverpool, New York 13088

EcoLogic, LLC
Atwell Mill Annex, Suite S-2
132 ½ Albany Street
Cazenovia, New York 13035

April 2011

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
ACJ	Amended Consent Judgment
AMP	Ambient Monitoring Program
AWQS	ambient water quality standards
BAF	Biological Aerated Filter
CALM	Consolidated Assessment and Listing Methodology
CSLAP	Citizens Statewide Lake Assessment Program
CSO	combined sewer overflow
CWA	Clean Water Act
DO	dissolved oxygen
EBM	ecosystem-based management
HRFS	high rate flocculation settling
km	kilometers
km^2	square kilometers
LA	load allocations
m	meters
Metro	Metropolitan Syracuse Wastewater Treatment Plant
mg/L	milligrams per liter
MGD	million gallons per day
mt	metric tons
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
OLP	Onondaga Lake Partnership
OLWQM	Onondaga Lake Water Quality Model
PWL	Priority Waterbodies List
SPDES	State Pollution Discharge Elimination System
SRP	soluble reactive phosphorus
SSV	Site-specific Variance
SUNY-ESF	State University of New York College of Science and Forestry
TDP	total dissolved phosphorus
TMDL	Total Maximum Daily Load
TP	total phosphorus

TSI	trophic state index
UAA	use attainability analysis
µg/L	microgram per liter
UFI	Upstate Freshwater Institute
USGS	U.S. Geological Survey
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WLA	waste load allocations

EXECUTIVE SUMMARY

ES.1 Introduction

This White Paper has been prepared to assist Onondaga County in carrying out informed policy deliberations with respect to future management decisions regarding Onondaga Lake, including such elements as state and federal regulations, water quality standards and guidance documents, nutrient impacts, natural and anthropogenic factors, and Metro and stormwater permit conditions. Current information related to water quality and attainment of designated uses is summarized and reviewed in the context of state and federal policies. It is intended to provide perspective to County policymakers on both the technical and legal considerations that should enter into deliberations about next steps with respect to Onondaga Lake.

ES.2 Onondaga Lake Currently Meets its Designated Uses for Recreation and Fishing

New York State Department of Environmental Conservation (NYSDEC) classifies surface waters for their designated best use. Onondaga Lake has both Class B and Class C segments. The best uses of Class B waters are primary and secondary contact recreation and fishing. The best use of Class C waters is for fishing. In addition, the water quality of Class C waters is to be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

The U.S. Environmental Protection Agency (USEPA) requires states to periodically examine water quality conditions, and employ an objective and scientifically defensible methodology to assess whether the designated uses are supported. NYSDEC has developed a set of metrics and criteria for this evaluation, and ranks waterbodies with respect to use attainment; those waterbodies with designated uses considered “precluded” or “impaired” are eligible for placement on the 303(d) list, named after the Clean Water Act (CWA) section describing such requirements. This biannual requirement under the CWA is a compilation of waterbodies whose current conditions do not support the designated uses.

Onondaga Lake was originally placed on the state’s list of impaired waters in 1998 based on excessive ammonia, bacteria, and phosphorus levels that impacted water quality and the aquatic biology. The lake was delisted, i.e., no longer impaired, for ammonia in 2008 following the Metropolitan Syracuse Wastewater Treatment Plant (Metro) upgrade. As discussed in more detail in this White Paper, recent monitoring data indicate that phosphorus concentrations no longer impair the lake for recreation and fishing.

As required by the Amended Consent Judgment (ACJ), Onondaga County has an extensive ambient water quality and biological monitoring program in place—the Ambient Monitoring Program (AMP)—to measure conditions, compare results to state standards and guidance values, and to evaluate use attainment. AMP data from 2008 to 2010 have been examined using the NYSDEC objective metrics and criteria for assessing whether designated uses are met. Based on this evaluation, the lake supports its designated use for recreation and fishing.

ES.3 The Importance of Phosphorus to the Lake

Lakes are classified according to their productivity, or trophic state, using three primary indicator parameters: total phosphorus (TP), chlorophyll-a (a measure of algal abundance), and Secchi disk transparency (a measure of water clarity). The scale ranges from "oligotrophic," exhibiting clear water and low productivity, to "eutrophic," exhibiting abundant algae and high productivity. Lakes at an intermediate state are considered "mesotrophic."

The trophic state of Onondaga Lake has shifted dramatically; once eutrophic, the lake is now in the mesotrophic range, with TP, algae, and water clarity conditions comparable to those of nearby Oneida Lake and several of the smaller Finger Lakes.

The productivity of Onondaga Lake is controlled by the availability of phosphorus. Algae and aquatic plants, which form the base of the lake's food web, continue to grow until the available phosphorus is depleted. Excessive phosphorus can cause nuisance algal blooms.

While phosphorus can cause lakes to become eutrophic, it is the effects of phosphorus—turbid waters and excessive weed growth—that diminish the recreational and aesthetic quality of lakes for the public. In the 1990s, NYSDEC sought to quantify the relationship between the causal variable (phosphorus) and the response variables (algal abundance, dissolved oxygen [DO], and water clarity). NYSDEC also sought to relate the trophic state of a lake to its perceived suitability for recreational use, and applied a statistical technique to define TP levels associated with a low risk of conditions that would diminish the lake's attractiveness for recreational use. This TP guidance value was set at 0.020 milligrams per liter (mg/L), and is applied as a summer (June 1 to September 30) average value in the upper waters. Recent conditions in Onondaga Lake are generally consistent with the TP guidance value. However, despite the fluctuations in Onondaga Lake's summer TP between 2008 and 2010 (17, 16, and 25 micrograms per liter [µg/L]), the lake exhibited consistently low algal abundance and was free of nuisance blooms. Moreover, the lake meets all requirements for oxygen in its upper layers and provides sufficient DO for coolwater species in the lake.

ES.4 Phosphorus Sources and Relative Impact on Algal Growth

Phosphorus enters the lake from Metro, industrial discharges, and watershed sources including agriculture and urban areas. Prior to the 2005 major upgrade to the treatment facility, Metro contributed approximately 65% of the annual total phosphorus load to Onondaga Lake. Since 2005, following construction of treatment improvements at a cost of approximately $175 million, the Metro (Outfall 001 and Outfall 002) contribution averages approximately 31% of the annual phosphorus load.

Recent investigations by Upstate Freshwater Institute (UFI) have tested 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 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.

The implication of this finding is that the TP sources to Onondaga Lake are not equivalent with respect to their potential to stimulate algal growth. The "effective phosphorus" loading from Metro is no longer the most significant source of phosphorus stimulating algal production during the summer recreational period. It is our understanding that NYSDEC can accommodate the differential bioavailability of TP sources in the Total Maximum Daily Load

(TMDL) by allocating "effective TP" inputs. It will be important to use the Onondaga Lake Water Quality Model (OLWQM) to project the changes in water quality in the lake over the summer recreational period attained by any additional reduction in Metro effluent TP.

ES.5 Phosphorus and Dissolved Oxygen

In addition to its impact on algal density and water clarity, TP can affect the DO status of lakes. Deeper lakes typically develop thermal stratification during the summer; the sun's energy warms the upper waters, and this warmer water layer (the epilimnion) rests on top of the cooler, denser waters below (the hypolimnion). In Onondaga Lake, thermal stratification is evident by mid to late May. The warmer, upper waters (where sunlight penetrates and supports the growth of algae and plants) are separated from the deeper, colder waters. Density differences caused by the thermal gradients (difference in temperatures) are sufficient to prevent wind-induced mixing of the deep waters, which then become isolated from exchange with the atmosphere, the primary source of DO in the lake. DO in the hypolimnion is used up as microorganisms decompose organic material settling down from the epilimnion; the DO is not replenished until winds can mix the water column in the fall as the waters cool and density gradients diminish.

Oxygen depletion in a lake is a function of supply and demand. The supply of DO present in a lake's hypolimnion depends on the lake's morphology (the relative volume of upper and lower waters), while the demand depends on the amount of organic material to be decomposed. As Onondaga Lake's TP and algae levels have declined, so has the extent of hypolimnetic anoxia—both the volume of affected water and the duration of low DO conditions. The DO in the lake's upper waters, cited as an impairment in the ACJ, currently meets the ambient water quality standards (AWQS).

Onondaga Lake is not unique among New York State (NYS) lakes in exhibiting DO depletion in the hypolimnion. The 2009 NYSDEC Clean Lakes Assessment Report concluded that more than 70% of the state's assessed lakes demonstrated hypolimnetic DO depletion and ambient concentrations below the state standards for DO.

ES.6 Dissolved Oxygen Standards

Seasonal anoxia is evident in many freshwater lakes and impoundments throughout the U.S. USEPA has not issued specific guidance to states regarding how to apply DO standards to lakes and reservoirs; consequently, states may interpret and apply the DO criteria for stratified waterbodies as they deem appropriate. Based on a review of each state's regulatory approach to hypolimnetic anoxia in stratified waters, a variety of approaches have been adopted. Some states specifically exclude the hypolimnion of stratified lakes from compliance with AWQS for DO; others have developed a more complex approach that has different DO requirements based on the fishery; and many do not address the issue. Each of these approaches has been approved by USEPA as consistent with the CWA.

In New York, the DO standards cite hypolimnetic DO requirements for only Class A-Special waters, which apply to a limited number of lakes (e.g., Lake George). For all other classes of waters, including Onondaga Lake, NYSDEC assigns a specific reference in their regulations (T) where they believe trout waters are relevant; Onondaga Lake does not have such a designation. Moreover, no explicit approach to evaluate compliance with DO standards in hypolimnetic waters, nor any acknowledgement that natural conditions could cause or contribute to oxygen depletion is included in NYSDEC regulations.

Table ES-1

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.

The NYSDEC Consolidated Assessment and Listing Methodology (CALM), dated May 2009, includes a specific commitment to examining the applicability of AWQS for DO in hypolimnia of stratified lakes; NYSDEC acknowledges that hypolimnetic anoxia may be

naturally occurring, and will rely on best professional judgment in a case-by-case basis to determine whether designated uses are being met.
It will be important to apply the OLWQM (developed with funding support and oversight by the Onondaga Lake Partnership [OLP], which included an independent Scientific Peer Review panel and process), to assess the relative importance of natural conditions affecting Onondaga Lake's seasonal hypolimnetic anoxia.

ES.7 DO Status and Use Attainment

The applicability of NYS's water quality standard for DO in the hypolimnion of thermally stratified lakes during the summer may be subject to interpretation. The resolution of how the current standard should be applied will be important for determining the levels of additional point and/or non-point controls that federal and state regulators require to meet the standards.

A fundamental issue from a policy standpoint with respect to Onondaga Lake is whether and to what extent hypolimnetic DO depletion impairs Onondaga Lake for its designated use. Among the factors to consider is the nature of the lake's fish community. NYSDEC has not classified Onondaga Lake as "waters suitable for trout survival and propagation" (i.e., trout waters). Trout and other coldwater fish species require DO and temperature conditions that are more stringent than those required for propagation and survival of coolwater and warmwater fish species. The White Paper on coldwater fisheries in the lake prepared in 2004 for the OLP (referred to here as the NYSDEC White Paper) explores this issue of use attainment and hypolimnetic DO as it relates to fish propagation and survival in detail.

The occurrence of seasonal anoxia in the deep waters of Onondaga Lake does not impair attainment of its designated use for fishing and aquatic life protection. The water quality and aquatic habitat conditions in the lake fully support the goal of sustainable warmwater and coolwater fisheries, and a transitory coldwater fishery. This goal has been supported by NYSDEC professional fishery scientists, and is being applied to habitat restoration plans being developed by Honeywell in concert with state and federal regulators.

Currently, Onondaga Lake supports a diverse and productive biological community. More than 45 species of fish have been identified in the lake. These species include warmwater and coolwater species, as well as transitory coldwater species with diversity and productivity comparable to other regional mesotrophic lakes.

ES.8 Regulatory Framework

States are afforded some flexibility within the provisions of the CWA to address unique circumstances related to water quality conditions and use attainment. This White Paper describes a range of approaches that NYSDEC may take, subject to approval by USEPA Region 2, to structure a cost-effective and environmentally responsible approach to the Phase III TP limit for the Metro facility as described in the ACJ. The alternatives range from delisting the lake as impaired for TP and adopting the modified Metro Stage II limit (0.10 mg/L) as final, to imposing the Phase III limit of 0.02 mg/L set forth in the ACJ, as well as several intermediate options.

The framework for each alternative discussed in the White Paper is consistent with the provisions of the CWA, USEPA policy on adaptive management, and NYS's commitment to ecosystem-based management. In each case, the action would be initiated by NYSDEC and would require USEPA Region 2 approval. Other EPA regions have approved similar actions and have developed guidance for states on making submittals. It is anticipated that related engineering and modeling analyses currently underway, including the Metro phosphorus optimization evaluation, the OLWQM, and the evaluation of alternatives, will provide additional insight into the environmental benefits and costs associated with various management approaches. The range of regulatory approaches to address the current set of circumstances includes:

- Recognize that Onondaga Lake meets its designated uses for recreation and fishing based on NYSDEC listing criteria; move Onondaga Lake to the section of the 303(d) list requiring additional monitoring, and suspend definition of the Metro Phase III effluent TP limit until a few additional years of monitoring expands the understanding of the lake's response to: 1) the reduced Metro load, 2) Honeywell's in-lake remedial projects, and 3) CSO and Green Projects, which may impact in-lake phosphorus concentrations.
- Adopt a site-specific guidance value for TP for Onondaga Lake that defines a target endpoint higher than the current TP guidance value of 0.02 mg/L in the upper waters.
- Add subcategories of NYS surface water classifications for stratified lakes and reservoirs to the State's DO standard to account for the seasonal occurrence of

hypolimnetic DO depletion based on natural conditions, irreversible anthropogenic conditions, and/or biological communities.

- Request a Site-specific Variance (SSV) for Onondaga Lake that would permit higher summer average TP and seasonal hypolimnetic anoxia. This alternative would include completion of and regulatory acceptance of a use attainability analysis (UAA). The SSV would be in place for a 3-year period, and then would be re-evaluated. This alternative would provide a 3-year window for NYSDEC to promulgate the subcategories of classification for seasonal DO depletion. Sufficient data are available from the AMP and the OLWQM to perform a scoped UAA that would satisfy USEPA's requirements.

The White Paper further discusses the many non-reversible changes to the Onondaga Lake ecosystem and its interconnected waterways that ultimately affect the habitat and fish community providing support for each of these actions.

ES.9 CONCLUSION

The County anticipates that related engineering and modeling analyses currently underway, including Metro phosphorus optimization evaluation, the OLWQM, and the evaluation of alternatives, will provide additional insight into the environmental benefits and costs associated with approaches being considered by state and federal regulators to achieve further reductions of phosphorus inputs into Onondaga Lake.

NYSDEC personnel are analyzing the current state of the lake and its watershed as they develop a regulatory TMDL allocation for TP based on its impact on algal blooms and DO. This allocation will ultimately affect the level of treatment and, potentially, the point of discharge of Metro wastewater, and will be formalized in the Stage III effluent TP limit for the facility. The allocation may also affect municipalities throughout the watershed, including more stringent requirements for stormwater controls. Whatever its final requirements, a TMDL allocation will affect every resident and business within Onondaga County.

