The P Project
Reducing Phosphorus in the Finger Lakes

Annotated Bibliography

Phosphorus Research Conducted in the
Cayuga Lake and Owasco Lake Watersheds

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This annotated bibliography is a compilation of research related to phosphorus loading in the Owasco and Cayuga Lake watersheds. Several studies, such as those relating to phosphorus cycling by zebra mussels, may not be studies about either Owasco or Cayuga Lakes directly, but are relevant because they deal with characteristics of the biota and limnology of these lakes. Some of the summaries may seem repetitious to the reader, since many of the studies cited in this bibliography had very similar focuses. I included all of these for the sake of thoroughness.

Background and Important Terms:

Cayuga and Owasco Lakes are both thermally stratified lakes. This means that in the warmer months, generally May through November, the lakes are divided between a warm upper layer of water called the epilmnion and a cooler, deep layer of water called the hypolimnion. The meeting of these two layers is called a thermocline. When the lakes are stratified, there is little mixing of nutrients between the layers. From late November to early spring, the lake becomes unstratified, or mixes. When the lake waters mix, nutrients from the bottom sediments mix through the water column.

A lake's productivity is classified on a trophic scale based on nutrient levels and plant production. The primary classifications on this scale are oligotropic, or low nutrient levels; mesotrophic, or moderate nutrient levels; and eutrophic, or high nutrient levels. Sometimes intermediate classifications are used, such as hypotrophic (very low nutrient levels) meso-eutrophic (medium-high trophic levels), or hypereutrophic (very high nutrient levels).

Phosphorus levels are measured differently for different purposes. In the reports summarized below, the two main measurements used were total phosphorus (abbreviated as TP) and soluble reactive phosphorus (abbreviated as SRP). TP is a measurement of all the forms of phosphorus, dissolved and particulate, found in a sample. SRP is primarily a measurement of dissolved phosphorus (though some particulate phosphorus will likely be picked up in a SRP sample). It is a measure of the phosphorus that reacts to a reagent, and gives a better indication of the amount of phosphorus directly available for uptake by algae and other aquatic organisms than TP. TP is a combination of SRP and all other forms of phosphorus.

Abbreviations used throughout this bibliography:

CSO:	Combined sewage overflow.
DO:	Dissolved oxygen, a measure of oxygen carried in water.
GIS:	Geographic information system, a means of remote sensing.
LSC:	Lake Source Cooling, an air-conditioning system for Cornell University that uses water from deep in Cayuga Lake to cool Cornell Buildings. At no time does the water leave the pipes or have contact with other water. The warmed water is returned to a shallow area at the southern end of Cayuga Lake.
NYSEG:	New York State Electric and Gas, a power company.
P or P Loading:	Phosphorus, or phosphorus loading.
TP:	Total phosphorus, a commonly measured form of phosphorus in water.
SRP:	Soluble reactive phosphorus, another commonly measured form of aquatic phosphorus.

Barlow, John B. et al. 1970. Eutrophication of Water Resources of New York State: Observations on Nutrient Limitation on Summer Phytoplankton in Cayuga Lake, 1967 and 1968. ***Cornell Water Resources and Marine Sciences Center:*** **Technical Report No. 21.**

The low levels of both nutrients and phytoplankton in the summer stratification period indicate that nutrient supplies closely regulate algae growth. Cayuga Lake in the summer has very low levels of silicate and phosphate, but nitrate remains abundant. The researchers found that phosphate enhanced the growth of phytoplankton, contradicting the findings of Hamilton (see below) that silicate is the limiting factor of phytoplankton growth.

Barlow, John P. et al. 1973. Continuous-Flow Studies of Phosphorus as a Limiting Nutrient for Cayuga Lake Phytoplankton. ***Proc. 16th Conf. Great Lakes Res.*****: 7-14.**

Phosphorus affects phytoplankton abundance by stimulating (or, in under abundance, limiting) photosynthesis. P can also affect phytoplankton species composition. There is approximately a one-day lag time between phosphorus enrichment of a sample and increases in rates of photosynthesis.

Baystate Environmental Consultants, Inc. 1990. Biological Survey of Southern Owasco Lake: Cayuga County, New York. ***Baystate Environmental Consultants, Inc.*** **Final Report.**

This study surveyed the various biological communities in the Southern end of Owasco Lake and concluded that the area was subject to considerable ecosystem stress or disturbance. They found that the "existing littoral habitats at depths of 3 to 10 ft in the surveyed area appears to be of poor to moderate quality," because of introduction of nutrients and sediment from upstream human activities (pg. 17). The silts and clays that were deposited on the bottom were dense and depauperated bottom fauna. They concluded that proposed dredging in the area would create a vertically more complex environment.

Birge, Edward A., and Chancey Juday. 1914. A Limnological Study of the Finger Lakes of New York. ***Bull. U.S. Bur. Fisheries*****, 32: 525-609.**

Phosphorus was not tested in this study. In Cayuga Lake on August 20, 1910, DO was tested at 13 depths, from 0 meters to 122 meters. The % saturation ranged from 100.4 at 0 meters to 83.2 at 122 meters. The highest % concentration was 116.7 at 18 meters depth. On August 13, 1910, DO was tested in Owasco Lake at 10 depths ranging from 0 meters to 50 meters. At 0 meters, the % saturation was 106.4, and at 50 meters was 79.5. The highest concentration was 15 meters, with a concentration of 110.6.

Bouldin, D.R. et al. 1974. Lakes and Phosphorus Inputs: A Focus on Management. *New York State College of Agriculture and Life Sciences at Cornell University*, Information Bulletin 127.

This report studied 13 watersheds in New York and found that of the dissolved phosphorus in these watersheds, 55% came from sewage, 18% from agricultural runoff, 15% from forest runoff, 6% from residential runoff, and 6% from atmospheric fallout. This contrasted strongly with the land uses, where 50% was forested, 48% agricultural uses, and only 2% residential. Secondary treatment of sewage removes about 20% of the phosphorus content and tertiary treatment removes 75-90%. Septic systems appear to leak less phosphorus to the watersheds than sewage treatment plant effluent, because the soil in leach fields, even in defective systems, removes much of the phosphorus. A study of three sewage treatment plants near Buffalo found that the 1973 ban on phosphates in detergents reduced effluent phosphorus by 50-60%. A study on reducing phosphorus loading to the Fall Creek watershed found that the least expensive means of control is tertiary sewage treatment, followed by control of barnyard runoff. Avoidance of winter spreading of manure and reduction in corn acreage were much more expensive. For Cayuga Lake, the cost per year for tertiary treatment of sewage would be $280,000.

