Cayuga Lake Modeling Project

http://cayugalakemodelingproject.cornell.edu

Frequently Asked Questions

Updated 06/15/2017

1. Project Background

1.1 What is the Cayuga Lake Modeling Project (CLMP)?

In 2012, the New York State Department of Environmental Conservation (NYSDEC) and Cornell University agreed to conduct a detailed study of the sources and fate of phosphorus in Cayuga Lake. The primary goal of this project was to build a computational water quality model of Cayuga Lake and its watershed, providing a better understanding of where phosphorus comes from, and how it affects the lake ecosystem. Cornell funded this initiative, and consulted with NYSDEC to develop a team of scientific and engineering experts to conduct the work. The CLMP was completed in December 2016.

The partnership between Cornell and the NYSDEC represented a unique application of an emerging approach to water resources management; this approach focuses on science-based decision making and sustainable resource use. The insights from this investigation will help NYSDEC as they manage other lakes in the state.

1.2 Why did Cornell complete the CLMP?

The CLMP was included as a condition of the regulatory permit issued to Cornell in 2013 for continued operation of the Lake Source Cooling facility. Links to the State Pollution Discharge Elimination System (SPDES) permit, the associated fact sheets, and the NYSDEC responses to comments on the draft permit are on the NYSDEC web site at http://www.dec.ny.gov/lands/88250.html.

Earlier regulatory permits for operating the LSC facility required Cornell to monitor eight sites in southern Cayuga Lake for phosphorus, water clarity and chlorophyll-a. That monitoring program, in place from 1998- 2012, was designed to support a statistical evaluation of the potential impacts of the LSC return flow on lake water quality conditions. The extensive data set failed to detect any impact of the LSC facility on Cayuga Lake water quality. However, the water quality of southern Cayuga Lake changed over this period; chlorophyll-a concentrations increased slightly despite enhanced phosphorus removal at the two wastewater treatment plants discharging to the lake's southern shelf. NYSDEC and Cornell decided that a water quality model of Cayuga Lake could help elucidate phosphorus dynamics.

The CLMP was completed in December 2016. Mathematical models of the lake and watershed were will be turned over to the NYSDEC for their use. The model will allow NYSDEC to analyze the lake dynamics so that they can prepare a Total Maximum Daily Load (TMDL) allocation for phosphorus, or decide on other beneficial actions to improve water quality conditions. Since 2002, the southern basin of Cayuga Lake has been on state and federal lists of impaired waters, and a TMDL has been required. Lacking a suitable analytical tool, NYSDEC has not been able to complete the phosphorus TMDL analysis for southern Cayuga Lake. The CLMP model will have a special focus on the impaired southern shelf.

1.3 Can you describe the Project Team and how the community was involved?

The project was overseen by NYSDEC. Cornell University consulted with NYSDEC to assemble a team of scientific experts to assess water quality conditions throughout the entire lake, compile information regarding the contribution of nutrients and sediment from the watershed, and develop the mathematical models linking the watershed inputs to the quality of the lake. Upstate Freshwater Institute (UFI) http://www.upstatefreshwater.org/ a not-for-profit research corporation located in Syracuse NY was responsible for the lake water quality modeling. Cornell Professor Todd Walter http://www.hydrology.bee.cornell.edu/ led the watershed assessment and modeling. The Community Science Institute (CSI) http://www.communityscience.org/ was a resource to the watershed modeling group. The project team drew on other local experts in diverse areas, ranging from biological monitoring to detailed evaluations of water motion within the lake (hydrodynamics). EcoLogic LLC http://www.ecologicllc.com/ supported outreach efforts, and helped maintain communication among the project team and the community. The NYSDEC convened a Cayuga Lake Technical Advisory Committee comprised of local water resources experts and the US Environmental Protection Agency (USEPA) formed a Model Evaluation Group (MEG) that included national and international experts in mathematical modeling.

NYSDEC and Cornell welcomed active community participation. The Cornell project team maintained a web page, with meeting announcements, meeting summaries, findings, and other materials for community review. The NYSDEC created a list serve to notify interested parties when new information is released, and maintained a Cayuga Lake project web page on Finger Lakes information site http://www.dec.ny.gov/lands/88250.html.