1 INTRODUCTION

1.1 White Paper Objectives

This document has been prepared for Onondaga County as a summary of the existing conditions related to phosphorus concentrations and hypolimnetic oxygen levels, and how these water quality conditions affect the attainment of the state's designated uses for Onondaga Lake. State and federal regulations and policy are reviewed along with recent monitoring data detailing the lake's water quality and aquatic habitat conditions. The Onondaga Lake Phosphorus White Paper is intended to support Onondaga County officials as they make policy decisions in a cost-effective and environmentally responsible manner.

It is anticipated that related engineering and modeling analyses currently underway, including the Metropolitan Syracuse Wastewater Treatment Plant (Metro) phosphorus optimization evaluation, the Onondaga Lake Water Quality Model (OLWQM), and the evaluation of alternatives, will provide additional insight to the environmental benefits and costs associated with these approaches.

1.2 Site Background

1.2.1 Onondaga Lake and Watershed Characteristics

Onondaga Lake is located within central New York State (NYS), immediately northwest of the City of Syracuse (latitude 43°06'54", longitude 76°14'34"; Figure 1). The lake is relatively small, with its main axis measuring approximately 7.6 kilometers (km), a surface width ranging between 1 and 2 km, and a surface area of 11.7 square km (km^2). 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 1). 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 rather narrow in Onondaga Lake due to bathymetry (refer to Figure 1). Under the present 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 past.

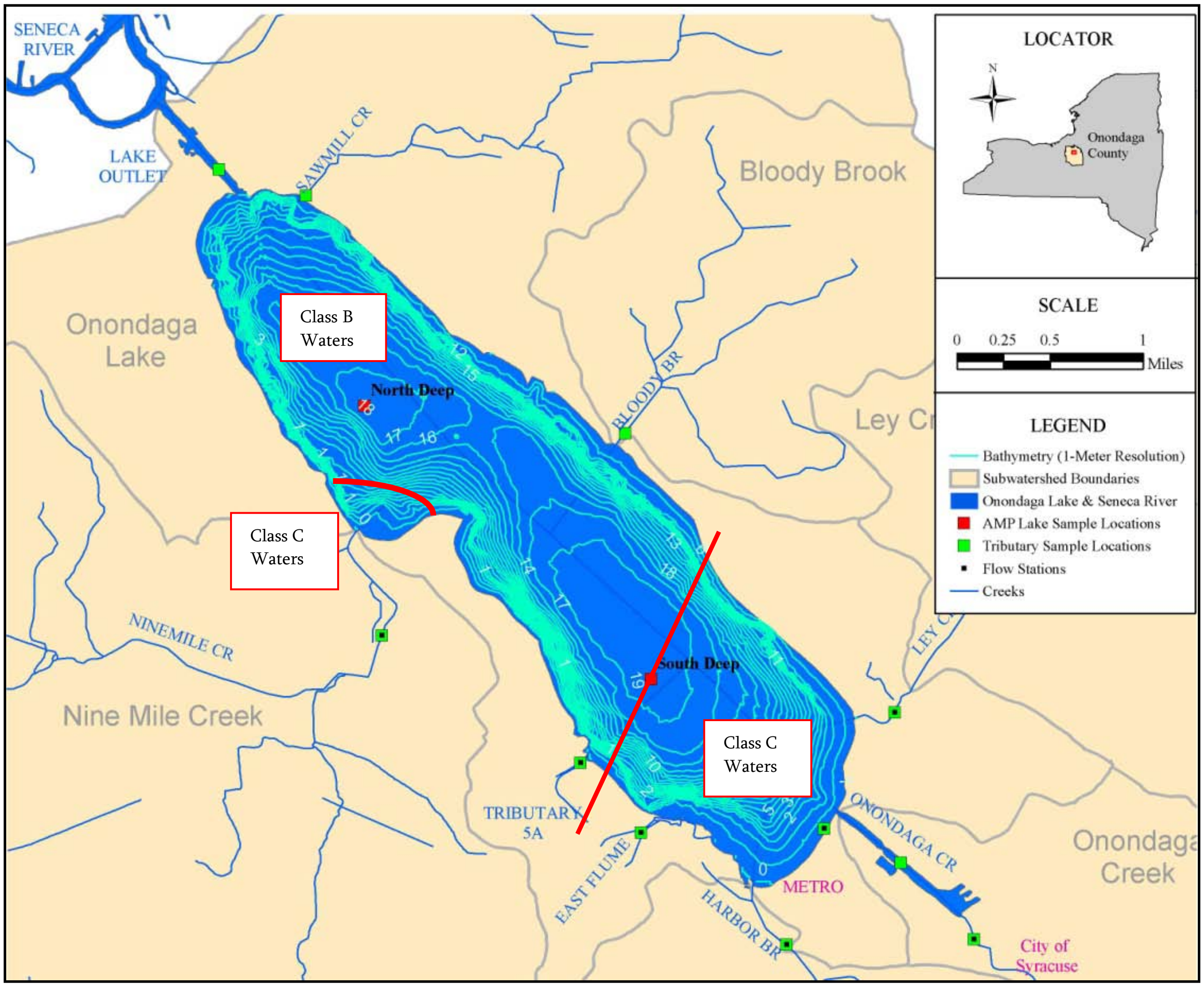


Figure 1 Map of Onondaga Lake, NY

Onondaga Lake drains a watershed covering approximately 725 km^2, nearly all of which lies within Onondaga County (Figure 2). A tributary network consisting of six major sub-basins comprises the majority of the watershed, with the remainder consisting of nearshore areas that drain directly to the lake. The major tributaries and their corresponding drainage areas are listed in Table 1. Onondaga Lake discharges into the Seneca River (Figure 1), which flows in a northerly direction and joins the Oneida River to form the Oswego River, ultimately discharging into Lake Ontario.

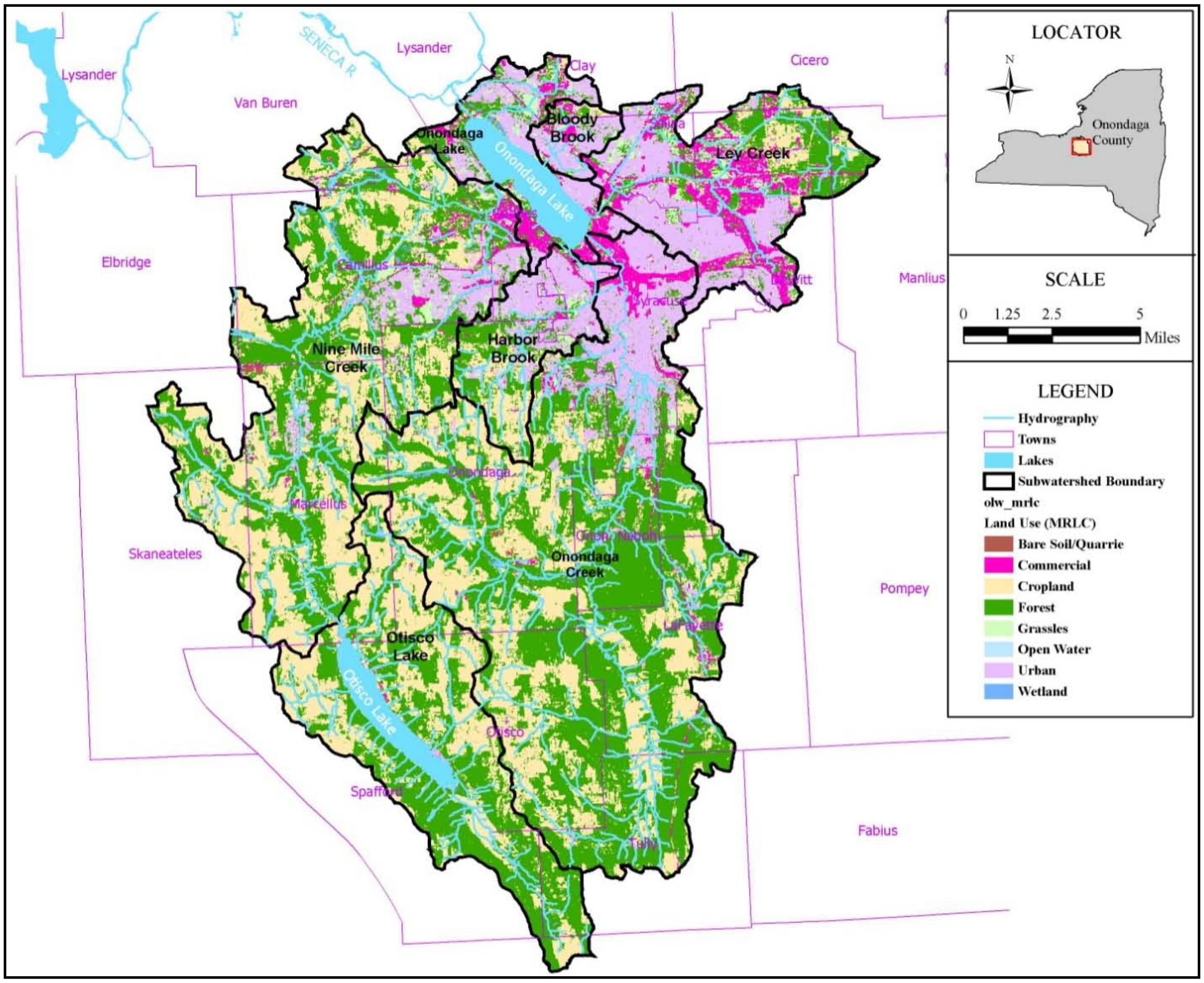


Figure 2 Onondaga Lake Watershed Land Use Characteristics

Table 1

Onondaga Lake Major Tributaries and Drainage Areas

Tributary	Drainage Area		
	Square Kilometers	Square Miles	Percent of Total
Nine Mile Creek/Otisco Lake	298	115	41
Onondaga Creek	285	110	39
Ley Creek	76	29	10
Harbor Brook	35	14	5
Direct Drainage/Sawmill Creek	21	8	3
Bloody Brook	10	4	1
Total	725	280	100

The Onondaga Lake watershed is highly urbanized compared with other lakes in the Seneca-Oneida-Oswego River Basin. Land use within the watershed is classified as approximately 20% urban, 40% forest, and 30% agricultural (Figure 2). Land use varies among the tributaries (Table 2) with the percent urban land use ranging from a high of 55% for Ley Creek to 7% for Ninemile Creek (Table 2).

Table 2

Onondaga Lake Watershed Land Use

Tributary	Percent Cover by Land Use Type			
	Forest	Agricultural	Urban	Other[1]
Nine Mile Creek/Otisco Lake	41	40	7	12
Onondaga Creek	50	31	12	7
Ley Creek	18	8	55	19
Harbor Brook	28	22	41	9
Direct Drainage/Sawmill Creek	14	3	38	45
Bloody Brook	14	5	69	12

[1] Other includes wetlands, open water, and grasses.

In addition to discharge of treated municipal wastewater effluent, industrial point sources and non-point sources (such as runoff from agricultural, suburban, and urban areas and discharges from the combined sewer system) contribute pollutants (nutrients, sediment, bacteria, metals, and pesticides) to the lake.

1.2.2 Lake Trophic Status

The productivity of Onondaga Lake, like most inland lakes, is limited by the availability of phosphorus. Excessive phosphorus induces eutrophication, and such over-productive waters support an abundant community of algae and cyanobacteria (blue-green algae). Three primary indicator parameters are used to evaluate a lake's trophic status: total phosphorus (TP), chlorophyll-a, and Secchi disk transparency. By all three measures, the trophic state of Onondaga Lake has shifted dramatically, as demonstrated by reductions in the lake's trophic state index (TSI; Figure 3) calculated from summer average TP, chlorophyll-a, and Secchi disk transparency. These results confirm that Onondaga Lake has become less productive, and trophic state indicator parameters are now generally within the mesotrophic range. These conditions are comparable to those in nearby Oneida Lake and several of the smaller Finger Lakes (Table 3). The change in lake trophic status is largely driven by the steep decline in Metro TP loadings that reduced epilimnetic TP concentrations from summer highs of approximately 0.1 milligrams per liter (mg/L) during the summers of the late 1990s to 0.016, 0.017, and 0.025 mg/L over the summers of 2008, 2009, and 2010, respectively[1].

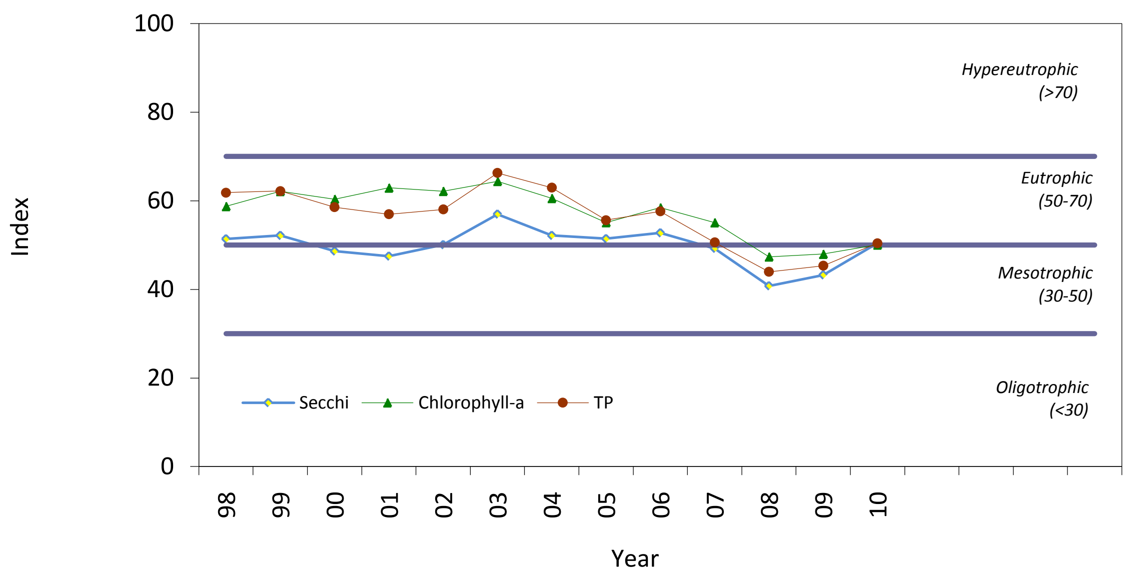


Figure 3 Carlson Trophic State Index for Onondaga Lake, 1998-2010

[1] The modest increase in summer epilimnetic TP in 2010 compared to 2008 and 2009 may be related to interannual variability in: 1) the magnitude and timing of rainfall events and associated watershed non-point phosphorus sources, including discharges from the mudboils, 2) changes in the ecology (e.g., alewife abundance) and consequently the internal cycling of phosphorus within the Lake, or 3) both of these mechanisms.

Table 3

Trophic State Parameters of Selected Regional Lakes

Lake	Data Source	Year(s)	Summer Average, Upper Waters TP (mg/L)	Chlorophyll-a (µg/L)	Secchi disk transparency (m)	Hypolimnetic Anoxia
Oneida[1]	Cornell Biological Field Station	2005-2008	0.020	4.8	NA	No
Cayuga (southern basin)	Cornell Utilities	2009	0.017	5.1	2.9	No
Cayuga (mid-lake)	Cornell Utilities	2009	0.012	5.7	4.8	No
Cazenovia	CSLAP[2]	2008	0.012	3.3	5.2	Yes
Conesus	SUNY-Brockport	2009	0.021	5.8	2.1	Yes
Otisco	Hobart William Smith Colleges	2005-2008	0.013	3.7	3.1	Yes
Onondaga	Onondaga County AMP	2008 - 2010	0.019	6.2	3.0	Yes

[1] Oneida Lake does not stratify during the summer; however, there are occasional transitory periods of anoxia.