Burkholder, Paul R. 1929. Studies in the Phytoplankton of the Cayuga Lake Basin. *Cornell University Graduate School*, Thesis.

This report mentions “tremendous quantities of silt-laden water” entering Cayuga Lake at the southern end after heavy rains. It also mentions that Como Lake (sic) is picturesque and that “due to its remote location, the natural conditions have not yet been marred by man’s activity, but a new highway has been constructed there recently.” Phosphorus loading is not specifically discussed in this paper.

Cayuga County Planning Board. 1971. Cayuga County Lakeshores. *Cayuga County Planning Board.*

The report cites the Cayuga Lake shoreline south of Long Point and a bluff south of Levanna on Cayuga Lake as areas that need particular attention for erosion control measures. It says that sedimentation is an increasing problem at the north ends of both Owasco and Cayuga Lakes. It notes the shoreline of Cayuga Lake from Cayuga Village northward, Cayuga Lake south of Long Point to the Tompkins County Line, and the whole northern half of Owasco Lake as the most serious potential sources of pollution from housing development. Most of their recommendations relate to regulating land use around the lakes: zoning changes, purchasing abandoned railroad rights and wetlands, subdivision regulations, a renewable land acquisition fund, and special districts to control waters and lakeshores.

Derrick, David G. 1971. A Study of Water Quality and Factors Affecting Water Quality in the Fall Creek Watershed. ***Cornell University College of Engineering:*** **A Design Project.**

Potential point sources of pollution to the watershed include the septic system and waste stabilization pond at the George Jr. Republic boarding school, which was not achieving the desired degree of treatment at the time this was written. Other potential point sources, including the NYSEG route 13 building sewage system, a trailer park, and the Cornell Water Treatment Plant, appeared to be operating correctly. Some potential non-point sources of pollution included dairy farms and un-sewered households with septic systems that may be inappropriate for the soil type. While phosphorus levels were not tested in this study, two parameters of interest are the DO content of fall creek tributaries, which averaged 8.1 mg/l over the 5 sampling sites, and suspended solids, which averaged 3.6 mg/l over the 5 sampling sites. While most of the samples showed a high DO content, the content at the Lake Como outlet was very low, probably because Lake Como is eutrophic. Also, there was a slightly higher than normal oxygen demand at the effluent discharge of the Dryden wastewater treatment plant.

Dikshit, A.K. and Daniel P. Loucks. 1996-7. Estimating Non-Point Pollutant Loadings—II. A Case Study in the Fall Creek Watershed, New York. ***Journal of Environmental Systems,*** **25(1) 81-95.**

In the Fall Creek watershed, about 50% of the land is forest and wooded, with cropland as the next largest land use. This model takes elevation, land-use, meteorological data, and soil types into account and estimates that when all agricultural land-uses are shifted to corn production, potential run-off increases by 15%, soil erosion by 2%, and phosphorus by 2%. If all agricultural land went idle, the TP load would decrease by 90%, and if it went entirely to urban residential, the phosphorus load would decrease by almost 100%. This last number seems very suspect to me.

Eastern Oswego Basin Regional Water Resources Planning Board. 1973. Interboard Plan for the Greater Finger Lakes—Oswego River Basin: Summary Report.

Some of the short-term recommendations of this plan relevant to our interests include: multi-purpose reservoir planning for Dutch Hollow Brook for water quality improvement and storage; lake outlet improvements for Owasco Lake; public acquisition of water rights in the Owasco Outlet for flow regulation, land treatment to reduce sediment inflows to Owasco Lake and plans to improve the water quality of the lake; regionalization of wastewater system management including improved treatment efficiency; acquisition and protection of 24,615 acres of wetlands; and erosion control and drainage improvements for 95,400 acres of agricultural lands.

Fox, Jean Nichols and Lyle S. Raymond, Jr. 1972. A Primer on Lake Pollution with a Supplement on the Quality of Cayuga Lake. ***Cornell Water Resources and Marine Science Center:*** **Educational Leaflet No. 2 in a Series on Cayuga Lake.**

Cayuga Lake has 331 billion cubic feet of water, with 36.8 billion cubic feet of water added each year. Besides the Great Lakes, it is the second deepest lake east of the Rockies. Pollution in the lake tends to be localized. Concentrations of phytoplankton occur on open, deeper parts of Cayuga Lake. DO levels haven't changed in the deeper portions of the lake since they were first taken in 1910. Complete phosphorus measurements weren't taken until 1967.

Genesee/ Finger Lakes Regional Planning Council and EcoLogic LLC. 2000. Cayuga Lake Watershed Preliminary Watershed Characterization. ***Genesee/ Finger Lakes Regional Planning Council and EcoLogic LLC***

This report cites areas of particular concern for erosion and rates individual sites. This includes drainage ditches, stream banks, etc. Fall Creek is the largest tributary of Cayuga Lake. Other large tributaries include (in order of drainage area) Salmon Creek, the Cayuga Inlet, Taughannock Creek, Sixmile Creek, Yawger Creek, Paines Creek, and Great Gully Creek. The water residence time (hydraulic retention time) of Cayuga Lake is 5-12 years. The stratified time of the year for Cayuga Lake is June through November. The water mixes through the winter. TP concentration in the winter in Cayuga Lake is correlated to algal abundance the following summer.

Genesee/ Finger Lakes Regional Planning Council and EcoLogic LLC. 2001. Cayuga Lake Watershed Restoration and Protection Plan. ***Genesee/ Finger Lakes Regional Planning Council and EcoLogic LLC***

This plan says that the main source of phosphorus in Cayuga Lake comes from sediment loading. Other sources include two wastewater treatment plants, septic systems, residential and agricultural runoff, and the Cornell LSC project. The LSC takes cool water from a deep part of the lake, uses it to air condition buildings at Cornell, and transports it to a shallower part of the Southern end of the lake along with phosphorus-containing sediments. The report recommends testing for phosphorus in various places and remediation to prevent nutrient loading from various sources.