In addition to the web site and list serve, NYSDEC adopted a three-tiered approach to community engagement related to the CLMP. The first tier was public meetings to keep the community informed as the project develops. These meetings, which were open to all, were held at various milestones throughout the five-year project duration. The second tier was periodic technical briefings throught the monitoring and modeling project elements. Finally, NYSDEC participated in monthly meetings of the Cayuga Lake Monitoring Partnership, a committee of the Tompkins County Water Resources Council.

EPA Region 2 has several important roles in the Cayuga Lake Modeling Project. In addition to participating in the NYSDEC TAC EPA has also convened a Model Evaluation Group (MEG) to provide technical review of the hydrodynamic model, the eutrophication/water quality lake model, and the watershed model. The EPA has final approval for any phosphorus TMDL or other water quality strategy that NYSDEC proposes as an outcome of the CLMP.

1.4 How does the CLMP relate to the RPP?

The Cayuga Lake Watershed Restoration and Protection Plan (RPP) is a collaborative management plan and planning process for the Cayuga Lake watershed that began in 2001. Led by the Intermunicipal Organization (IO), a voluntary partnership of 31 watershed municipalities, the RPP was updated in early 2017 through a collaborative effort among the IO, the Cayuga Lake Watershed Network, and the Town

of Ithaca. The effort to update the RPP was independent of the CLMP. To read the 2017 RPP, link to http://www.cayugalake.org/files/all/clwrpp_2017_final_4_30_17.pdf

1.5 How much did the CLMP cost and how long did it take to complete?

Cornell invested about $3 million on the CLMP over a five year period to monitor Cayuga Lake and its tributary streams and develop water quality models of the lake and watershed. These funds were drawn from the university's budget for facilities and energy management, and included the costs of university project managers and outreach activities. The final models and reports were submitted to NYSDEC in December 2016.

2. Major Findings

The CLMP has generated new and important information on several topics relevant to the long-term management of Cayuga Lake and other waterbodies.

- **The significance of phosphorus bioavailability**. Phosphorus fractions (dissolved, particulate, etc.) differ in their ability to support algal growth. To control phytoplankton growth, it is essential to identify and limit the supply of biologically available phosphorus. In Cayuga Lake, about 95% of bioavailable phosphorus originates from watershed nonpoint sources. The implication is that long-term management of the lake will depend on measures such as setbacks and buffers that reduce the risk of phosphorus-enriched runoff reaching streams.

- **Total phosphorus concentration is a flawed indicator of trophic state in nearshore areas affected by inflows from large tributary streams**. The CLMP investigations documented that the elevated total phosphorus concentrations in nearshore areas following storms are associated with sediment particles (mud) flowing in from erodible tributary basins. The phosphorus bound to these mud particles has a very low bioavailability and thus does not stimulate algal growth.

- **Cayuga Lake circulation is complex and dynamic.** Significant mixing occurs among the regulatory-defined segments of the lake, so isolating the southern shelf as the focus of a TMDL for phosphorus was not a viable approach to a water quality protection plan. In light of this information, NYSDEC has decided to prepare a whole lake TMDL.

- **Food web complexities.** The proliferation of invasive dreissenid species (zebra and quagga mussels) in Cayuga Lake has affected the cycling of nutrients and energy. Phosphorus concentrations in the deeper water have increased over time, with no related increase in lakewide algal abundance as measured by chlorophyll-*a*. This finding reinforces the need to take an ecosystem-based management approach.

- **The Lake Source Cooling facility has no adverse impact on Cayuga Lake water quality, lakewide or on the southern shelf.** The LSC return flow reduces water residence time of the southern

shelf which has two positive water quality impacts. First, since residence time is shorter than phytoplankton growth rate, algal blooms do not develop despite the point and nonpoint source phosphorus loads to this segment. Second, the enhanced flushing of the shelf helps replace the sediment-laden stream water entering during storm events with clear water from deep in the lake. The phosphorus-eutrophication model projects that total phosphorus, chlorophyll-*a*, and sediment in the waters of the southern shelf would be higher without the circulation of water through the LSC facility. Relocating the LSC outfall into deeper water would have a similar effect; sediment and total phosphorus levels on the shelf would not decline (and may increase slightly), with no improvement to the overall lake. Thus, imposing flow limits on the facility or extending the outfall are counter indicated as a means to water quality improvement.

3. Total Maximum Daily Load (TMDL)

3.1 What is a TMDL?

Total Maximum Daily Load (TMDL) is the amount of a particular substance, such as phosphorus, that can be added to a body of water from all sources without causing meaningful environmental harm.