[2] Citizens Statewide Lake Assessment Program (CSLAP), a cooperative effort of New York State Department of Environmental Conservation (NYSDEC) and the Federation of Lake Associations

1.2.3 Lake Dissolved Oxygen Resources

Lakes deeper than about 10 m at northern latitudes typically develop stable thermal stratification during the summer; the sun's energy warms the upper waters, and this warmer water layer rests on top of the cooler, denser waters below. In Onondaga Lake, stable thermal stratification is evident by mid to late May of most years. The warmer upper waters (epilimnion) are separated from the deeper, colder waters (the hypolimnion) by a zone of rapid temperature change (the thermocline). Density differences caused by the thermal gradients are sufficient to prevent wind-induced mixing, and the deeper waters become isolated from exchange with the atmosphere, the primary source of dissolved oxygen (DO) in the lake.

The upper sunlit region of the lake supports photosynthesis and algal growth, while the deep waters do not. Organic matter produced in the epilimnion gradually settles through the water column and is decomposed primarily in the surface sediments underlying the hypolimnion. Water quality differences between the epilimnion and hypolimnion become increasingly pronounced as the summer progresses. The supply of DO in the hypolimnion is depleted by microorganisms decomposing organic material, and is not replenished until the waters cool in the fall and density gradients diminish sufficiently to allow wind mixing of the entire water column.

The rate of oxygen depletion in a lake is a function of supply and demand of oxygen. The supply of oxygen present in a lake's hypolimnion depends on the lake's morphology, while the demand for oxygen depends on the amount of organic material to be decomposed. Two lakes with chlorophyll-a concentrations lower than measured in Onondaga Lake (refer to Table 3) illustrate this point. Cayuga Lake, surface area 172 km^2 with a maximum depth of 132 m, has a tremendous supply of well-oxygenated hypolimnetic waters and decomposition of the moderate mass of algae produced does not deplete the hypolimnetic oxygen resources. In contrast, Cazenovia Lake, surface area 5.7 km^2 with a maximum depth of 14 m, exhibits consistent and pronounced hypolimnetic oxygen depletion due to the limited supply of oxygen to support aerobic decomposition of organic matter in the surface sediments.

The DO in Onondaga Lake's hypolimnion declines once the summer thermal stratification develops and the deep waters are isolated from atmospheric exchange. The lake's DO concentration in 2010 is plotted in Figure 4.

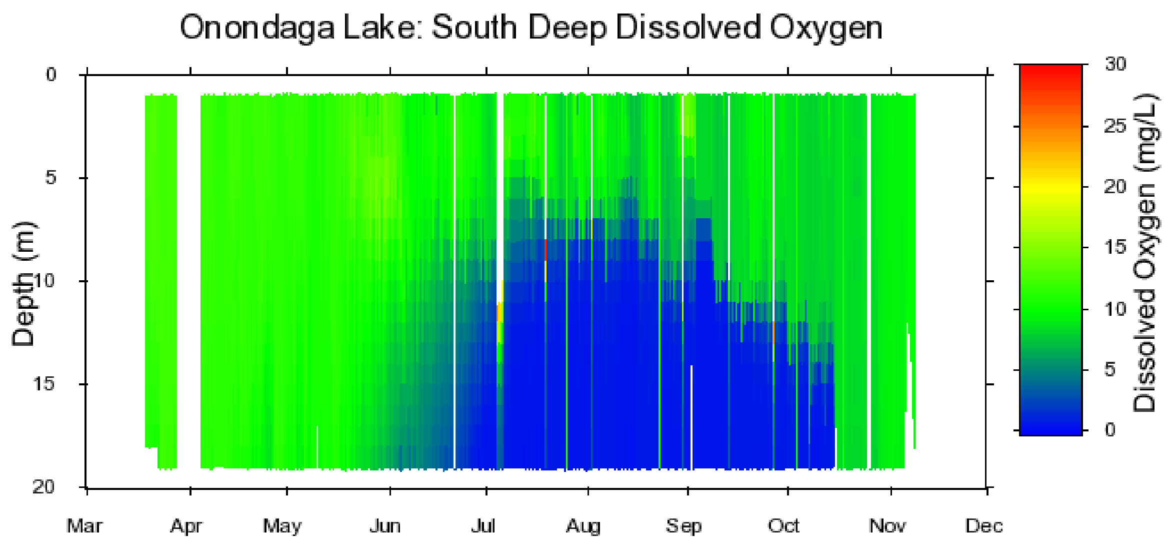


Figure 4 2010 Dissolved Oxygen Profiles of Onondaga Lake at South Deep
(source: Upstate Freshwater Institute [UFI]; http://www.ourlake.org/html/onlcontours.html)

As set forth in the Amended Consent Judgment (ACJ), summer algal blooms caused by elevated phosphorus concentrations contributed to low DO concentrations in Onondaga Lake's upper waters during fall mixing. Prior to 1999, fall DO concentrations routinely violated the ambient water quality standards (AWQS) for protection of aquatic life in the lake's upper waters (Figure 5). Since 1999, fall DO concentrations have consistently met the AWQS. Moreover, since the recent upgrades to Metro, the onset of hypoxia in the hypolimnion has occurred later in the year than observed prior to the upgrades.

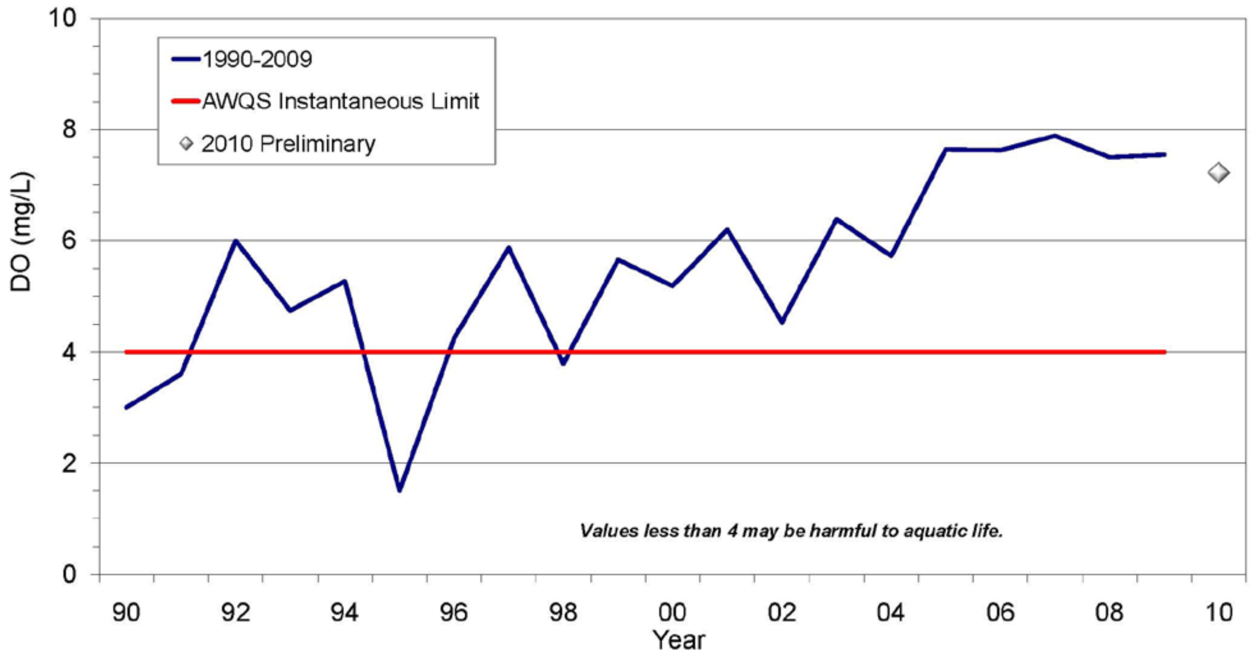


Figure 5 Minimum Dissolved Oxygen Concentrations, Onondaga Lake Upper Waters (0-3 m) in October (South Deep Station)

1.2.4 The Metropolitan Syracuse Wastewater Treatment Plant (Metro)

Wastewater disposal within the lake dates back to the 1800s, with the first treatment system, consisting of an interceptor sewer and primary treatment, established along the lake's southern shore in the early 1900s (Effler 1996). As part of the original combined sewer system that was constructed in the City of Syracuse, numerous combined sewer overflows (CSOs) discharged a mixture of untreated wastewater and stormwater to Onondaga Creek, Ley Creek, and Harbor Brook during wet weather flows. The water quality issues within the lake associated with the sewage and industrial waste discharges prompted a number of projects to abate the pollutant loadings associated with these CSOs, in addition to the continual upgrade and improvement of wastewater treatment systems. Metro is an 85 million gallons per day (MGD) tertiary treatment facility serving the City of Syracuse and surrounding areas located on the south shore of the lake. Historically, Metro accounted for 20% of the annual average inflow of water, approximately 65% of its annual TP loadings, and 90% of the total ammonia loading. This plant, originally constructed in 1925 and upgraded in 1960, was further upgraded to provide secondary and tertiary treatment in the late 1970s and early 1980s, respectively.

Contravention of state water quality standards for DO, ammonia, and bacteria led to the development of a draft Municipal Compliance Plan and ultimately an ACJ. The 1998 federal court-ordered ACJ commits Onondaga County to implementing upgrades to the wastewater collection and treatment system, including Metro and the CSOs. The ACJ obligates the County to comply with specific effluent limitations and monitoring requirements as set out in Metro's State Pollution Discharge Elimination System (SPDES) permit. This permit governs the CSOs as well as the Metro plant. In general terms, the ACJ prohibits the discharge of effluent from Metro and the CSOs that causes or contributes to contravention of water quality standards within the lake. Specifically, the ACJ established a three-stage compliance schedule for phosphorus in the Metro effluent (Table 4).

Table 4

ACJ Specified Metro TP Effluent Limits and Associated Compliance Schedule

Stage	Period	Limit		Required Compliance Date	Actual/Projected Compliance Date
		(lb/day)	(mg/L)		
1	12-month rolling average	400	---	01/01/1998	01/01/1998
2	12-month rolling average	---	0.12	04/01/2006	04/01/2006
Modified Stage 2	12-month rolling average	---	0.10	11/16/2010	11/16/2010
3	12-month rolling average	---	0.020[1]	12/01/2015	Pending

[1] Final effluent limits for phosphorus (effective December 1, 2015) may be modified based on revised Total Maximum Daily Load (TMDL) for Onondaga Lake. NYSDEC anticipates promulgating revised TMDLs for Onondaga Lake in 2011, subject to U.S. Environmental Protection Agency (USEPA) approval as provided pursuant to Section 303(d) of the Clean Water Act (CWA).

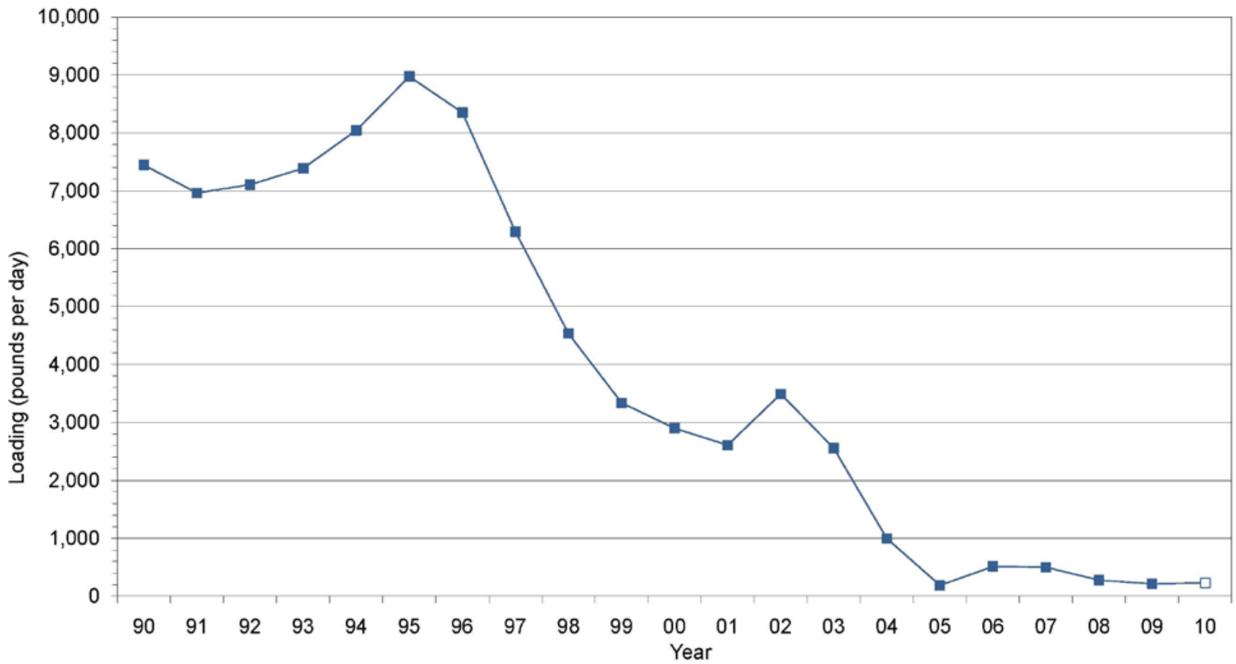
1.2.5 The 1997 Phase 1 Total Phosphorus TMDL

NYS regulations (NYSCRR 6 Part 703.2) include a narrative standard for phosphorus that specifies: "none in amounts that will result in growth of algae, weeds, and slimes that will impair the waters from their best use." This narrative standard has been translated by the New York State Department of Environmental Conservation (NYSDEC) to a numerical guidance value as 0.020 mg/L TP for all class AA, A, and B ponded waters except lakes Champlain, Erie, and Ontario (NYSDEC 1988). This statewide guidance value was developed based on the correlation of TP, chlorophyll-a, water clarity, and perceived suitability for recreational use. The Phase 1 Total Maximum Daily Load (TMDL) developed by the NYSDEC in 1997 calculated average growing season (mid-May through mid-September) epilimnetic TP concentrations using a mathematical model developed by Doerr et al. (1996) and compared these against the 0.020 mg/L guidance value under both wet and dry year conditions. The TMDL indicated that a TP Metro effluent limit of 0.020 mg/L combined with an approximately 50% reduction in non-point TP loading (including CSO TP loading) would satisfy the guidance value for TP in the lake under the more critical dry year simulation. This reduction estimate included an explicit margin of safety of 10%.

Contemporary water column monitoring data indicate that in 2 of the last 3 years, Onondaga Lake has met the summer average epilimnetic guidance value for TP of 0.020 mg/L, while TP Metro discharges were five times that estimated to achieve the same epilimnetic phosphorus concentrations (Doerr et al. 1996). This suggests significant divergence in TP fate mechanisms between contemporary conditions in the lake and that represented in the 1997 TMDL modeling effort. Phase 2 TMDL analyses scheduled for completion by 2011 will be based on contemporary Metro effluent and Ambient Monitoring Plan (AMP) data and an enhanced water quality model (NYSDEC 1997). The Phase 2 TMDL will finalize the waste load allocations (WLA) for Metro and the load allocations (LA) for non-point sources of TP to the lake.