Godfrey, Paul Joseph. 1982. The eutrophication of Cayuga Lake: a historical analysis of the phytoplankton's response to phosphate detergents. ***Freshwater Biology,*** **12: 149-166.**

The report says that phytoplankton summer crops have doubled in the past 60 years at the point at which this was written, and that spring algal crops increased 20-fold. The researcher believes that phosphate fertilizers are the cause of this.

Hamilton, D.H. Jr. 1969. Nutrient Limitation of Summer Phytoplankton Growth in Cayuga Lake. *Limnology and Oceanography*, 14(4): 579-590.

This study used phytoplankton collected from Cayuga Lake and tested them with different combinations of nutrients. The phytoplankton population is partially limited by nutrients after the spring bloom. The phosphate levels that were tested were 10 to 30 times higher than natural levels, but did not stimulate photosynthesis, and may even be inhibited by phosphorus. The study findings seem to indicate that silicate is instead the limiting factor of phytoplankton growth.

Hamilton, Lawrence S., director. 1971. An Ecosystem Approach to Planning for the Owasco Lake Basin. *Department of Natural Resources, Cornell University.* Results of a Seminar.

This report exhaustively examines all the potential land and water uses in the Owasco watershed. At the time this was written, several major sources of suspended sediments in Owasco Lake were: sewer projects in Fleming and Moravia, a development at the north end of the Inlet, the Emerson Park project, construction on route 38 on the west side of the lake, and high school construction near the Outlet. It says there is actually a surprisingly low level of erosion given the steep slopes of many glens and gullies that empty into the lake but that most are heavily forested and more intensive agriculture takes place on fairly level ground. Human sewage is the main waste item deposed via water in the Owasco watershed, but the effects of this on fish populations in the Inlet has been minimal. The southeastern shore of Owasco Lake has a high potential for nutrient runoff into the lake, as well as on the west side in Scipio and Venice. Owasco and Fleming, because they are situated on impervious glacial till, are ineffective sites for ground disposal of wastes and have a high rate of septic system and leach field failure.

Heidtke, Thomas M. 1992. Development of a Land Runoff Total Phosphorus Loading Model for Owasco Lake. *Upstate Freshwater Institute.*

This report gives an explanation for a computer model designed to estimate the impact of development and land management on phosphorus loading of Owasco Lake. It also shows how these loads are expected to change in response to long-term development and management and how water quality in Owasco Lake will change in response to loading trends. To calculate these loads, the model uses GIS delineation of the watershed sub-basins, land-use distributions, soil texture distribution in the sub-basins, topography, slope, and unit area loadings (TP mass load per unit area for the year).

Heidtke, T.M. and M.T. Auer. 1993. Application of a GID-Based Nonpoint Source Nutrient Loading Model for Assessment of Land Development Scenarios and Water Quality in Owasco Lake, New York. *Wat. Sci. Tech.*, 28(3-5): 595-604.

This paper is a more technical explanation of the model described in the previous citation. It estimates that 42% of the TP loading of Owasco Lake originates from the Owasco Inlet and Deckerville-Dresserville sub basins. The potential uncertainty of the model arises from portions of the watershed that are outside Cayuga County. The maximum error from this is 5-15%.

Hennigan, Robert G. 1986. Owasco Lake Management Study. ***Robert G. Hennigan Associates.***

This report cites many of the findings in Effler et al., including that phosphorus loading to Owasco Lake decreased by 50% over the last decade; phytoplankton growth was reduced by 45% over the last decade; and eutrophication was not presently a problem and wasn't expected to be in the foreseeable future. Like almost every other management plan, this recommends instituting a comprehensive lake and major tributary monitoring program and public education.

Hennigan, Robert G. 1991. Management Action Plans Cayuga County Lakes. ***Robert G. Hennigan Associate,*** **Draft Report.**

The only lake in this report of interest for our purposes is Lake Como. The report says there is one major tributary to the lake flowing in from the North and the outlet flows southeast to Fall Creek. The watershed of Lake Como is 37% agricultural, 57% forest and wetlands and the rest is residential and open space. The major problem with the lake is weed infestation and the report recommends an investigation about establishing a lake protection district by the Town of Summerhill, continuous harvesting and dredging for weed control, and regular monitoring for weed control. The issue of septic leachate is not discussed.

James, William F. et al. 2001. Enhanced Phosphorus Recycling by Zebra Mussels at High Density in Relation to Food Supply. ***U.S. Army Corps of Engineers Waterways Experiment Station,*** **ERDC WQTN-PD-09.**

At densities of over 1,300 mussels per square meter, TP concentrations in the outflow from the experiment exceeded the outflow from the control. The zebra mussels were most likely losing this P from their body tissues. At density levels of less than 600 per square meter, most of the P exported was in the form of SRP. Rates of net TP increased with increasing density over 600 per square meter, and rates of net SRP were elevated at rates under 600 per square meter. This indicates that zebra mussels recycle greater amounts of P per unit tissue at higher densities.

Klitgaard, K.A., C.T. Bailey, A.T. Vawter. 1994. Environmental Problem Solving in the Cayuga Basin: Towards an Interdisciplinary Understanding of a Regional Watershed. ***Wells College.*** **Preliminary Edition.**

This is a workbook to accompany a course at Wells College. It guides the reader through the history, geology, and limnology of the Cayuga Lake watershed, as well as explaining how to measure stream output and phosphorus loading.

Likens, Gene E. 1974. The Runoff of Water and Nutrients from Watersheds Tributary to Cayuga Lake, New York. *Cornell University Water Resource and Marine Science Center,* Technical Report 81.

The total watershed area for Cayuga Lake, including the surface area of lakes in the drainage basin, is 4051 square kilometers, including 1860 square kilometers draining directly into the lake, 2018 square kilometers from the Seneca River, and 173 square kilometers of lake surface. This study tested various nutrients in tributaries of Cayuga Lake. They tested total phosphorus and molybdate reactive phosphorus. Some of the highest molybdate reactive phosphorus concentrations occurred during February and March, and also in October and November. Salmon and Fall Creeks had high concentrations in July 1971, and the Cayuga Inlet had low concentrations in the winter and peaked in September and October.

Likens, Gene E. 1974. Water and Nutrient Budgets for Cayuga Lake, New York. *Cornell University Water Resource and Marine Science Center,* Technical Report 82.