3.2 Why is NYSDEC completing a phosphorus TMDL for southern Cayuga Lake?

The TMDL is a regulatory approach to setting limits on specific pollutants when water quality conditions are considered impaired. Waters are considered impaired when current conditions do not fully support the designated uses. For southern Cayuga Lake, the designated uses include recreation, drinking water supply, and protection of the aquatic biota. Southern Cayuga Lake was considered to be impaired for those designated uses based on elevated concentrations of phosphorus, silt/sediment, and pathogens. If, after the modeling and TMDL are complete, there is no feasible set of actions that would restore water quality conditions to a level that fully supports the designated use, a Use Attainability Analysis (UAA) process may be the next step. The UAA is a structured, scientific evaluation of the factors affecting a designated use. For southern Cayuga Lake, for example, a UAA might examine the extent to which natural sediment input from the tributaries affects water clarity, thus precluding swimming in this region of the lake.

3.3 Who else might be affected by a TMDL for southern Cayuga Lake?

Two wastewater treatment plants, serving the Ithaca area and Cayuga Heights, have regulated discharges to southern Cayuga Lake. In recent years, both of these facilities have focused on enhanced phosphorus removal. It is possible that NYSDEC will update the discharge permits for these facilities, to more accurately reflect their existing effluent quality. The TMDL will also consider management scenarios for other sources of phosphorus to the southern lake basin, including runoff from developed areas and agricultural lands.

3.4 What information does NYSDEC require to complete the phosphorus TMDL?

The Cayuga Lake phosphorus TMDL requires water quality models capable of quantifying the relationship between phosphorus inputs and lake water quality. Now that the models are complete, NYSDEC will use this tool to determine the total amount of phosphorus that can be added to the lake while maintaining water quality standards, and then allocate the allowable loading among all the sources. The allocation will include significant watershed sources, wastewater treatment plants, and industrial users. There is a consideration for future growth in the TMDL allocation.

3.5 How will the phosphorus TMDL be implemented?

Each TMDL has an implementation plan, which is prepared by NYSDEC and approved by the EPA. The implementation plan will include specific actions and milestones to bring the phosphorus input from all sources to the target level. The target level will be defined based on attainment of water quality conditions that support the designated uses of southern Cayuga Lake. A recent local example is the phosphorus TMDL for Onondaga Lake (Syracuse NY), finalized and accepted in June 2012. http://www.dec.ny.gov/docs/water_pdf/tmdlonfinal.pdf

4. Modeling project

4.1 Can you provide an overview of the modeling efforts?

Two models—a watershed model and a lake model— were developed. The watershed model predicts the movement of water and phosphorus from the watershed to the lake. The lake model predicts water motion in the lake and how phosphorus affects water quality conditions and aquatic life such as plankton, inclusive of point source discharges. Linkage between the two models occurs at the points where water and materials from the watershed reach the lake (i.e., the tributary mouths). The project team built upon well-established modeling approaches that have been approved by the federal Environmental Protection Agency (EPA) and NYSDEC in multiple applications.

4.2 Did the Cayuga Lake Modeling Project include monitoring of the lake and watershed?

Lake and stream monitoring (sampling, flow measurement, and sample analysis) was completed in 2013. There were several components to the monitoring effort:

(1) Monitoring selected significant tributaries between April and October 2013 to characterize external loading of nutrients and sediment under a range of hydrologic conditions.

(2) Lake-wide monitoring of water quality conditions and the lake biota.

(3) Process studies to specify key model inputs. For example, UFI associates tested the various inputs to Cayuga Lake—including selected tributary streams and treated effluent from wastewater treatment

plants—for phosphorus bioavailability. These site-specific studies supported the construction of a realistic model of the potential impact of various phosphorus sources on stimulating algal growth.

4.3 Was one year of monitoring data adequate to develop the model?

This is an important question, given the year-to-year variability in weather conditions affecting runoff and transport through the tributary streams. Fortunately, the 2013 monitoring effort successfully captured a full range of streamflow conditions, including several significant storm events.