1.2.6 Public Investment in Advanced Treatment at Metro

Since the mid-1990s, Onondaga County, NYS, and the federal government through the Onondaga Lake Partnership (OLP) have invested over $175 million in the treatment and abatement of phosphorus and ammonia loadings to Onondaga Lake. Beginning in 1995, the aeration system within Metro's secondary clarifiers was modified to achieve seasonal nitrification. However, due to temperature limitations on the nitrification process, effluent ammonia remained elevated during the colder months of the year. In January 2004, Onondaga County brought an advanced tertiary treatment process online. Since then, up to 126 MGD of secondary-treated wastewater is routed to a Biological Aerated Filter (BAF) process for year-round conversion of ammonia to nitrate. Operation of the BAF process has lowered Metro effluent ammonia levels from highs of over 10 mg/L to less than 1 mg/L, significantly reducing the ammonia loading and associated oxygen sink while increasing the nitrate loading to the lake (Figure 6). Increased concentrations of nitrate do not pose a risk of harm to the aquatic environment; rather, the elevated nitrate levels help prevent the proliferation of cyanobacteria (blue-green algae, which can develop dense mats and degrade the lake's aesthetic quality). In addition, elevated nitrate concentrations help keep phosphorus present in the lake bottom sediments from being released back into the water column during the summer when DO is depleted in the deep waters overlying the lake bottom. Both of these effects are beneficial to the lake ecosystem.



2010 data are preliminary, and represent Metro only (no bypass).

Figure 6 Ammonia Discharged to Onondaga Lake from Metro (Outfall 001)

Removal of phosphorus from Metro effluent has been a central focus of the engineering improvements at the plant due to the importance of phosphorus to lake ecology. Until recently, phosphorus concentrations in Onondaga Lake were so high that algal growth generally was limited by light attenuation rather than nutrients. Since 1987, the County has experimented with the amounts and types of chemicals added to the secondary wastewater system to maximize phosphorus removal and reduce phosphorus loadings to the lake (Figure 7). More recently, in February 2005, Metro's high rate flocculation settling (HRFS) process for phosphorus removal came online and continues to reduce external loading from the plant and thus improve the phosphorus condition in the lake. With the HRFS, Onondaga Lake became a phosphorus-limited system.

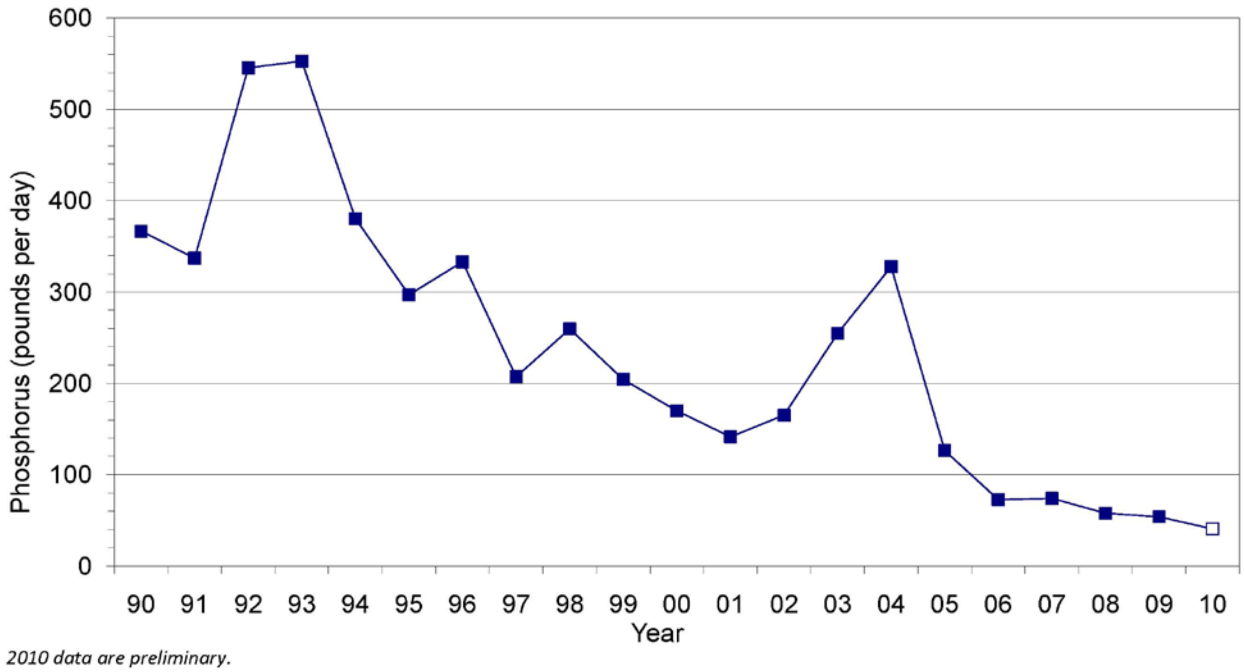


Figure 7 Phosphorus Discharged to Onondaga Lake from Metro (Outfall 001)

The introduction of HRFS to the Metro treatment train in 2005 has reduced the TP loading to the lake from Metro by approximately 86%. The HRFS process includes the introduction of ferric chloride, the formation of iron-phosphorus flocs, and subsequent micro sand enhanced settling. The HRFS process also brought about significant changes in the characteristics of Metro effluent. This effluent, along with samples from the lake tributaries, was subjected to bioassay studies, using a standard technique developed for use in the Great Lakes Basin, to assess the bioavailability of particulate phase phosphorus.

The 2009 bioassay studies concluded that the Metro effluent consists predominantly of iron-enriched particles not recovered during the HRFS process. These are larger particles that settle out rapidly from the water column and tend to carry nearly all of the particle-bound phosphorus from Metro. The particles from the tributaries are predominantly finer and remain suspended in the lake for longer periods. The bioavailability assays indicated that only a small proportion of the particle-bound phosphorus in the Metro effluent is available for release into the water column to stimulate phytoplankton productivity (Table 5).

Table 5

Bioavailable Fraction of Particulate Phosphorus Loads in Onondaga Lake Inflows

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

Source: UFI

1.2.7 Modeling Tools

NYSDEC anticipates issuing a revised TMDL for phosphorus including the allocations of point and non-point sources as one means of addressing contemporary water quality conditions within the lake including hypoxia within the hypolimnion during the summer months. The TMDL will consider further phosphorus treatment at Metro as well as the diversion of Metro effluent from the lake and into the Seneca River. The development of TMDLs and the need for an assessment of the Metro/Seneca River diversion option required a mechanistic understanding of watershed loads and the concomitant water quality dynamics of both Onondaga Lake and the adjacent Seneca River. To address this need, the OLP funded the development of mechanistic models of the Onondaga Lake Watershed (Coon and Reddy 2008), Onondaga Lake (QEA 2007), and peer review of the Three Rivers System model (QEA 2005), which was funded by Onondaga County. Collectively, these models allow the assessment of various point and non-point source phosphorus abatement measures, and will be central to evaluating any additional phosphorus load reduction strategies, if any, required to meet the Phase 2 phosphorus TMDL.

1.2.8 Stakeholder Perspectives

The OLP sponsored an analysis of stakeholders' perspectives in a public outreach effort that extended from 2005 to 2007 (EcoLogic et al. 2007). The findings of the public outreach effort documented that residents of Syracuse and Onondaga County want a revitalized Onondaga Lake that is available to citizens primarily for non-commercial, public use. Citizens are aware that most of the shoreline of the lake is already in County ownership, and they want to retain public control of and access to the lake. Although many local residents are aware that there have been improvements in lake water quality, these improvements have made little difference to the ways most people connect with the lake and its shoreline. While the community's vision for a rehabilitated Onondaga Lake is complex, the most significant elements may be distilled into a single statement: Reconnect with Onondaga Lake. Many residents spoke of their desire for a "clean" fishery, i.e., without consumption advisories due to mercury and other contaminants. Anglers and others familiar with the fishery cited a productive bass fishery as a goal. It is worth noting that coldwater fisheries did not emerge as a common theme from the stakeholders' vision for the future of the lake.

2 DISCUSSION OF CURRENT CONDITIONS IN ONONDAGA LAKE

2.1 What are the Designated Uses of Onondaga Lake?

Onondaga Lake includes both Class B and Class C segments (Figure 1). As set forth in NYCRR Part 701.7, *"The best usages of Class B waters are primary and secondary contact recreation and fishing. These waters shall be suitable for fish, shellfish, and wildlife propagation and survival."*

As set forth in NYCRR Part 701.8, *"The best usage of Class C waters is fishing; these waters shall be suitable for fish, shellfish, and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes."*

2.2 Does Onondaga Lake Water Quality Support its Designated Uses?

2.2.1 What Data are Used to Answer this Question?

States, territories, and authorized tribes are required to use a defensible, scientifically sound, and consistent methodology for waterbody assessment. NYSDEC has published their Consolidated Assessment and Listing Methodology (CALM) to provide specific criteria to assess compliance for each of the designated uses.

States must complete periodic assessments of water quality and habitat conditions in order to evaluate whether standards are met, and whether the designated uses are supported. In New York, the results of this evaluation are published in the 305(b) list, also known as the Priority Waterbodies List (PWL); surface waters exhibiting symptoms of degradation are categorized on the PWL based on the severity of water quality and/or habitat degradation (Table 6).

Table 6

Criteria Used to Categorize Severity of Water Quality and/or Habitat Degradation

Severity	Criteria
Precluded	*Frequent/persistent* water quality, or quantity, conditions and/or associated habitat degradation *prevents all aspects* of the waterbody use.
Impaired	Occasional water quality, or quantity, conditions and/or habitat characteristics *periodically prevent* the use of the waterbody, or; Waterbody uses are not precluded, but some aspects of the use are *limited* or *restricted*, or; Waterbody uses are not precluded, but *frequent/persistent* water quality, or quantity, conditions and/or associated habitat degradation *discourage* the use of the waterbody, or; Support of the waterbody use *requires additional/advanced* measures or treatment.
Stressed	Waterbody uses are not significantly limited or restricted, but occasional water quality, or quantity, conditions and/or associated habitat degradation *periodically discourage* the use of the waterbody.
Threatened	Water quality currently supports waterbody uses and the ecosystem exhibits no obvious signs of stress, however *existing or changing land use patterns* may result in restricted use or ecosystem disruption, or; Monitoring *data reveal increasing contamination* or the presence of toxics below the level of concern, or; Waterbody uses are not restricted and no water quality problems exist, but the waterbody is a *highly valued resource* deemed worthy of special protection and consideration.

Source: NYSDEC Section 305(b) Assessment Methodology, May 2009
http://www.dec.ny.gov/docs/water_pdf/asmtmeth09.pdf

For Onondaga Lake, the County's AMP provides the data to compare current conditions in the lake to the NYSDEC criteria. Built on the foundation of a water quality monitoring program in place since 1970, the AMP was included in the ACJ as a central component of an "adaptive management" strategy; data generated by the program have allowed NYSDEC, U.S. Environmental Protection Agency (USEPA), and Onondaga County to evaluate the lake's response to pollution abatement measures. Both water quality and biological monitoring programs are included in the program. The AMP provides an extensive dataset to evaluate whether the lake has attained its designated uses. A summary of the AMP is included in Appendix A.

In New York, waterbodies with designated uses considered precluded or impaired are eligible for placement on the 303(d) list. This list is named for the section of the Clean Water Act (CWA) requiring states, territories, and authorized tribes to assess water quality conditions within their jurisdictions and compare the data to promulgated standards. The 303(d) list is a product of this assessment; waterbodies are placed on the list when additional controls are needed to bring water quality into compliance with standards and criteria.

2.2.2 How Do Conditions in Onondaga Lake Compare to the NYSDEC Criteria?

To assess whether Onondaga Lake is currently meeting its designated uses based on the NYSDEC published criteria and methodology, the lake's water quality conditions in 2008, 2009, and 2010 are compared with the CALM criteria. This 3-year period encompasses a period when the Metro ammonia and phosphorus treatment systems were operating within permit limits, and there was a range of wet and dry weather conditions affecting watershed loading conditions (Table 7).

Table 7

Weather Summary for the Syracuse Area 2008-2010

Year	Average Temperature (°F)	Annual Precipitation (in.)	Summer (May-Aug) Rainfall (in.)
2008	48.2	41.91	13.43
2009	47.6	35.36	15.38
2010	49.8	41.43	20.08
30-year average (1971-2000)	47.8	40.05	14.68

2.2.3 Does the Lake Meet the Swimmable Criteria?

Rule-based criteria are in place to assess whether swimming and other recreational activities are supported by water quality conditions. The two uses, while closely related, are evaluated separately. The water quality criteria used to assess attainment of recreational use are based on the trophic state criteria that relate to water clarity (TP, Secchi disk transparency, and chlorophyll-a). For designated public bathing areas, use attainment is further assessed by the abundance of coliform bacteria, which are used to indicate the potential presence of pathogens.

According to NYSDEC, evaluation of public bathing use applies to waters specifically designated as suitable for public beaches and bathing areas, which see an increased level of swimming use and are more regularly monitored by public health agencies (NYSDEC 2009). Onondaga Lake does not have any areas that are specifically designated as suitable for public beaches and bathing areas, nor do any public health agencies monitor the nearshore waters for indicator bacteria. However, the AMP does include monitoring for the presence and abundance of indicator bacteria, due to a requirement in the ACJ requiring documentation of attainment of bacteria standards within the Class B segment of Onondaga Lake.

Criteria for a waterbody to be listed as impaired for public bathing include the following:

- NYS/Local Health Department has issued temporary closures of the waterbody to swimming, based on water quality (e.g., bacteriological, clarity) monitoring data.
- Sufficient streamflow/water levels to support swimming uses are artificially restricted.
- Swimming use requires additional measures (e.g., aquatic weed harvesting/control).
- Monitoring data show exceedances of impaired criteria (e.g., coliform, clarity) more than 10% (suspected) or 25% (known) of the time. That is, if the waterbody appears to meet clarity and coliform criteria at least 90% of the time, or has more than 75% of samples that are at acceptable levels, the water is not impaired for public bathing.

Impairment criteria include:

- Total coliform (median): exceeds 2400/100 ml
- Fecal coliform (geometric mean): exceeds 200/100 ml
- Clarity: water clarity less than 1.2 m

Results from 2008 to 2010 are summarized in Table 8. The conclusion from this assessment is that Onondaga Lake met the NYSDEC criteria used to evaluate attainment of swimmable conditions for these years.

Table 8

Results of Indicator Bacteria Levels in Onondaga Lake 2008-2010

Year	Bacteria: Percent of Monthly geometric mean values of fecal coliform bacteria < 200 cfu/100 mL			Water clarity: Percent of individual Secchi disk transparency measurements at nearshore stations >1.2 m		
	Class B	Class C	Lakewide	Class B	Class C	Lakewide
2008	100%	100%	100%	94%	95%	95%
2009	100%	100%	100%	100%	85%	93%
2010[1]	100%	100%	100%	100%	78%	89%

[1] The reduced water transparency in 2010 is attributed to the effects of higher rainfall and/or the increased abundance of alewife.

2.2.4 Does the Lake Meet the Recreational Use Criteria?

Assessment criteria for this use are similar to those for public bathing; the focus is on water clarity as indicated by chlorophyll-a, Secchi disk transparency, and phosphorus. For a waterbody to be listed as impaired for recreation, one of the following criteria must be met:

- NYS/Local Health Department has issued temporary closures of the waterbody or portions of the waterbody to swimming, boating, or other recreational use due to water quality concerns.
- Sufficient streamflow/water levels to support recreational uses are artificially restricted.
- Recreational use of water requires additional measures (e.g., weed harvesting/control).
- Public bathing uses are assessed as impaired or precluded.
- Monitoring data show exceedances of impaired criteria (e.g., coliform, clarity) more than 10% (suspected) or 25% (known) of the time.
- Observational criteria indicating restricted recreational uses are noted more than 50% of the time.