The largest amount of water enters Cayuga Lake in March and April and the smallest amount in August. The largest source of water entering Cayuga Lake comes from the Seneca River (34.8%), followed by Fall Creek (11.6%), the Combined Inlet Creek (10.9%), Salmon Creek (10.4%) and Taughannock Creek (4.4%). Cayuga Lake annual discharges 17.96% of its total volume. 91% of the total yearly input of water to the lake comes as runoff, with 9% directly entering the lake through precipitation. 69% of molybdate reactive phosphorus (MRP) and 66% of TP enter the lake between November and April, the non-growing season. 2-3% of phosphorus enters the lake from precipitation. Annually, 73.9% of MRP and 64.1% of TP are retained in the lake, primarily in lake sediments, which act as a nutrient sink. The annual net gain of TP is about 1.4 times that of MRP, and the annual output of TP is 2.3 times that of MRP. 33.9% of MRP in Cayuga came from the Combined Inlet watershed, which receives effluent from the Ithaca sewage treatment plant. Phosphorus loading seems to be more closely correlated with urban activities than agricultural activities, whereas the opposite is true for nitrates. This seems to be because agricultural lands retain phosphorus more easily, whereas sewage and industrial wastes contribute much more phosphorus than nitrogen. This is accentuated by the use of phosphate detergents. However, non-urban disturbance of ecosystems also accelerates phosphorus output. Phosphorus export from watersheds on sedimentary rock, like most of the Cayuga Lake watershed, is approximately double that of watersheds on igneous rock. A lake with an undisturbed, forested watershed may receive 40-60% of TP from precipitation as opposed to only 2-4% when the watershed is inhabited and under human land management.

Ludyanskiy, Michael L., et al. 1993. Impact of the Zebra Mussel, a Bivalve Invader. *BioScience,* 43(8): 533-544.

This report does not look at Cayuga or Owasco Lakes, but since both have zebra mussel infestations, the information is relevant. Zebra mussels, as filter feeders, remove algae and suspended sediment from the water column. There is also evidence that they reduce phosphorus from water. This report cites a previous report, saying, "He predicts biodeposition of most nutrients on the lake floor, a decline in primary production, increased development of the benthic community, and reduction in biomass and production of zooplankton and other components including fish."

Matthews, David A. et al. 2002. Limnological and Statistical Issues for Monitoring the Impact of a Lake Source Cooling Facility: Cayuga Lake, NY. *Lake and Reservoir Management,* 18(3): 239-256.

Cornell University built a cooling system for the campus that takes cold water from deep in the lake, transfers it by pipe up to the campus and transfers the heated water back to a shallow shelf in the southern end of the lake. This system has no external input of chemicals or nutrients because the water never leaves the pipes. However, it has the potential of transferring phosphorus from lake sediments in the hypolimnion to the warmer epilimnion. The initial impact statement for the project estimated a 3-7% increase in total phosphorus on the shelf from the LSC project. It is difficult to assign loading responsibility to the LSC because two wastewater treatment plants and several tributaries have their outlets on the shelf as well. The report states that the TP loads from the LSC will always be modest compared to those of the wastewater treatment plants.

McDonald, AJ and SJ Riha. 2003. Event-driven Phosphorus Loading in the Owasco Lake Watershed. *Unpublished.* Interim Report.

Storm-event phosphorus and sediment testing in Dutch Hollow Brook and the Owasco Lake Inlet found that P loading was highest in both water bodies in the winter, and that rates were three times higher in the Inlet. The rate of sediment loading was strongly correlated with P loading in Dutch Hollow Brook, less so in the Inlet. The report speculates that the looser correlation for the Inlet might be related to P loading from the Moravia and Groton wastewater treatment facilities. Sediment and P loading have declined in both streams since the late 1990's, with the Inlet appearing to show a real reduction and Dutch Hollow's possibly being an artifact of flow rate reductions.

Miller, Gary L. 1984. The status of aquatic vegetation in the three Finger Lakes of Cayuga County New York. *Environmental Studies Program, University of North Carolina—Asheville.*

This study looked at the species composition and abundance of aquatic vegetation in Cayuga, Owasco, and Skaneateles Lakes in 1984 as compared to a study on the same topic done in 1978. Cayuga Lake had the most extensive populations of aquatic plants, primarily in shallow areas with a silt bottom. Some of the report's recommendations include appointing one or more full-time watershed inspectors to enforce water quality regulations, creating a "Lake District Zoning Board," designating critical watershed areas, banning septic systems a certain distance from the lake shore, extending municipal sewer systems where possible along the Owasco shoreline, adding tertiary treatments to sewage treatment plants to reduce nitrates and phosphates, erosion control measures along the tributaries of Owasco Lake, and continued education efforts at all levels.

Miller, Gary L. 1988. An Update and Inventory of Aquatic Vegetation in Six Lakes of Cayuga County, New York (Como, Cross, Duck, Otter, Parker & Little Sodus Bay). ***Environmental Studies Program, University of North Carolina – Asheville.***

Lake Como is the only lake in this study in either the Cayuga or Owasco Lake watersheds. Data taken in the summer of 1987 about the species distribution of aquatic plants in Lake Como was compared to data taken in 1977. The study found that the species composition had changed and the density increased since 1977, with vegetation coverage often 100%. Like other studies, this cites septic system malfunctions and septic leachate as a major problem for Lake Como.

Mills, Edward L. 1975. Phytoplankton Composition and Comparative Limnology of Four Finger Lakes, With Emphasis on Lake Typology. ***Cornell University Graduate School:*** **Thesis.**

The lowest concentrations of SRP in Owasco and the other Finger Lakes studied occurred in the late summer. In the fall, after the thermal stratification ended, SRP levels increased. The annual range of SRP in Owasco Lake was 17.8 mg/m3 in 1972, the year of Hurricane Agnes, and 13.4 in 1973. The seasonal integrated averages (integrated for the upper 10 meters of water by day for each season) of SRP were 3.7 mg/m3 during the 1972 summer stratification, 4.4 during the 1972 autumnal overturn, 7.6 in winter 1973, 4.1 in the 1973 vernal mix, and 1.2 in the 1973 summer stratification. SRP was highest in the fall and winter for all the lakes studied. The annual range of TP in 1973 in Owasco Lake was 7.1-17.5 mg/m3. The winter and vernal mix average TP in Owasco was 13.9 mg/m3 and 9.7 in the 1973 summer stratification. Owasco only has a slight reduction in dissolved oxygen in the hypolimnion during the summer stratification. Owasco is mesotrophic.

Moran, Elizabeth et al. 2000. The State of the New York Lake Ontario Basin: A Report on Water Resources and Local Watershed Management Programs. ***Mercury Print Productions.***

This summarizes the DEC priority water bodies list and analyzes the percentages of regional resources allocated to local priorities that relate to water body impairments. It lists the agencies involved in watershed management, monitoring, and remediation.

Naseman, Alan R. et al. 1992. Phosphorus and Suspended Solids Loading from Owasco Lake's Largest Tributaries. ***Cayuga County WQMA.*** **Interim Report.**

This study examined phosphorus loading in the Owasco Inlet and Dutch Hollow Brook, which together carry 70-80% of the surface water entering Owasco Lake. The Inlet had a higher baseline (non-storm event) phosphorus content than Dutch Hollow Brook. Most of the phosphorus from the Owasco Inlet entering Owasco Lake was from sewage effluent, most of which probably comes from the Moravia wastewater treatment plant. Dutch Hollow Brook's phosphorus load came almost entirely from storm events.

New York State Conservation Department. 1963. Cayuga Lake Basin: Preliminary Investigation of its Problems. ***New York State Conservation Department Division of Water Resources.***

This report mentions sedimentation and "direct discharge of septic tank effluents from cottages along the lake shore" as major sources of pollution in Cayuga Lake and says that sedimentation at the southern end of the lake near Ithaca has been a problem since at least 1835. Sedimentation has also occurred for many years at the northern end and the western shore. It notes inadequately treated sewage from Seneca Falls and Waterloo, as well as cannery wastes from Waterloo as pollutants and that the Health Department has noted localized areas of moderate to serious pollution in the lake. The report recommends comprehensive sewerage planning and land treatment to prevent erosion.

New York State Department of Environmental Conservation. 1975. A Macroinvertebrate Study of Owasco Inlet and Owasco Outlet. ***New York State Department Conservation Division of Pure Waters.***

Siltation was a major problem in the Owasco Inlet and also a problem in the Outlet. There were pollution problems in the Inlet from Groton storm sewers, a chicken farm, and the Groton sewage treatment plant. The water quality downstream from the Moravia sewage treatment plant was good. Water quality in the Owasco Outlet at the mouth of the Outlet and in the City of Auburn was good to moderately degraded. Downstream from the Auburn sewage treatment plant, water quality was severely degraded, with black sludge deposits visible and a strong sewage odor to the water. The degradation was evident at multiple sampling sites downstream. Water quality downstream from the Port Byron sewage treatment plant was satisfactory.

New York State Department of Environmental Conservation. 1975. Macroinvertebrate Survey of Fall Creek. ***New York State Department Conservation Division of Pure Waters.***

The water quality of Virgil Creek (a tributary of Fall Creek) downstream from the Dryden sewage treatment plant was slightly impacted. Six Mile Creek had poor water quality, probably because of chlorine used at the Ithaca Water Filtration Plant, and the Lower Cayuga Lake Inlet had poor to grossly polluted water near the discharge of the Ithaca sewage treatment plant. The water quality in the Upper Cayuga Lake Inlet and Fall Creek was good.

New York State Department of Environmental Conservation. 1987. Biological Stream Assessment: Fall Creek and Virgil Creek Tompkins County, New York. ***New York State Department Conservation Division of Water.***

In 1986, the Dryden sewage treatment plant was upgraded and its effluent was diverted from Virgil Creek to join the Freeville discharge in Fall Creek in Freeville. The water quality in Fall Creek was found not to be significantly altered downstream of the sewage discharge, and had actually improved since a survey in 1975. Water quality in Virgil Creek, like Fall Creek, was non- to slightly impacted and had improved since the sewage effluent was diverted.

New York State Department of Environmental Conservation. 1990. Biological Stream Assessment: Owasco Outlet Cayuga County, New York. ***New York State Department Conservation Division of Water.***

This study used traveling kick samples to collect macroinvertebrates in the Owasco Outlet in order to assess stream health. They found that macroinvertebrate populations were slightly to moderately impacted upstream of the Auburn sewage treatment plant discharge, and significantly impaired downstream of it. This impairment was thought to be due to high oxygen demand and toxic constituents of the discharge. Possible impairment was reported downstream of the Port Byron sewage treatment plant discharge.

New York State Department of Environmental Conservation. 1992. 20 Year Trends in Water Quality of Rivers and Streams in New York State: Based on Macroinvertebrate Data 1972-1993. ***New York State Department of Environmental Conservation Division of Water.*** **Executive Summary.**

The only water body on this list that declined in water quality was the Owasco Outlet below the Port Byron wastewater treatment plant. Above the plant, the Outlet showed no change from the 1972 data. Fall Creek, a tributary of Cayuga Lake, showed improvement below Freeville and Etna and no change above Freeville and from Varna to Ithaca.

New York State Department of Environmental Conservation. 1993. 1993 Report: Priority Water Problem List Summary. ***New York State Department of Environmental Conservation Division of Water.***

In the Cayuga Lake watershed, from Cayuga County the priority water bodies are Cayuga Lake, Lake Como, and Yawger Creek and from Tompkins County Cascadilla Creek, the Cayuga Inlet, Cayuga Lake, Dryden Lake, Fall Creek, and Six Mile Creek. Of these, the primary pollutant in Cayuga Lake (Cayuga County) and Lake Como is nutrients, both from on-site systems (septic systems), and the primary pollutant in Yawger Creek is silt from agriculture. In Tompkins County, all but Dryden Lake have silt as their primary pollutant. Dryden Lake's is nutrients. The primary source for these is stream bank erosion and agriculture. In the Owasco Lake watershed in Cayuga

County, the priority water bodies are Dutch Hollow Brook, The Owasco Inlet, Owasco Lake, Sucker Brook, and Veness Brook. For our purposes the Owasco Outlet, which is also on this list, will be considered in this group.