The only numerical criterion for TP related to recreational use assessment is the current NYSDEC statewide guidance value of 0.020 mg/L. This limit is associated with the designation of “threatened” lakes and ponds. Associated criteria for a waterbody to be listed as “impaired” for recreational use include a Secchi disk transparency less than 1.2 m, and chlorophyll-a concentration above 15 micrograms per liter (μg/L). These criteria are applied as a summer (June to September) average condition in the upper waters.

Three years of summer monitoring data are compared with the NYSDEC criteria for use impairment. The summer average conditions are presented in Table 9, and the percent of individual measurements that fall within the range NYSDEC has defined as suitable for recreational use are presented in Table 10.

Table 9

NYSDEC Published Criteria for Recreational Use Impairment

Compared with Recent Onondaga Lake Data (Summer Average)

	NYSDEC Threshold Values			**Onondaga Lake AMP Data** ***Summer Average (June 1- Sept 30), 0-3 m, South Deep station***		
Criteria	**Impaired**	**Stressed**	**Threatened**	**2008**	**2009**	**2010**
Total P, mg/L	Pending[1] (was 0.040)	0.020	N/A	0.016	0.017	0.025
Chlorophyll-a, μg/l	>15	>12	>8	5.5	5.9	7.2
Secchi disk transparency, m	<1.2	<1.5	<2.0	3.8	3.2	2

[1] According to NYSDEC, nutrient criteria for ponded waters are currently under development.

Table 10

NYSDEC Published Criteria for Recreational Use Impairment

Compared with Recent Onondaga Lake Data (Individual Measurements)

Year	**Phosphorus:** *Percent of TP measurements in upper waters (0-3m) at South Deep* <0.020 *mg/l, June 1 – Sept. 30*	**Chlorophyll-a:** *Percent of chlorophyll-a measurements in upper waters (0-3m) at South Deep <15 µg/l, June 1- Sept. 30*	**Water clarity:** *Percent of Secchi disk transparency measurements at South Deep >1.2 m June 1- Sept. 30*
2008	88%	100%	100%
2009	81%	100%	100%
2010	22%	100%	90%

Based on this assessment, recreational use for water clarity and algal blooms (the response variables) were consistently met over the 2008 to 2010 period. In 2010, the criterion for phosphorus (causal variable) was not met, although it was met in 2008 and 2009.

2.2.5 Does the Lake Meet the Aquatic Life Protection Criteria?

The ACJ cited water quality impairment due to elevated ammonia and TP (and resultant algal blooms), low DO in the lake's upper waters during fall mixing, and excessive bacteria from CSOs. These water quality parameters are measured and reported as part of the AMP, as are the lake's food web components (phytoplankton, macrophytes, zooplankton, mussels, benthic macroinvertebrates, and fish). Multiple life stages of the fish community are monitored annually, including nesting, larval, juveniles, and adults (refer to Appendix A). With this design, the AMP tracks water quality and biological conditions in the lake. Both lines of evidence document that Onondaga Lake meets the designated use for aquatic life protection.

2.2.5.1 Ammonia

The AMP has documented the reductions in ammonia concentrations in the lake as year-round nitrification facilities were completed at Metro. Since completion of the BAF system in early 2004, the ammonia load from Metro has decreased by 98% and the lake is in full compliance with the AWQS (Table 11). In recognition of the lake's compliance with the AWQS for ammonia, NYSDEC delisted Onondaga Lake as impaired by ammonia in the 2008 303(d) list.

Table 11

Percent of Ammonia Measurements in Compliance with Ambient Water Quality Standards, Onondaga Lake, 1998-2010 (note that 2010 data are provisional)

Depth	Percent Measurements in Compliance, NYS Standard												
(m)	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

2.2.5.2 Phosphorus and Hypolimnetic Dissolved Oxygen

Improvements to the Metro treatment plant have resulted in a 78% reduction in TP input (Table 12a) and a 94% decrease in soluble reactive phosphorus (SRP) input (Table 12b) to Onondaga Lake from this point source. Nonetheless, the contemporary total dissolved phosphorus (TDP) in Metro effluent represents 27% on the TDP loading to the lake. In addition, as noted in section 1.2.6 and summarized in Table 5, a recent evaluation of the Metro effluent provided evidence that the particulate phosphorus is extremely low in bioavailability (i.e., ability to stimulate algal growth).

Table 12

Comparison of Metro and Tributary Phosphorus Loading, Before and After HRFS Process[1]

a) Total Phosphorus

	1990-1998 (pre-ACJ)				2007-2009 (post- HRFS)			
Monitored and Gauged Site	**Flow (%)**	**TP (mt)**	**TP (% load)**	**TP (mg/l)**	**Flow (%)**	**TP (mt)**	**TP (% load)**	**TP (mg/l)**
Metro:								
Fully Treated	21%	52	57%	0.56	18%	8.1	22%	0.096
Bypass	0.94%	8.5	7.5%	1.8	0.38%	2.1	5.7%	1.2
Watershed:								
Onondaga Creek	34%	20	19%	0.12	36%	13	34%	0.076
Ninemile Creek	32%	10	10%	0.065	34%	9.4	25%	0.059
Ley Creek	8.7%	5.7	5.8%	0.14	8.2%	3.4	9.0%	0.088
Harbor Brook	2.1%	0.71	0.71%	0.070	2.5%	1.2	3.2%	0.102
Tributary 5A	0.72%	0.17	0.19%	0.054	0.22%	0.12	0.33%	0.12
East Flume	0.23%	0.19	0.18%	0.20	0.20%	0.10	0.28%	0.11

b) Soluble Reactive Phosphorus

	1990-1998 (pre-ACJ)				2007-2009 (post- HRFS)			
Monitored and Gauged Site	**Flow (%)**	**SRP (mt)**	**SRP (% load)**	**SRP (mg/l)**	**Flow (%)**	**SRP (mt)**	**SRP (% load)**	**SRP (mg/l)**
Metro:								
Fully Treated	21%	12	59%	0.13	18%	0.30	6.2%	0.004
Bypass	0.94%	2.5	9.7%	0.50	0.38%	0.39	8.2%	0.23
Watershed:								
Onondaga Creek	34%	3.3	16%	0.021	36%	1.5	32%	0.009
Ninemile Creek	32%	1.7	7.9%	0.011	34%	1.5	31%	0.009
Ley Creek	8.7%	1.4	6.1%	0.033	8.2%	0.54	12%	0.014
Harbor Brook	2.1%	0.25	1.1%	0.024	2.5%	0.45	9.3%	0.038
Tributary 5A	0.72%	0.030	0.17%	0.010	0.22%	0.033	0.72%	0.031
East Flume	0.23%	0.065	0.29%	0.092	0.20%	0.033	0.70%	0.037

c) Total Dissolved Phosphorus

	1990-1997 (pre-ACJ)				2007-2009 (post- HRFS)			
Monitored and Gauged Site	Flow (%)	TDP (mt)	TDP (% load)	TDP (mg/l)	Flow (%)	TDP (mt)	TDP (% load)	TDP (mg/l)
Metro:								
Fully Treated	NA	NA	NA	NA	18%	2.3	21%	0.027
Bypass	NA	NA	NA	NA	0.38%	0.70	6.3%	0.42
Watershed:								
Onondaga Creek	NA	NA	NA	NA	36%	2.6	24%	0.015
Ninemile Creek	NA	NA	NA	NA	34%	3.9	34%	0.024
Ley Creek	NA	NA	NA	NA	8.2%	0.95	9.2%	0.025
Harbor Brook	NA	NA	NA	NA	2.5%	0.52	4.7%	0.044
Tributary 5A	NA	NA	NA	NA	0.22%	0.045	0.46%	0.043
East Flume	NA	NA	NA	NA	0.20%	0.055	0.54%	0.060

Notes:

mt: metric tons

NA: not available

[1] TP includes dissolved and particulate fractions of both organic and inorganic species. Smaller tributaries, including Bloody Brook and Sawmill Creek, and direct drainage are not routinely monitored, as they collectively contribute a small percent of the annual inflow to the lake. Recent data suggest that Bloody Brook may contribute dissolved organic phosphorus disproportionate to its flow. Further investigations are planned.

While phosphorus is not a toxic substance, it does indirectly affect a lake's suitability for aquatic life by its effect on DO conditions and habitat. The AMP measures DO at frequent intervals from spring through fall. Field monitoring is supplemented by the water quality buoys placed at the South Deep station and maintained by the County and Upstate Freshwater Institute (UFI). The results confirm that the deep waters of the lake become devoid of DO during the summer (refer to the buoy data from 2010 displayed in Figure 4). The AMP tracks DO conditions in Onondaga Lake's deep waters and calculates an integrated metric, volume-days of anoxia. This integrates the volume of the lake affected by low DO and the duration. This metric is plotted for 1992 to 2009 in Figure 8. The reduction in the height of the bars in the graph indicates that the volume of the lake affected by low DO and the duration of anoxic conditions are diminishing.

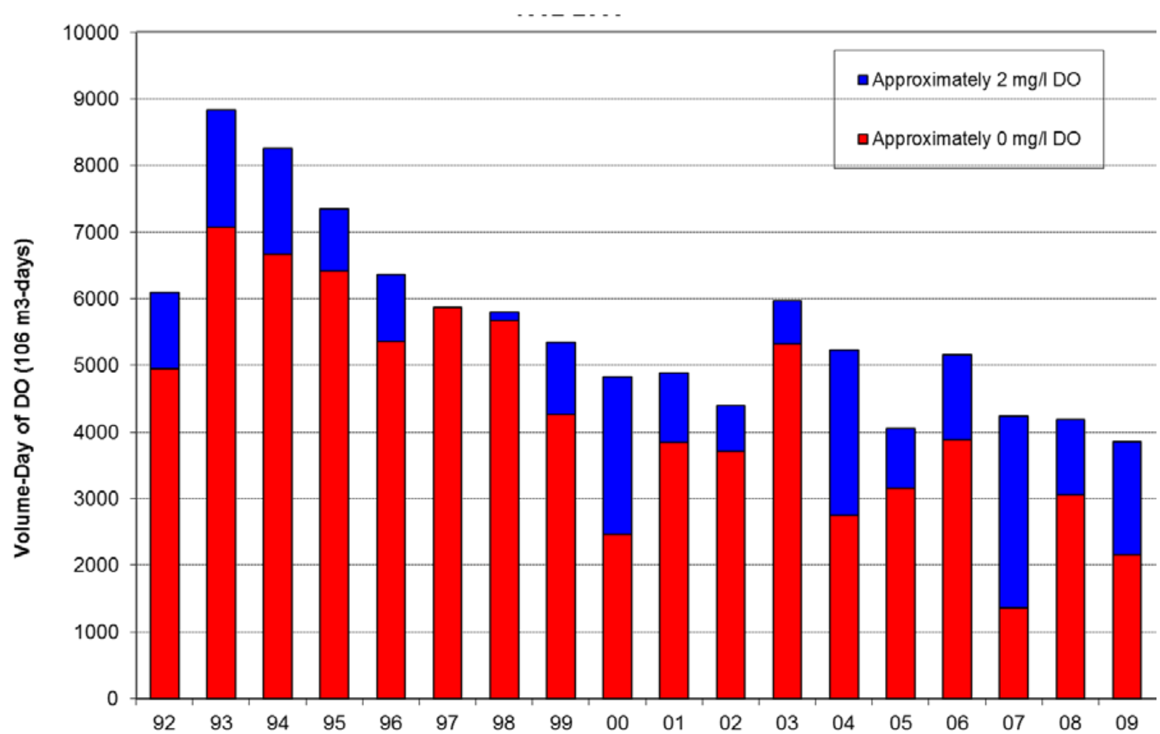


Figure 8 Volume-days of Anoxia and Hypoxia (DO <2 mg/L) in Onondaga Lake

2.2.6 Is Onondaga Lake Unique in Exhibiting Hypolimnetic Anoxia?

As part of their 2010 305(b) report on the status of NYS waters, NYSDEC has documented the frequency of occurrence of oxygen depletion in stratified lakes, and concluded that the majority of lakes in the NYSDEC database exhibit oxygen depletion during stratification. Based on NYSDEC's most recent analysis of water quality in NYS lakes,

> *"…dissolved oxygen standards are commonly violated, and anoxic conditions (functionally defined as DO readings <1 mg/l to account for inaccuracies in very low level dissolved oxygen measurements and the lack of DO data within the last meter or two of water depth immediately above the sediment-water interface) are routinely experienced. This table shows that* ***more than 70% of assessed waters that are thermally stratified experience hypoxia in the hypolimnion {emphasis original to NYSDEC report}.*** *There has been much discussion about the occurrence of "natural" DO depletion in lakes due to morphometry and focusing. Without sediment coring data for the vast majority of these lakes, it is impossible to separate out natural and culturally-induced DO depletion in these lakes…However, the high percentage of assessed lakes experiencing hypoxic conditions suggests that this phenomenon needs*

> *to be far more closely monitored and evaluated. The NYSDEC will devote significant effort in the upcoming 305b cycle to fully assessing the existing (electronic and hard copy) dissolved oxygen database, recognizing the limitations inherent in comprehensively evaluating the paucity of full profile data, as well as a renewed effort to collect additional full water column profiles in all subsequently sampled lakes."* (NYSDEC 2009; Clean Lakes Assessment Report, Appendix)

Clearly, many lakes in New York exhibit oxygen depletion in the hypolimnion during the summer stratified period.

2.2.7 How Do Other States Assess Compliance with DO in Stratified Lakes?

Seasonal anoxia is a physical phenomenon that affects freshwater lakes and impoundments throughout the U.S. To date, USEPA has not issued specific guidance to states regarding how to apply the DO criteria and AWQS to lakes and reservoirs. Therefore, states are able to interpret and apply the DO criteria for stratified waterbodies as they deem appropriate. Based on a review of each state's regulatory approach to hypolimnetic anoxia in stratified waters, a variety of approaches has been adopted (Appendix B). Each of these approaches has been approved by USEPA as consistent with the CWA.

Many states (23) do not specify within the text of their AWQS the depth in the water column at which compliance is to be evaluated. States that do not explicitly address DO standards for the deep waters of stratified lakes (the hypolimnion) are located within all regions of the U.S. The AWQS for DO in NY waters cite hypolimnetic DO requirements for only Class A-Special waters, which apply to a limited number of lakes (e.g., Lake George). For all other classes of waters, including Onondaga Lake, there is a reference to trout waters and non-trout waters, but no citation of how to evaluate compliance with AWQS in hypolimnetic waters, nor any acknowledgement that natural conditions could cause or contribute to oxygen depletion (Table 13).

Table 13

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.

The NYSDEC CALM document, dated May 2009, includes a specific commitment to examining the applicability of AWQS for DO in hypolimnia of stratified lakes; NYSDEC acknowledges that hypolimnetic anoxia may be naturally occurring, and will rely on best professional judgment in a case-by-case basis to determine whether designated uses are, in fact, being met.

> *"As the New York State water quality standards rule-making effort moves forward, NYSDEC will evaluate the current dissolved oxygen standards for freshwater in light of available research and adopt a criterion that might better reflect the natural occurrence of low dissolved oxygen in deeper waters and its impact on use support. (See also Impacts Due to Natural Conditions/Conflicting Uses in the Listing Methodology.) A general relationship between dissolved oxygen data, water chemistry and aquatic biology and assessed impacts to aquatic life use support is shown in Table 8."*
> (NYSDEC 2009)

The issue is whether and to what extent hypolimnetic DO depletion impairs Onondaga Lake for its designated use. Among the factors to consider is the nature of the lake's fish community. NYSDEC has not classified Onondaga Lake as waters suitable for trout survival and propagation (i.e., trout waters). Trout and other cold water fish species require DO and temperature conditions that are more stringent than those required for propagation and survival of cool and warm water fish species. Subsequent sections of this White Paper explore this issue of use attainment and hypolimnetic DO as it relates to fish propagation and survival.