New York State Department of Environmental Conservation. 1996. The 1996 Priority Waterbodies List for the Oswego-Seneca-Oneida River Basin. ***New York State Department of Environmental Conservation Division of Water.***

In the Cayuga Lake watershed, the following water bodies are on the list: Big Salmon Creek, Cayuga Lake, Lake Como and Little Salmon Creek in Cayuga County and Cascadilla Creek, the Cayuga Inlet, Cayuga Lake, Dryden Lake, Fall Creek, and Six Mile Creek in Tompkins County. Of these, "nutrients" is listed as the primary pollutant for all of the water bodies in Cayuga County and Dryden Lake in Tompkins County. The primary pollutant in the other water bodies in Tompkins County is listed as silt. For those with nutrients as the primary pollutant, several have agriculture listed as the primary source and the others have on-site systems (septic systems). For those silt as the primary pollutant, agriculture and stream bank erosion are listed as the primary sources. In the Owasco Lake Watershed, Dutch Hollow Brook, Owasco Inlet Tributaries, Owasco Lake, Sucker Brook, and Veness Brook in Cayuga County are on the list. For our purposes, we will include the Owasco Lake Outlet, which is on the list, in this group. Silt is listed as the primary pollutant for all in this group except for Owasco Lake, which has pathogens as its primary pollutant and the Owasco Outlet with nutrients. Dutch Hollow's primary pollution source is hydromodification, Owasco Inlet tributaries' is "natural occurrence" (natural turbidity of the water), Owasco Lake's is on-site systems, Owasco Outlet's is CSO's, Sucker Brook and Veness Brook's primary source of pollution is stream bank erosion.

New York State Department of Environmental Conservation. 1996. New York State Water Quality 1996: Submitted Pursuant to Section 305(b) of the Federal Clean Water Act. ***New York State Department of Environmental Conservation Division of Water.***

In the section on the Seneca-Oneida-Oswego River Drainage Basin, this report notes that all of the significant lakes in the basin were on the 1993 Priority Water Problem List. It says that Cayuga Lake is showing severe signs of eutrophication, and that Owasco is showing evidence of eutrophication from nutrients and sediments from shoreline erosion, tributaries, and agriculture. Eutrophication in the Oswego River is due to sewage discharges, CSO's, and agricultural runoff in its basin.

New York State Department of Environmental Conservation. 1999. The Oswego-Seneca-Oneida Rivers Basin Report 1995-1996: Rotating Intensive Basin Studies Water Quality Assessment Program. ***New York State Department of Environmental Conservation Department of Water.***

This report finds that the Owasco Lake watershed is impacted by high sediment loading in some streams, especially the Owasco Inlet from stream bank erosion. Raw sewage discharges and sewage overflows also impair water quality. The Owasco Outlet is

moderately impacted by sewage and municipal/industrial sources. In order of severity: "Owasco Inlet tributaries" is listed as precluded; Owasco Lake, Owasco Outlet tributaries, the Owasco Outlet, Sucker Brook and Veness Brook are impaired; Dutch Hollow Brook is stressed; and none in this area are listed as threatened. The sources of contamination are on-site systems, CSO's, stream bank erosion, and hydromodification. In the Cayuga Lake Watershed in order of severity, Cayuga Lake, Lake Como, and Yawger Creek are impaired; the Cayuga Inlet, Cascadilla Creek, Dryden Lake, Fall Creek, and Six Mile Creek are stressed; and Cayuga Lake and Big and Little Salmon Creeks are threatened. The sources of contamination are on-site systems, agriculture and stream bank erosion.

New York State Department of Environmental Conservation. 2001. Water Quality Study of the Finger Lakes. *New York State Department of Environmental Conservation Department of Water.*

This study included a Synoptic Water Quality Study and Sediment Core Analysis of all 11 Finger Lakes. Exploring historical phosphorus data, the report found that the mean epilimnetic TP levels in Owasco Lake have remained essentially constant since the mid-1970's, whereas levels have fallen in the other large Finger Lakes, suggesting that external phosphorus loading of the lake has not been significantly reduced. The study recommends continued efforts to reduce external P-loading. Cayuga Lake was studies in three parts, the northern end, southern end, and deep middle region. The primary pollutant in the northern end is nutrients, and in the northern end it is both nutrients and sediment. TP levels in the lake have declined since the mid-1970's, possibly with the help of zebra mussels. However, total phosphorus levels in the south end routinely exceed NYS guidelines.

New York State Department of Environmental Conservation. 2002. Owasco Outlet Biological Assessment. *New York State Department of Environmental Conservation Department of Water.*

This study monitored the Owasco Outlet from Auburn to below Port Byron. The Outlet water quality was determined to be slightly impacted, based on kick samples of stream macroinvertebrates both above and below the Auburn sewage treatment discharge area. At four of the five sites below the treatment plant, invertebrate fauna had improved since a 1990 survey, and the community upstream of the treatment plant was very similar to that at the first collection site below it. Also, the decline in the fauna below the Port Byron sewage treatment plant that was recorded in 1990 was not seen in 2002. Along the length of the outlet, the primary stressors were most likely nutrients and urban and industrial runoff.

Newbold, J. Dennis. 1972. Oxygen Depletion in a Thermally Stratified Lake. *Cornell University Graduate School:* Thesis.

This thesis applies a model determining oxygen depletion of a thermally stratified lake to Cayuga Lake. Cayuga is a warm monomictic lake, meaning that it mixes once and

stratifies once each year. The stratification period usually extends from May until November. The thermocline, the boundary between different temperature layers, in Cayuga Lake is not stationary but continuously distorted. According to the model, oxygen depletion in the middle and lower layers of the lake depend on the interplay of diffusion of DO between layers and benthic demand for oxygen.

Oglesby, Ray T. et al. 1973. Owasco Lake and Its Watershed. *Cornell University Water Resources and Marine Sciences Center.* Technical Report 70.

The water samples for this study were taken in Owasco Lake, as well as the Owasco Inlet, Sucker Brook, Dutch Hollow Brook, and the Owasco Lake Outlet. The report notes high turbidity after heavy rains and during the spring snow melt. It also notes a greening and turbidity of the lake from phytoplankton during the summer, though not to the levels apparent in eutrophic lakes. Of the plant nutrients studied, they "determined that phosphorus was the critical factor controlling the production of phytoplankton in Owasco Lake." They estimated that the Owasco Lake Inlet contributed 87% of the biologically available phosphorus to the lake, while Dutch Hollow Brook had "very low concentrations of soluble phosphorus." About half of the phosphorus load in the Inlet was estimated to come from sewage treatment plants (the Groton and Moravia sewage treatment plants were not designed to remove phosphorus) and septic systems. The report says, "agriculture does not appear to be a major contributor of phosphorus to Owasco Lake." Also, they estimate that about 88% of SRP entering the lake through tributaries remains in the lake each year. An appendix to the report recommends giving the Owasco Inlet a "scenic river" designation under the Wild River Law, which would somewhat restrict development around the designated area.

Oglesby, Ray T. 1974. Limnological Guidance for Finger Lakes Management. *Cornell University Water Resources and Marine Sciences Center.* Technical Report 89.

This report finds that Cayuga and Owasco lakes have the highest "calculated specific loadings" of phosphorus of all the Finger Lakes. Specific loading is defined as grams of phosphorus per square meter per year. It finds that 59% of phosphorus inputs in Cayuga Lake come from "domestic wastes" (sewage?), 39% from land runoff, and 2% from "atmospheric fallout," described as rain and dust. Conversely, most of Owasco Lake's phosphorus, 62% comes from land runoff, 36% from domestic wastes, and 2% from atmospheric fallout. It also estimated the change in specific loading in the Finger Lakes from 1970, before the law prohibiting phosphates in household cleaners, to 1974 after the law went into effect. No explanation is given as to how this estimation was made. However, the report estimates a 30% decrease in phosphorus loading of Cayuga Lake, compared to only an 18% decrease in Owasco Lake. The report also makes some claims that have been contradicted by later reports, including, "Runoff from agricultural lands does not seem to be a major source of phosphorus to the Finger Lakes…" and "A lessening of phosphorus input, with subsequent decrease in the production of algae and possibly rooted plants, will reduce the production of fish in the Finger Lakes."

Oglesby, Ray T. 1978. The Limnology of Cayuga Lake. In: Bloomfield, Jay A., ed. Lakes of New York State Volume 1: Ecology of the Finger Lakes. *Academic Press,* 1-120.

Cayuga lake is mesotrophic based on biological and chemical characteristics and the low rate of phosphorous exchange between the hypolimnion and the epilimnion. When using another model, total loading vs. mean depth, vs. ratio of mean depth to water residence time, the lake appears eutrophic. One interesting statistic in this chapter is that the annual per capital discharge of phosphorus in household wastes was assumed to be 1.5 kg, with 20% removed by primary and secondary treatment prior t0 June 1973. After the June 1973 banning of phosphorus in household laundry detergents, this chapter says that the discharge of phosphorus was reduced by 50%. At the time this was written, sewage treatment plants served approximately 52% of the watershed's population.

Peterson, Bruce J., et al. 1974. The Physiological State With Respect to Phosphorus of Cayuga Lake Phytoplankton. *Limnology and Oceanography,* 19(3): 396-408

The experiments in this study used natural assemblages of phytoplankton collected from Cayuga Lake and tested in lab experiments. The study found that Cayuga Lake phytoplankton species are limited by phosphorus. The rate of photosynthesis increase with phosphorus enrichment, but phytoplankton are seldom phosphorus deficient in their natural setting. They found no evidence that any of the phytoplankton species tested grew more poorly under phosphorus-enriched conditions, however some of their results "supported the observation that added phosphorus had no significant effect." Also, some summer species of phytoplankton (different species are in greater abundance at different times during the year) may be at their maximum rates of photosynthesis and added phosphorus could not increase this.

Pezzolesi, Tim et al. 2000. State of the Owasco Lake Watershed. *Owasco Lake Management Plan Steering Committee and Cayuga County Water Quality Management Agency.*

Surveys conducted by the researchers found that more than half of the septic systems in the watershed do not have accurate installation records, and most of the systems in the watershed are outdated and do not meet current standards.

Schaffner, W.R. and R.T. Oglesby. 1978. Limnology of Eight Finger Lakes: Hemlock, Canadice, Honeoye, Keyka, Seneca, Owasco, Skaneateles, and Otisco. In: Bloomfield, Jay A., ed. Lakes of New York State Volume 1: Ecology of the Finger Lakes. *Academic Press,* 313-470.

This chapter says that the Owasco Inlet has good water quality when it reaches the lake, even though it receives primarily treated waste from Groton and secondarily treated waste from Moravia. In the 1920's it had much more point-source pollution from a cheese factory, typewriter works, sewage, and a milk shipping station in Locke. The highest concentrations of SRP in the Inlet at the time this was written was below the Groton waste water treatment plant and were two times higher below Moravia than above Groton.

Schaffner, W.R. and R.T. Oglesby. 1978. Phosphorus Loadings to Lakes and Some of Their Responses. Part 1. A New Calculation of Phosphorus Loading and its Application to 13 New York Lakes. *Limnology and Oceanography,* 23(1): 120-134.

This study developed a new model for calculating Ps loading to lakes, based on data from 13 Finger Lakes, including Owasco and Cayuga. Instead of TP, the new calculation is based on BAP (biologically available phosphorus), defined as the sum of soluble reactive, soluble unreactive, and potentially desorbable phosphorus from particulate matter. Loading is defined in this new model as the amount of BAP annually added to the volume of the epilimnion in a deep, stratified lake, or the total lake volume for shallower, unstratified lakes.

Sterns & Wheler, LLC. 1994. Environmental Investigation and Assessment Cayuga Lake Source Cooling. *Sterns & Wheler, LLC: Interim Report.*

Construction of the LSC would increase the turbidity of Cayuga Lake but the impact would be temporary. No measurable increase of SRP occurred in the lower waters (60 and 70 meter depth) in 1994 as the summer season progressed. In the estimated annual TP budget of southern Cayuga Lake, the LSC would provide 2%. The Ithaca wastewater treatment plant is 36% of the budget, the Cayuga Heights wastewater treatment plant is 11%, and tributaries and non point sources provide the other 51%.

Sterns & Wheler, LLC. 1996. Results of the 1995 Investigation Lake Source Cooling Cornell University. *Sterns & Wheler, LLC: Interim Report.*

This report finds that there would be no significant environmental impacts on the Cayuga Lake ecosystem from the LSC. The region of effluent release from the system has high turbidity and is highly productive for algae. In general, TP and SRP are higher in deeper water. This study found, though, that the mean TP was higher at the 2-meter depth site sampled than at the 70-meter depth site. The report concludes that recycling phosphorus from 60 or 70 meters depth won't adversely affect water quality at the outfall location.