Similar to the listing criteria for recreational use and public bathing, NYSDEC has set forth guidelines for assessing whether hypolimnetic anoxia in a waterbody represents an impairment of its designated use. Based on the extensive biological data available for Onondaga Lake, it appears that the best usage of the lake is not impaired by seasonal anoxia in the hypolimnion.

2.2.8 Does Onondaga Lake Meet its Designated Use for Fishing?

Class B surface waters best usages are primary contact recreation and fishing. The fishable portion of this standard includes water suitable for fish propagation and survival. Class C waters also should be suitable for fish propagation and survival, with fishing listed as the best usage of these waters.

Fishing was banned in Onondaga Lake in 1972 because of mercury contamination. The ban was lifted in 1986 and modified into a catch and release fishery; recreational fishing was permitted but possession of lake fishes was not. Further modifications to the fish consumption advisories and regulations have occurred over the years, and there is no longer a blanket restriction on possession of all fish. The current advisory sets forth consumption limits on specific species, and includes the warning that women under age 50 and children under age 15 should not consume fish from Onondaga Lake. There is a do not eat advisory for bass over 15 inches, all walleye, carp, channel catfish, and white perch; up to four meals per month for brown bullhead and pumpkinseed; and up to one meal per month for all other species. Advisories are in place due to mercury, PCBs, and dioxin contamination in the lake.

The biological portion of the Onondaga County AMP was developed to assess the suitability of the lake for fish propagation and survival. Annual surveys are conducted to assess larval, juvenile, and adult fish populations and determine the overall fish community composition and document any changes that may be attributed to the improvements at Metro. In addition, researchers at State University of New York College of Environmental Science and Forestry (SUNY-ESF) have been sampling the lake fish population since the late 1980s, which allows for an extensive temporal dataset for comparison.

Currently, Onondaga Lake supports a diverse and productive biological community. Since the AMP fish program was initiated in 2000, over 45 species of fish have been identified in the lake with the total number of species captured in any one year increasing from 24 species in 2000 to 28 in 2009. These species include both warmwater and coolwater species as well as transitory coldwater species with diversity and productivity comparable to other regional lakes.

Evaluation of nest building and surveying of young fish provides information on the overall health of the fish community within the lake and success of reproductive efforts 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. Nesting surveys are conducted each year as part of the AMP to document the number (by species, if possible) and spatial distribution of the nests. Nest builders in the lake include the centrarchid species (bass, sunfish, rock bass) and bullhead. Larval surveys and littoral seining are conducted throughout the year to assess reproductive success and to identify the species that are reproducing in the lake. Both the diversity and richness of young fish have increased over the decade of the AMP, indicating more species are reproducing and supporting a balanced fish community.

Suitable habitat is essential for sustaining the fishery. Macrophytes provide essential habitat for numerous fish species and mediate numerous ecosystem processes including light, temperature, and nutrient dynamics within the littoral zone. Prior to the improvements at Metro, the macrophyte community was thought to be impeded by unsuitable substrates. However, since 2000, macrophyte coverage has expanded from 85 acres in 2000 to 409 acres in 2010. As of 2010, more than 50% of the littoral zone supported macrophyte growth. Coincidentally, zebra mussels also were able to successfully colonize the lake by 2000, and have been followed by the closely related quagga mussel. It is thought that the reduction in ammonia due to improvements at Metro contributed to the establishment (Spada et al. 2002). Zebra and quagga mussel colonization may have contributed to the increased clarity in the lake, allowing for better light penetration and increased macrophyte establishment at deeper levels.

Temperature and oxygen are also critical components for habitat suitability for numerous species. Fish communities are classified based on temperature tolerances from coldwater to warmwater communities. Onondaga Lake is dominated by a warmwater fishery, composed of largemouth bass, sunfish, bullhead, carp, and white perch, and several coolwater species including smallmouth bass, northern pike, walleye, and several sucker species. DO levels typically above 5 mg/L are necessary for the majority of species in the lake. The critical factor is maintaining the desired oxygen concentrations within the zones of the lake that contain suitable temperatures for each species. Coolwater and coldwater species may be more influenced by lower oxygen concentrations during the warmer summer months when the colder hypolimnion becomes anoxic for a period of time. This is most limiting to sustaining coldwater species, while the coolwater species appear to find suitable habitat just above this layer where oxygen concentrations and temperature are more suitable.

Onondaga Lake currently meets its designated use for fishing. The lake supports a diverse and productive fish community, and is a popular site for recreational angling. Fishing derbies have become increasingly popular.

3 FISHERIES GOALS, STATUS, AND RESTORATION

3.1 What are the Goals for Onondaga Lake's Fish Community?

As noted above, Onondaga Lake currently supports a diverse fishery, including many warmwater and coolwater species, as well as transitory coldwater species, primarily brown trout. Historically, the lake supported coldwater fisheries, with the Onondaga Lake whitefish and Atlantic salmon reported in abundance prior to the 1880s (Beauchamp 1908). However, overfishing, channel modifications, pollution, development of the watershed, and other factors led to the declines of these coldwater species prior to the 20th Century. The numerous dams on the Oswego River system precluded movements of salmon from Lake Ontario to the Onondaga Lake tributaries, where the fish would spawn. These spawning impediments contributed to the decline in migratory species in the lake. Restoration efforts for such species would need to consider upstream passage for desired species while minimizing passage of invasive and exotic species.

More recently, the eutrophic conditions in Onondaga Lake may have limited the available habitat for coldwater species, due to the lack of oxygen in the hypolimnion during the summer months. Both the Onondaga Lake whitefish (likely the cisco – *Coregonus artedii*), and Atlantic salmon have been identified as coldwater species possible for restoration in Onondaga Lake. While there has been much debate over the past 20 years on the feasibility of a coldwater fishery in Onondaga Lake, recent documents suggest a more likely goal for the lake would be a sustainable warm and coolwater fishery, with a transitory coldwater fishery. The recent White Paper on coldwater fisheries in the lake prepared in 2004 for the OLP (referred to here as the NYSDEC White Paper) and the draft Onondaga Lake Remedial Design Elements for Habitat Restoration (Habitat Plan; Parsons et al. 2009) prepared for Honeywell's lake cleanup both propose a transitory coldwater fishery for the lake, with coldwater species sustained in the lake tributaries.

The NYSDEC White Paper was prepared as a recommended goal statement for the OLP regarding fishery objectives for the lake. The Atlantic salmon and cisco were both considered in the document with life history characteristics and environmental requirements summarized for both species. The conclusions of the paper, which were supported by input from NYSDEC fishery managers, support the goal statement of a resident warmwater and coolwater fishery in the lake, a transient coldwater fishery in the lake, and a coldwater fishery in the tributaries.

Honeywell developed the Habitat Restoration Plan with input from the Technical Work Group on design and species of interest. This group included representatives from NYSDEC, USEPA, U.S. Fish and Wildlife Service (USFWS), as well as Honeywell's team from SUNY-ESF, Mississippi State University, Terrestrial Environmental Specialists, Anchor QEA, O'Brien and Gere, and Parsons. Together, the group has worked over the past several years to develop and agree upon an approach for habitat restoration in the lake that includes the habitat needs of numerous representative species. There was much discussion among the group on coldwater fish and where they fit in the plan; the most recent recommendation was to include habitat for transitory coldwater species in the lake, with a sustainable coldwater fishery in the tributaries, in agreement with the NYSDEC White Paper.

3.2 What is the Current Status of Onondaga Lake's Fish Community?

3.2.1 County AMP

The Onondaga County AMP has included an extensive fish sampling component since 2000, incorporating different types of sampling gear to assess nesting, larval, juvenile and adult stages of numerous species (as summarized in Appendix A). 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 subsequent shift from eutrophic to mesotrophic conditions, are expected to expand available fish habitat within both the littoral and pelagic zones of the lake.

Onondaga Lake supports a varied recreational fishery, with largemouth bass, smallmouth bass, bluegill and pumpkinseed (Lepomis or sunfish species), yellow perch, and brown bullhead some of the more common sport fish present. Population characteristics of these species are investigated annually during the AMP to assess changes in the quality of the sport fishery. Information obtained during the sampling program is used to assess the relative abundance of these species in size classes available to anglers. In addition, many anglers participate in the Angler Diary program and summarize their catch rates for largemouth and smallmouth bass, which are compared to other local waterbodies.

Anglers from across the region, both recreational and professional, enjoy fishing in Onondaga Lake. Local amateur and regional/national professional tournaments are increasingly popular on the lake; the only other regional lake hosting these professional events is Oneida Lake. The local Salt City Bassmasters regularly holds weekly or bi-weekly tournaments during the season. In addition, the national Bassmasters Memorial Tournament was held on Onondaga Lake in 2007 and the Junior Bassmasters Tournament in 2008.

As part of the annual AMP, a data visualization tool was developed to graphically represent the habitat available for coldwater fish species in Onondaga Lake from May 15 to November 15 (185 days). This 6-month period is used because it encompasses the summer season when the upper waters of the lake can reach temperatures that are potentially stressful to the coldwater fish community. The resulting fish space metric is based on suitable temperature (less than 22°C), and DO (greater than 5 mg/L) within the water column as measured from the AMP South Deep station. Available habitat for the coldwater fish community is calculated as a percent of the theoretical total, using volume-days as the measurement (Figure 9). From this figure, there is a period during mid-summer when conditions are not suitable for coldwater species throughout the water column.

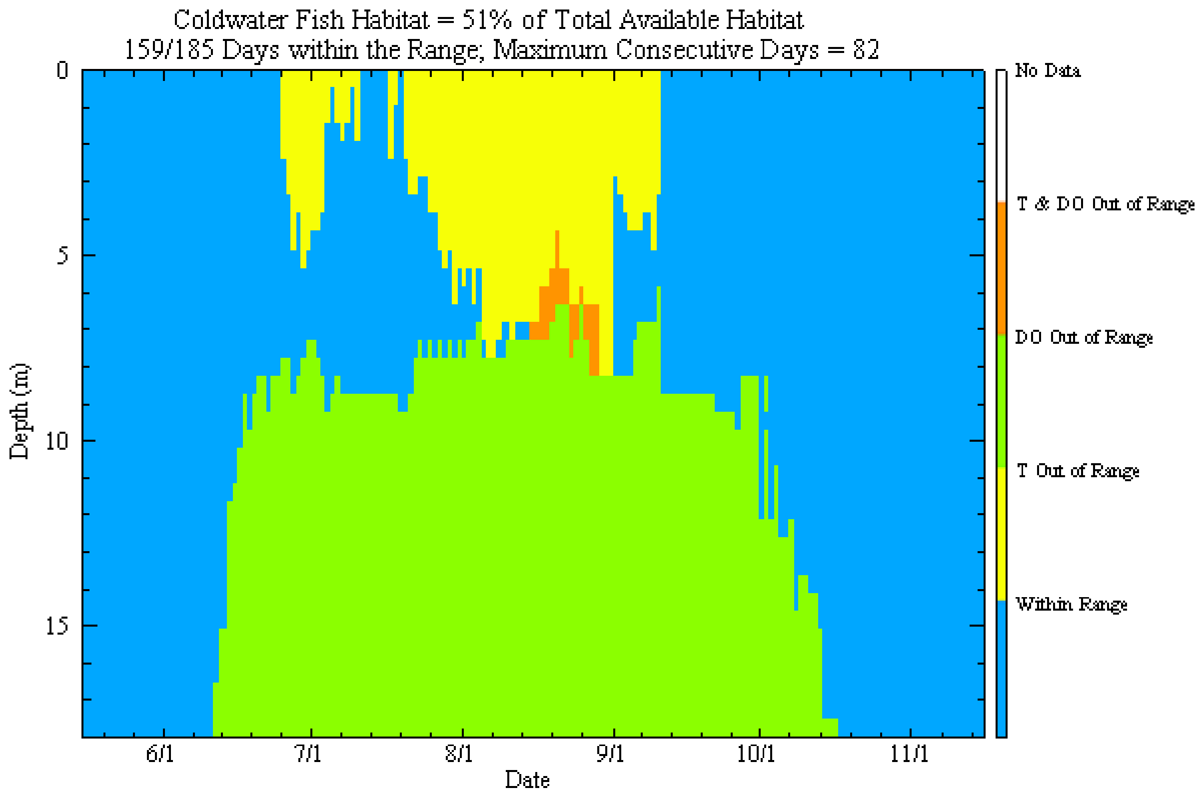


Figure 9 Coldwater Fish Habitat in Onondaga Lake in 2009

Notes: blue: temperatures and DO within range; yellow: temperature out of range; green: DO out of range; orange: both temperature and DO are out of range.

A similar graphic displays the availability of habitat suitable for the coolwater fish community. The resulting fish space metric is based on suitable temperature (less than or equal to 25°C), and DO (greater than or equal to 4 mg/L) within the water column as measured from the AMP South Deep station (Figure 10). Based on this assessment, suitable conditions exist for coolwater species throughout the year.

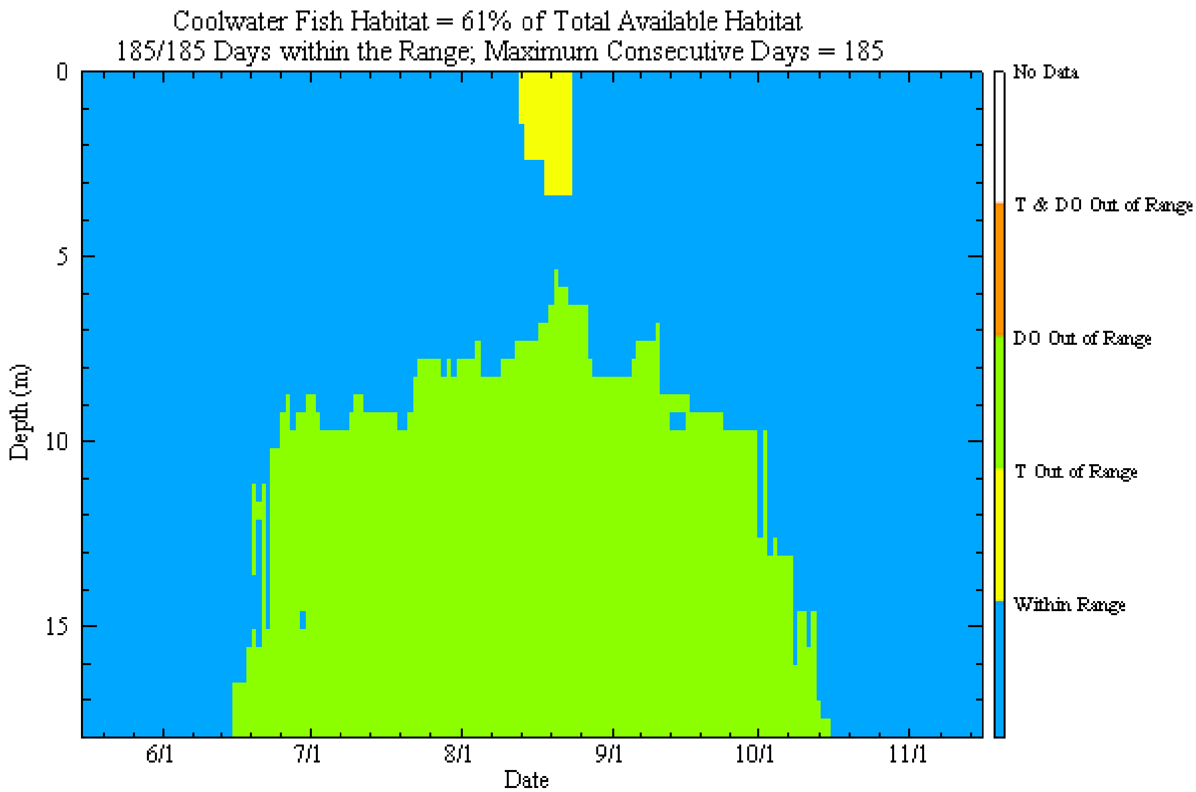


Figure 10 Coolwater Fish Habitat in Onondaga Lake in 2009

Notes: blue: temperatures and DO within range; yellow: temperature out of range; green: DO out of range; orange: both temperature and DO are out of range

There is increasing interest in nutrient levels in lakes and what the proper balance may be for meeting fish production needs versus limiting the algal blooms that create aesthetically unpleasing conditions. Biomass of fish at or near the top of the trophic level (i.e., top predators such as bass and walleye) is highly dependent on the amount of primary production at the base (Lindemann 1942; Ney 1996). Reductions in nutrient loadings result in lower algal production, clearer water, reduced fish biomass, and ultimately, poorer fishing. Developing a sound understanding of this interplay is critical to achieve the various goals on the lake and maintain the current level of fish production.

During the development of the Oneida Lake Management Plan (CNYRPDB 2004), there was discussion among the fishery group on the suitable level of TP in the lake and if 0.020 mg/L might be too low to sustain the fishery in the lake. It was recognized that maintenance of a strong fishery, for which Oneida is well-known, was highly dependent on a phosphorus management plan that balances the need for clear water and for a productive fishery. Based on studies by Cornell researchers, it was determined that the fishery had not been negatively impacted at TP levels of 0.020 mg/L, which had been observed for several years, but any further reductions in phosphorus could lower fish production (CNYRPDB 2004). For Onondaga Lake, it is important to recognize the balance between phosphorus concentration and fish production, and assess at which levels fish production may be negatively impacted. The TP concentration that causes excessive algal blooms varies with the characteristics of the water body, and should be evaluated on a case by case basis. For Onondaga Lake, the link between TP concentration, primary production, and upper trophic level fish species needs to be considered so suitable concentrations can be established that do not reduce fish production from desired levels.

3.3 Native vs. Non-native

The issue of native versus non-native species and determining how to manage the lake for a diverse array of species has been challenging. While early documents indicate the lake once supported both Atlantic salmon and ciscos (Onondaga Lake whitefish), both coldwater species, it is not likely, 200 years later, that the lake will be able to support these native coldwater species due to irreversible changes in the watershed. Several cool and warmwater species were apparently native to the lake as well including bass, pike, pickerel, perch, and catfish. These species currently reside in the lake or within the watershed and may be more likely to maintain sustainable populations in the lake. As part of the Honeywell Habitat Plan, numerous habitats are being designed to support the various representative species including a pike spawning wetland area near the southwest corner of the lake. Lake sturgeon have recently been documented from the lake as well, with an active stocking program in place on Oneida Lake since the mid-1990s; these fish apparently have expanded their range into the Oswego River system, including Onondaga Lake. The proliferation of the alewife in the lake introduces another management issue. These forage fish contain the enzyme thiaminase, which interferes with the reproductive success of some salmonid species.

4 IMPACTS OF HUMAN-INDUCED AND NATURAL CONDITIONS ON USE IMPAIRMENTS

Onondaga Lake and its watershed have been affected by a number of non-reversible human-induced and natural perturbations that affect the water quality and habitat condition of the lake.

4.1 Anthropogenic Impacts

4.1.1 Wetland Loss

The lowering of the lake level and the associated loss of wetlands has retarded the lake's capacity to filter nutrient loads from the watershed, destroyed spawning habitat for several fish species, and has contributed to its present day state. In 1822, during the industrial development of the area, the northern outlet to the lake was dredged to open the waterway to the Seneca River, and eventually the Erie Canal system. This resulted in lowering the lake water level and drying up wetlands that once covered portions of present-day downtown Syracuse.

In addition to the lowering of the lake level, the channels of the lake's largest tributaries (Onondaga and Nine Mile creeks) have been altered from their natural states through channelization. In the mid-1800s, civic leaders concerned with sewage disposal and the risk of flooding straightened and deepened the Onondaga Creek channel to hasten flood water and sewage removal. Major flooding that occurred in the early 1900s prompted the City of Syracuse, the State of New York, and the Army Corps of Engineers to implement extensive channelization and damming of the creek.

Nine Mile Creek, the second largest natural tributary to Onondaga Lake, originates at Otisco Lake and flows through the Village of Marcellus and between seven Solvay wastebeds before entering Onondaga Lake at Lakeland. The creek is the receiving waters for the 0.4 MGD Marcellus Wastewater Treatment Plant, which is a source of phosphorus to the creek and Onondaga Lake. Nine Mile Creek was channelized near its mouth to Onondaga Lake to make room for a nearshore Solvay wastebed, which contains millions of tons of industrial waste from the Solvay Process (Allied Chemical and LCP, currently Honeywell).

This channelization of both Onondaga Creek and Nine Mile Creek has altered the natural structure and function of these systems. Moreover, the commercial and industrial development along their mouths to the lake has destroyed wetlands along with their associated nutrient trapping capabilities.

4.1.2 Flow Regulation in Three Rivers

With the dredging of the lake outlet in the early 1800s, Onondaga Lake's elevation was reduced to that of the adjacent Seneca River's, which is a part of the highly regulated Three Rivers System and consists of the Seneca, Oneida, and Oswego rivers. Flows within the Three Rivers System are regulated at several key control points, including the dams associated with the following canal structures:

- Lock CS-4 (Discharge from Seneca Lake)
- Lock CS-1 (Discharge from Cayuga Lake – includes flow from Seneca Lake)
- Locks E-25 and E-26 (Discharge from Erie Canal/Clyde River)
- Lock E-24 (Seneca River at Baldwinsville)
- Lock E-23 and the Caughdenoy Dam (Discharge from Oneida Lake through the Oneida River)
- Dam and Lock O-1 (Phoenix, first flow control point in the Oswego River downstream of the Seneca/Oneida River confluence)
- Locks O-2 and O-3 (Fulton area)
- Lock O-5 (Minetto)
- Locks O-6, O-7, and O-8 (Oswego)

These manmade structures developed for hydropower and navigation purposes altered the natural flow condition of the rivers and have contributed to the reduction in the assimilation capacity of the system. In addition to flow restrictions, they have significant impact on wetlands, fisheries, and recreational opportunities.

4.1.3 Tully Mudboils

Mudboils present in the Tully Valley have been observed since the late 1890s. These mudboils have continuously discharged sediment-laden water into nearby Onondaga Creek, the largest tributary of Onondaga Lake. According to the United States Geological Survey (USGS), the average sediment loading to Onondaga Creek from the mudboil area in the early 1990s was approximately 30 tons per day. The OLP and the USGS supported remediation efforts to control the sediment loading from the mudboils to Onondaga Creek and ultimately Onondaga Lake. These efforts successfully reduced the amount of sediment flowing into Onondaga Creek, to less than 1 ton per day.

In 2010, new mudboils known as rogues have developed outside of the areas that had been primarily controlled by USGS activities. These new mudboils have increased the sediment input to Onondaga Creek by an estimated 5 to 8 tons per day (William Kappel, USGS, personal communication January 26, 2011). The amount of phosphorus carried to the lake by the sediments is unknown but could be consequential.

Funding for monitoring, assessment, and controls for the mudboils has diminished. This could cause a dramatic increase in fine-grained sediments and phosphorus being discharged through Onondaga Creek and into the lake.

4.2 Natural Impacts

4.2.1 Zebra and Quagga (Dreissenid) Mussels

Zebra and quagga mussels, exotic species of bivalves, consume DO and release excess nitrogen and phosphorus as ammonia and SRP. These impacts represent a "natural" perturbation to the lake and have the potential to alter the traditional relationships between water column phosphorus concentrations and the lake's phytoplankton biomass. Indeed, in the adjacent Three Rivers System, dreissenid mussels, rather than phosphorus, are currently regulating the productivity of the system.

Dreissenid mussels invaded the Three Rivers System sometime between 1991 and 1993. Due to ammonia toxicity, the exotic mussels did not successfully colonize Onondaga Lake until 2000, when Metro improved ammonia treatment and in-lake concentrations approached the

AWQS. Dreissenid mussels represent the single largest perturbation to the river system over the water quality monitoring record and have increased in density in Onondaga Lake over the last several years. Zebra and quagga mussels filter phytoplankton and other suspended solids from the water column, and deposit feces and pseudofeces onto the sediment bed where they decompose and contribute to the sediment oxygen demand.

4.2.2 Lake Morphology

The morphology of Onondaga Lake makes it susceptible to hypolimnetic oxygen depletion. The lake has two distinct basins (Figure 1) both of which experience strong thermal stratification during summer. Thermal stratification inhibits oxygen transfer to bottom waters and decomposition of organic matter depletes hypolimnetic oxygen stores. Consequently, both the northern and southern basins experience hypoxia during lake stratification. It will be important to complete modeling analyses to evaluate the extent of hypolimnetic DO depletion under pre-colonization conditions (i.e., 100% forested watershed).

4.2.3 Fish Community Structure (alewives)

The Onondaga Lake fish community has experienced increased species diversity over the past two decades as water quality has improved. However, the presence and high abundance of alewives in the past decade (most notably between 2003 and 2006, with another increase in 2010) has had an impact on overall trophic dynamics. Alewives prefer to feed on large zooplankton, and can cause a shift in the overall composition of the zooplankton community, resulting in dominance of smaller zooplankton. Larger zooplankton are more efficient grazers and the presence of larger organisms results in less algae and clearer waters. A shift to smaller phytoplankton due to alewife grazing may result in an increase in algal abundance, resulting in negative public perception on the overall health of the lake.

4.2.4 Local Climate and Climate Change

Climate change is expected to result in warmer temperatures, loss of ice cover, and decreased lake levels in many areas. Lakes in the mid to high latitudes of the northern hemisphere, including the Great Lakes district, are projected to be most affected, with temperatures increasing each decade by an average of 0.45°C, with some lakes increasing as much as 1°C per decade (Schneider and Hook 2010). The warming climate could have considerable implications on Onondaga Lake's stratification and, consequently, impact DO resources. The timing and strength of stratification is a function of climate (i.e., incident solar radiation, wind mixing). Earlier and hotter summer periods may lead to longer stratified periods and extended isolation from surface mixing. Moreover, shorter term meteorological conditions have an impact on the rate of oxygen depletion via enhanced mixing from storms. Hydrology is also a function of climate, and increasing wetter periods with more intense and frequent winter and spring storms can produce increased runoff and phosphorus loads that stimulate algal growth and thus significantly impact DO conditions of the lake. Because these processes can vary considerably from year to year, the extent to which they contribute to hypolimnetic oxygen depletion is also likely to be variable.

5 RELEVANT REGULATORY ISSUES

This section provides background on the regulatory framework governing the policy decisions facing Onondaga County related to Onondaga Lake. The federal CWA provides the overarching regulatory framework governing point source controls, non-point source controls, and the goals for receiving water quality. USEPA has developed tools and guidance for the states to bring waterbodies into compliance, while recognizing the importance of regional perspectives and economic realities.

5.1 Clean Water Act and the 303(d) List

Under authority of the CWA, the USEPA requires states to classify waters for a designated use (e.g., water supply, recreation, aquatic life), to promulgate AWQS, which are enforceable limits on pollutants related to these designated uses, and to periodically evaluate whether the designated uses are, in fact, achieved. To support the states in meeting these responsibilities, USEPA scientists develop criteria, defined as the best professional judgment of limits on specific parameters that will support the designated use (e.g., ammonia concentrations that would not harm the aquatic biota). The federal criteria are not legally enforceable limits. States have the option of promulgating the federal criteria as their standards, or developing their own standards that are subject to USEPA approval.

The 303(d) list is a powerful tool for water quality management. Since passage of the CWA in 1972, regulations have focused on controlling point sources of pollution through limits on the concentration of pollutants in effluent discharges. Concentration limits are typically defined by technology and economics. This strategy has been successful in bringing about significant improvement in the quality of many waterbodies. However, challenges remain. There are some waterbodies where technology-based limits on effluent quality will not achieve compliance with water quality standards. Other waterbodies are affected by non-point sources of pollution such as runoff from urban areas or agricultural lands. The 303(d) list provides a mechanism for identifying those waterbodies where additional limits on point and non-point sources of pollution are needed.

In 1992, USEPA promulgated regulations for allocating pollutant loading to those waterbodies where technology-based effluent limits would not result in water quality conditions that meet standards and support designated uses. The framework adopted is the TMDL approach, where point and non-point sources of pollution are identified and a coordinated strategy for reduction is defined. Under the USEPA regulations, the first step is to list waters that are not meeting criteria set for specific designated uses. For each listed waterbody, the state, territory, or authorized tribe is tasked with identifying the amount by which point and non-point sources must be reduced to attain water quality conditions that support the designated use. The term TMDL is used to refer to both the planning process and the numerical load allocation.

5.1.1 Use Attainability Analysis

The CWA provides a mechanism for analyzing whether water quality standards are appropriate for a specific waterbody. The formal process is called a use attainability analysis (UAA). There are six situations where a UAA may result in a site-specific modification to an AWQS, or a reclassification of a designated use (USEPA 1994).

1. Naturally occurring pollutant concentrations prevent attainment of the use.
2. Natural, ephemeral, intermittent, or low flow water levels prevent attainment of use.
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be removed without causing more environmental damage (legacy pollutants).
4. Dams, diversions, or other types of hydrologic modification preclude attainment of the use and cannot be modified or restored.
5. Physical conditions related to the natural features of the waterbody such as the lack of substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses.
6. Controls more stringent than those required by the CWA's mandatory controls would result in substantial and widespread adverse economic and social impact.

Two examples of completed UAA in New York that were ultimately accepted by USEPA addressed: 1) water quality conditions in New York Harbor, a marine waterbody, and 2) a freshwater stream within the Seneca-Oneida-Oswego Basin. Several segments of the New York Harbor did not meet the federal policy goal for fishable and swimmable and NYSDEC completed a UAA to evaluate whether attainment of these uses in this highly urbanized and modified environment was possible. The analysis was completed in 1985, and resulted in an upgraded classification for several segments and no change in classification or designated use for other segments.

In the second example, the USEPA determined that NYSDEC was not required to reclassify a Class D segment of an unnamed tributary to the Seneca/Cayuga Canal (ONT-66-12-57), which ultimately flows to northern Cayuga Lake and out to the Seneca River. This 1992 decision was based on low water levels from the intermittent hydrologic regime.

5.1.2 Site-specific Variance

In its implementation of the CWA, USEPA policy provides for Site-specific Variances (SSVs). As defined by USEPA,

> *"A variance is a temporary modification to the designated use and associated water quality criteria that would otherwise apply. It is based on a use attainability demonstration and targets achievement of the highest attainable use and associated criteria during the variance period. Modifying the use through a variance process allows the state. . . to limit the applicability of a specific criterion and to identify an alternative designated use and associated criteria to be met during the term of the variance. The variance may be written to address a specified geographical coverage, a specified pollutant or pollutants, and/or a specified pollutant source."*

NYS guidance on variances does not reference natural conditions; however, federal regulations 40 CFR Section 131.10(g) includes physical conditions that preclude attainment of aquatic communities.