United States Environmental Protection Agency. 1974. Report on Cayuga Lake: Cayuga, Seneca, and Tompkins Counties, New York. *United States Environmental Protection Agency,* National Eutrophication Survey: Working Paper No. 153.

Cayuga Lake was tested on a variety of parameters in 1972 as part of the EPA's National Eutropication Survey. Cayuga is oligo-mesotrophic, even though the phosphorus loading it received should make it eutrophic. Some of the sampling parameters indicated that the level leans more towards mesotrophic. Six municipal sewage treatment plants in the watershed contribute 45.8% of Cayuga Lake's phosphorus, 30.2% of which came from the Ithaca sewage treatment plant. . TP levels in mg/l ranged from a low of .006 to a high of .039, with a mean of .011. Dissolved P in mg/l ranged from a low of .002 to a high of .016, with a mean of .007. The other data in this report are repeated elsewhere in other previously cited references.

United States Environmental Protection Agency. 1974. Report on Owasco Lake: Cayuga County, New York. *United States Environmental Protection Agency*, National Eutrophication Survey: Working Paper No. 163.

This study tested phosphorus levels in Owasco Lake in the fall of 1972 and determined that Owasco is mesotrophic. Compared to 25 other lakes in this study, one had less mean total phosphorus and four had less mean dissolved phosphorus. Accroding to a 1971 study, Owasco Lake is undergoing rapid eutophication. Though inorganic nitrogen levels were high compared to phosphorus, phosphorus was the limiting factor to algae growth. TP levels in mg/l ranged from a low of .007 to a high of .010, with a mean of .008. Dissolved P in mg/l ranged from a low of .005 to a high of .007, with a mean of .005.

Upstate Freshwater Institute. 1988. Limnological Analysis of Owasco Lake for 1986. *Upstate Freshwater Institute*, For the Cayuga County Health Department.

Phosphorus concentrations in Owasco Lake have decreased by a factor of 2 since the early 1970's. The trophic state of the lake improved from mesotrophic in the early 1970'd to oligo-mesotrophic at the time of this study. The lake-wide average TP concentration ranged from 3.1 to 6.2 mg.m-3, and the differences in TP between the epilimnion and hypolimnion were small. Progressive decreases in TP were observed in 1986 from late May until mid-July. The Owasco Inlet is enriched in phosphorus and turbidity as compared to the lake.

Upstate Freshwater Institute. 2000.Cayuga Lake Water Quality Monitoring, Related to the LSC Facility: 1998. *Upstate Freshwater Institute*. For Cornell University.

For this report, TP, total dissolved phosphorus (TDP), and SRP were measured at 8 locations, 9 times from July to October 1998. These measurements were taken before the LSC began operations. They found that the average estimated total soluble phosphorus (in kg*d-1) loading from May-October was 17.1 for the Ithaca Waste Water Treatment Plant, 7.0 for the Cayuga Heights Waste Water Treatment Plant, and 13.3 for Tributaries. These three sources discharge to the shallow Southern shelf of Cayuga Lake, where the LSC will discharge.

Upstate Freshwater Institute. 2000.Cayuga Lake Water Quality Monitoring, Related to the LSC Facility: 1999. *Upstate Freshwater Institute*. For Cornell University.

For this report, TP, total dissolved phosphorus (TDP), and SRP were measured at 8 locations, 18 times from April to November 1999. The LSC facility had not begun operations yet. They found that the average estimated total soluble phosphorus (in kg*d-1) loading from May-October was 13.7 for the Ithaca Waste Water Treatment Plant, 2.6 for the Cayuga Heights Waste Water Treatment Plant, and 13.3 for Tributaries. These three sources discharge to the shallow Southern shelf of Cayuga Lake, where the LSC will discharge.

Upstate Freshwater Institute. 2001.Cayuga Lake Water Quality Monitoring, Related to the LSC Facility: 2000. *Upstate Freshwater Institute*. For Cornell University.

For this report, TP, total dissolved phosphorus (TDP), and SRP were measured at 8 locations, 16 times from April to November 2000. The average TP of the lake source cooling (LSC) effluent was 12.0 (ug * L-1) (n=12), as opposed to 16.4 averaged across the total "shelf" of shallow water in Cayuga Lake where it is deposited. For SRP the average of the effluent was 5.8 (ug * L-1) (n=9) as opposed to 1.0 on the shelf. Turbidity was also higher in the LSC effluent than on the shelf as a whole. No conspicuous changes were seen on the shelf since the start up of the LSC facility.

Upstate Freshwater Institute. 2002.Cayuga Lake Water Quality Monitoring, Related to the LSC Facility: 2001. *Upstate Freshwater Institute*. For Cornell University.

For this report, TP, total dissolved phosphorus (TDP), and SRP were measured at 8 locations, 16 times from April to October 2001. The average TP of the lake source cooling (LSC) effluent was 12.5 (ug * L-1), as opposed to 19.2 averaged across the total "shelf" of shallow water in Cayuga Lake where it is deposited. For SRP the average of the effluent was 5.0 (ug * L-1) as opposed to 1.9 on the shelf. For both TP and SRP n=16. No conspicuous changes were seen on the shelf since the start up of the LSC facility in July 2000.

Upstate Freshwater Institute. 2003.Cayuga Lake Water Quality Monitoring, Related to the LSC Facility: 2002. *Upstate Freshwater Institute*. For Cornell University.

For this report, TP, total dissolved phosphorus (TDP), and SRP were measured at 8 locations, 16 times from April to October 2002. The average TP of the lake source cooling (LSC) effluent was 12.6 (ug * L-1), as opposed to 20.9 averaged across the total "shelf" of shallow water in Cayuga Lake where it is deposited. For SRP the average of the effluent was 4.0 (ug * L-1) as opposed to 2.1 on the shelf. For LSC effluent, n=31. For the shelf, n=16. No conspicuous changes were seen on the shelf since the start up of the LSC facility in July 2000.

Wunderlich, Michele. 2001. Owasco Lake Watershed Management Plan. *Cayuga County Soil and Water Conservation District.*

This plan was released pursuant to the State of the Owasco Lake Watershed Report in 2000. It outlines a series of short and long-term recommendations to reduce pollution and nutrient loading from various sources in the watershed including agricultural wastes, stream and lakeside erosion, biosolids, and wastewater treatment.