Seeking a SSV takes a considerable amount of time and requires completion of a UAA. The data to support a UAA should already be available through the AMP and the OLWQM. SSVs are generally granted for a 3-year period; a subsequent review evaluates what changes might be necessary. Application of the SSV could provide an interim step while NYSDEC completes the evaluation and modification of its AWQS for DO to address hypolimnetic conditions for warmwater, coolwater, and coldwater fisheries. The NYSDEC CALM publication states the Department's intent to evaluate DO standards for the hypolimnion.

USEPA allows and has approved subcategories for state water classifications for several states. There is a potential for a specific subcategory in NYS to deal with lakes with seasonal hypoxia. NYSDEC has recognized the need to address hypolimnetic anoxia in stratified lakes within the AWQS for DO, and has committed to this evaluation. Addition of subcategories for different hypolimnetic oxygen regimes could account for the range in fish communities (coldwater, coolwater, warmwater) in NYS lakes, while remaining consistent with the regulatory classification for aquatic life protection. Several states have taken the approach of linking DO standards to the nature of the fish community (refer to Appendix B).

5.2 Technical and Regulatory Genesis of the Phosphorus Guidance Value

Lakes are typically categorized by their level of primary productivity, as indexed by algal biomass and the types of vegetation and fisheries they support. Oligotrophic lakes, defined as lakes with a low level of productivity, exhibit low concentrations of nutrients and algal growth. Eutrophic lakes have elevated concentrations of nutrients and productivity; these lakes typically exhibit algal blooms and can develop seasonal hypolimnetic anoxia. Lakes of an intermediate level of productivity are termed mesotrophic. Phosphorus has been firmly established as the limiting nutrient for production in the majority of lakes.

While phosphorus can cause eutrophication, it is the effects of eutrophication that diminish the recreational and aesthetic quality of lakes for the public. Consequently, NYSDEC sought to quantify the relationship between the causal variable (phosphorus) and the response variables (algal abundance and water clarity). NYSDEC also sought to relate the trophic state of a lake to its perceived suitability for recreational use. The statewide network of volunteer monitoring, Citizens Statewide Lake Assessment Program (CSLAP), was used as the information base to establish this relationship.

During the summer of 1992, volunteer monitors were asked to complete a questionnaire describing their perception of the lake's suitability for recreational use at the time of sampling. Survey results were paired with the measurements of TP, water clarity, and chlorophyll-a on the same sampling day. Using a statistical cross-tabulation methodology that had been applied in other states for this purpose, NYSDEC scientists defined threshold TP measurements associated with an acceptably low risk (10%) of conditions that would diminish the lake's attractiveness for recreational use. This guidance value was set at 0.020 mg/L, and is applied as a seasonal (June to September) average value for the upper waters. NYSDEC published a Fact Sheet describing the genesis of the guidance value in 1993. Since that time, the 0.020 mg/L guidance value has been used to represent the narrative standard for phosphorus in ponded waters.

5.2.1 Current Initiatives to Develop Nutrient Criteria

In 1998, the USEPA released its strategy for addressing nutrient enrichment of surface waters; this included a requirement for states to develop numerical water quality standards. The numerical water quality standards are required for both causal (total nitrogen and total phosphorus) and response (chlorophyll and water clarity) parameters. The USEPA developed nutrient criteria on an ecoregional basis. States have the option to adopt the federal criteria as their nutrient standards, or to develop and promulgate state-specific standards.

To comply with this requirement, NYSDEC is in the process of developing nutrient criteria for lakes, reservoirs, streams, and rivers. The last progress update by NYSDEC is dated April 15, 2009. The program is moving slowly with no specific date targeted for completion. Nutrient criteria are being established as outlined by USEPA based on ecoregions. Onondaga Lake is in the Eastern Great Lakes/Hudson River Lowlands ecoregion, the largest in New York. NYSDEC intends to derive its own state-specific criteria for nutrients for both ponded and flowing waters, considering that this approach will allow for more appropriate standards that are reflective of the defined best uses of the waters in each ecoregion.

New York expects to move forward with two separate administrative actions. First, to establish as guidance values the nutrient criteria being derived for: 1) aquatic life in wadeable rivers and streams, 2) human health in ponded waters (focused on controlling algal density to reduce the risk of disinfection byproducts and algal toxins), and 3) recreational use in ponded waters. Fact Sheets supporting these draft guidance values were prepared in early 2008 and continue to undergo internal review. NYSDEC states that the numerical criteria listed in the draft fact sheets reflect values that have been used by NYSDEC for over 20 years, suggesting that they intend to codify the 20 μg/L guidance value for phosphorus as the TP criterion for ponded waters. To date, no internal drafts of the proposed nutrient criteria have been released, nor are they eligible for review under the Freedom of Information Act.

NYSDEC has been investigating values for nutrients in flowing waters that are protective of human health. Progress has been slow, and it appears that the criteria will not be released for comment before 2012. While Onondaga Lake would fall only into the Lakes and Reservoir category, the tributary streams in the watershed could be governed by the flowing waters nutrient criteria.

NYSDEC continues to perform studies on lakes and reservoirs based on its CALM document. The Department has extensive data on non-wadeable streams from its water quality surveys that have been performed over the course of the past three decades. They have been gathering additional data related to wadeable streams. Due to resource limitations, NYSDEC has not yet finished analyzing the significant data packages to allow for specific numerical recommendations to be developed. NYSDEC has not announced a date for completion of the nutrient criteria.

5.2.2 Site-specific Phosphorus Guidance Value

The current NYSDEC guidance value is applied statewide, with no accommodation for differences in a lake's natural setting (ecoregional differences in geology, soils, climate, etc.) or human impacts (land use, population density, stormwater and wastewater disposal, etc.). Detailed knowledge of the Onondaga Lake system, notably from three sources: the extensive AMP data, the OLWQM, and the assessment of phosphorus bioavailability, provide documentation for NYSDEC to use should they wish to seek a site-specific guidance value for Onondaga Lake.

5.3 Adaptive Management

From its inception, the ACJ has adopted adaptive management, defined as assessment and management tools that support incremental decision-making based on accumulated information, as the framework for evaluating the options for Onondaga Lake's rehabilitation.

While the term adaptive management was not in the regulatory lexicon when the ACJ was drafted, it does capture the thought process used to structure the "build and measure" aspects of Onondaga County's programs, notably, the requirement for the extensive monitoring program to assess the actual response of the lake to pollution abatement, and development of the suite of mechanistic water quality models.

Adaptive management is an approach to bring together the various state and federal programs as well as the stakeholders to provide for a coherent, consistent, and consensus-built program for Onondaga Lake. This concept is consistent with the ACJ and its subsequent amendments, including the fourth stipulation signed in November 2009. The regulatory options outlined above, including SSV, site-specific guidance values, and modifications to the AWQS for DO in stratified lakes to include subcategories, can all be considered facets of the adaptive management approach. In addition, this approach could enable the parties to consider the effectiveness of other programs underway in the watershed including the Honeywell remedial work, CSO abatement, and green infrastructure to reduce stormwater runoff.

Further, the concept of adaptive management is a key element of the ecosystem-based management (EBM) paradigm, defined as an integrated approach to watershed management that considers the entire ecosystem, including humans. In 2006, the New York State Legislature passed the New York State Ocean and Great Lakes Ecosystem Conservation Act (Article 14 of the Environmental Conservation Law), which was signed into law by Governor George Pataki. The act directs NYS agencies to adopt EBM, considered a step forward from existing management approaches that focus on target species or a suite of water quality parameters. Rather, EBM focuses on the interconnections between water resources and the communities they sustain. The overarching goal of EBM is to protect ecosystem services while fostering economic growth and community development.

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APPENDIX A
SUMMARY OF THE AMBIENT MONITORING PROGRAM BASIS OF DESIGN

Summary of the Ambient Monitoring Program Basis of Design

Metrics	Measured By	Monitoring Program Design
Suitability for Water Contact Recreation		
Indicator bacteria	Fecal coliform bacteria and E. coli abundance within the lake's Class B segment	Minimum 5 samples/month, 9 nearshore stations and South Deep during Metro disinfection season
Water clarity	Secchi disk transparency (nearshore, Class B)	Weekly measurements, 9 nearshore stations and South Deep (June 1- Sept): biweekly ice-free season
Trophic State	Total P, chlorophyll-a, and Secchi disk transparency	Weekly measurements (June – Sept) South Deep, biweekly April-Dec
Aesthetic Appeal		
Water clarity	Secchi disk transparency (open waters South Deep)	Weekly measurements (June – Sept) South Deep, biweekly April-Dec
Algal blooms	Algal abundance in summer	Biweekly measurements (ice-free season) South Deep for phytoplankton- weekly chlorophyll- a (June-Sept)
	Frequency, magnitude and duration of algal blooms	
Algal community	Composition of algal community (taxa)- by biovolume and count	
Aquatic Life Protection		
Ammonia	Ammonia N concentrations	Biweekly water column profiles, ice-free season
Nitrite	Nitrite N concentrations	Biweekly water column profiles, ice-free season
Dissolved oxygen (DO)	DO concentrations throughout the water column, ice-free season (additional sampling during fall mixing)	Biweekly water column profiles, ice-free season Weekly profiles, June – September Water quality buoy at South Deep, ice-free season
Sustainable Recreational Fishery		
Habitat quality	Volume of the lake with suitable water temperature and DO conditions over the annual cycle Macrophyte coverage	Temperature and DO profiles, weekly Annual aerial photography to map macrophyte cover; macrophyte surveys every 5 years.
Fish species successfully reproducing	Nesting surveys, larval sampling, young-of-year sampling (littoral and pelagic) adult surveys	Determination if target species (warmwater and cool water) are reproducing in the lake: • largemouth bass, smallmouth bass and sunfish • yellow perch • black crappie • rock bass • walleye and northern pike

APPENDIX B
STATE REGULATORY APPROACHES TO HYPOLIMNETIC ANOXIA IN STRATIFIED WATERS

Policy	States with this Policy (approved under the Clean Water Act)
States (23) with no explicit discussion of depth in water column where compliance with ambient water quality standards (AWQS) for dissolved oxygen (DO) is to be assessed	Arkansas, Connecticut, Florida, Georgia, Hawaii, Indiana, Kansas, Louisiana, Maryland, New Jersey, Maine, Minnesota, Missouri, Montana, New Jersey, Ohio, Oklahoma, Oregon, South Dakota, Vermont, West Virginia, Wisconsin, Wyoming
States (11) with promulgated standards defining specific water depths or strata for which AWQS for DO will be assessed	Tennessee (compliance at 5 ft) Alabama (compliance at 5 ft or, mid-depth for waterbodies less than 10 ft deep) Arizona (top meter) Pennsylvania, Iowa, Colorado (compliance in epilimnion) New Hampshire: Surface waters within the top 25 percent of depth of thermally unstratified lakes, ponds, impoundments and reservoirs or within the epilimnion shall contain a DO content of at least 75 percent saturation, based on a daily average and an instantaneous minimum DO content of at least 5 mg/l. *Unless naturally occurring, the DO content below those depths shall be consistent with that necessary to maintain and protect existing and designated uses.* Nevada: The DO standard from June to October applies only to the epilimnion. Illinois: AWQS apply to waters above the thermocline. In addition, there is a narrative standard …"waters below the thermocline in lakes and reservoirs must be maintained at sufficient DO concentrations to support their natural ecological functions and resident aquatic communities." Kentucky: Compliance measured at mid-depth. For trout waters, DO below epilimnion must be consistent with natural conditions Mississippi: For waters that are thermally stratified such as lakes, estuaries, and impounded streams: At mid-depth of the epilimnion if the epilimnion depth is 10 feet or less. At 5 feet from the water surface if the epilimnion depth is greater than 10 feet.
States (4) with regulations that specifically exclude the hypolimnia of stratified lakes from assessment of compliance with DO standard	Utah, Texas, Alaska, Idaho

Policy	States with this Policy (approved under the Clean Water Act)
State (1) with regulations stating that DO standards apply throughout the water column	Virginia (includes provision for development of site-specific criteria to reflect "natural water quality")
States (2) citing that DO in the hypolimnion can be below AWQS if it is due to natural conditions	North Carolina and North Dakota
States (3) citing that DO can be below AWQS if it is due to natural conditions (no specific reference to stratified lakes)	South Carolina, New Mexico, Delaware
States (4) with regulations that cite the type of fish community to be protected and refer to depth at which AWQS for DO to be evaluated	Rhode Island: While there is no reference to thermal stratification in freshwaters, DO criteria are stated as a water column average minimum for coldwater & warmwater fish communities New York: 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. Nebraska: No reference to stratified lakes; state has adopted different DO AWQS to protect coldwater (reproducing), coldwater (sustaining) and warm water fish communities. DO standards vary seasonally, and with presence/absence of early life stages. DO standards expressed as average, minima and duration of minima. Michigan: DO; inland lakes. (1) The following standards for DO shall apply to the lakes designated for coldwater fish: (a) In stratified coldwater lakes which have DO concentrations less than 7 milligrams per liter in the upper half of the hypolimnion, a minimum of 7 milligrams per liter DO shall be maintained throughout the epilimnion and upper 1/3 of the thermocline during stratification. Lakes capable of sustaining oxygen throughout the hypolimnion shall maintain oxygen throughout the hypolimnion. At all other times, DO concentrations greater than 7 milligrams per liter shall be maintained. (b) Except for

Policy	States with this Policy (approved under the Clean Water Act)
	lakes described in subdivision (c) of this subrule, in stratified coldwater lakes which have DO concentrations greater than 7 milligrams per liter in the upper half of the hypolimnion, a minimum of 7 milligrams per liter of DO shall be maintained in the epilimnion, thermocline, and upper half of the hypolimnion. Lakes capable of sustaining oxygen throughout the hypolimnion shall maintain oxygen throughout the hypolimnion. At all other times, DO concentrations greater than 7 milligrams per liter shall be maintained. (c) In stratified coldwater lakes which have DO concentrations greater than 7 milligrams per liter throughout the hypolimnion, a minimum of 7 milligrams per liter shall be maintained throughout the lake. (d) In unstratified coldwater lakes, a minimum of 7 milligrams per liter of DO shall be maintained throughout the lake. (2) For all other inland lakes not specified in subrule (1) of this rule, during stratification, a minimum DO concentration of 5 milligrams per liter shall be maintained throughout the epilimnion. At all other times, DO concentrations greater than 5 milligrams per liter shall be maintained.
State (1) with no language setting forth the depth at which DO compliance to be assessed in lakes in the statewide regulations, but with an example from an approved TMDL	Washington: (Spokane TMDL) Compliance is evaluated by averaging DO at 1 m depth intervals through water column, excluding the top 8 m as affected by algal photosynthesis.
State (1) with regional basin plans instead of statewide AWQS, with many waterbodies for which site-specific DO criteria have been developed	California – surface waters are classified by use (includes human & ecological); water quality objectives for DO expressed in various ways: minimum and/or statistical terms *(example of statistical terms: 50% upper and lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be less than or equal to an upper limit and greater than or equal to a lower limit. 90% upper and lower limits represent the 90 percentile values for a calendar year. 90% or more of the values must be less than or equal to an upper limit and greater than or equal to a lower limit.*