Calibration of the watershed model also utilized historical data. Dr. Walter and his colleagues drew on the extensive data collected throughout the Cayuga Lake watershed to select appropriate flux rates of water, sediment, and nutrients from subwatershed areas. These rates varied based on site-specific conditions of soils, land use, manure management practices, road networks and surface hydrology. Excellent long-term data sets exist for Fall Creek and Sixmile Creek. In addition, other shorter term historical datasets from various tributaries exist, including recent monitoring by the Community Science Institute. Part of the watershed modeling effort was to consolidate these data, effectively expanding on the 2013 results.

In Cayuga Lake, year-to-year variability is modulated by the lake's long water residence time (between 9 and 12 years). There is an extensive 15 year database of ambient water quality conditions in the southern lake. Other data sources include monitoring programs by NYSDEC, the City of Ithaca, the Finger Lakes Institute, and the Citizens Statewide Lake Assessment Program (CSLAP), which was led by the Cayuga Lake Watershed Network. The 2013 Cayuga Lake monitoring program collected additional samples along the entire 38-mile lake, including samples at multiple depths. These data were used to construct the water-quality model for the lake.

4.4 The 2013 permit required Cornell to do a lot of studies. How were these efforts overseen?

NYSDEC engineers and scientists with expertise in lake water quality and modeling provided technical review and oversight throughout the project. The CLMP scientists submitted a Quality Assurance Project Plan (QAPP) to NYSDEC in early 2013 to provide details of planned data collection, data analysis and interpretation, and watershed modeling. This document was reviewed and approved before sampling began in late March, 2013. A companion document that addressed the details of the lake model was submitted in 2015.

Cornell and NYSDEC were fully committed to conducting this work in an open and transparent manner, and provided regular opportunities for stakeholders to review and comment on progress. A technical workshop on the monitoring QAPP was held in January 2013. One outcome of this workshop was a revision to the overall Project Organization chart, to formally recognize the role of community stakeholders in providing input to NYSDEC. As discussed in FAQ section 1.4, NYSDEC joined the monthly meetings of the Monitoring Partnership committee of the Tompkins County Water Resources Council to keep technical stakeholders informed. Public meetings were held at appropriate project milestones,

approximately twice each year. Finally, both the NYSDEC and EPA appointed independent panels of water quality and modeling experts to oversee and review the project.

4.5 Did the prominent role of Cornell scientists in collecting and analyzing data and developing the models introduce any bias?

The Cayuga Lake model was developed by Upstate Freshwater Institute, an independent research organization that is not affiliated with Cornell. Some members of the Cornell faculty worked on this project, collecting data related to the lake's biological community and completing a detailed computational description of water circulation. The employment of these Cornell scientists did not depend on their finding results or analyzing data for Cornell's benefit. As tenured scholars at a world-class university, they are widely recognized as authorities within their disciplines and are ethically bound to find, analyze and report facts in an unbiased manner. Their reputations depend on it. Partly, they accomplish this by applying the scientific method, which tests competing alternative hypotheses and selects those that best fit the facts. They don't set out to prove hypotheses, but rather to test them. The scientists also have a local and professional interest in coming to a better understanding of Cayuga Lake and its watershed.

The project team developed a Quality Assurance Project Plan (QAPP) to document the details of the sampling and analytical program planned for the modeling project. The QAPP was developed by UFI scientists and reviewed with members of the technical stakeholder community at a workshop in late January, 2013. The QAPP was reviewed and approved by NYSDEC prior to the onset of monitoring. The final accepted QAPP document covering monitoring and watershed modeling is available on the project web site at http://energyandsustainability.fs.cornell.edu/file/20130311%20QAPP%20final.pdf.

All phases of model development were overseen by NYSDEC and reviewed by the Technical Advisory Committee (TAC) and Model Evaluation Group (MEG). This collaborative approach to model development, bringing together expertise and funding from multiple sources including permit holders, has been used for other projects. A recent local example is the Onondaga Lake phosphorus TMDL, which was accepted by EPA in June 2012.

4.6 What if the study had shown that the LSC facility might harm Cayuga Lake?

The models clearly demonstrate that the LSC facility does not have a significant adverse impact on the lake. When the project began, all parties recognized that Cornell would continue to comply with all permit conditions. If the CLMP indicated that operation of the LSC facility did adversely affect Cayuga Lake, Cornell planned to evaluate the costs and environmental benefits associated with several alternatives. These alternatives included: (1) reducing the volume of water circulated through the LSC facility, and replacing the cooling capacity with electrically-driven chillers, and (2) modifying or relocating the LSC facility's outfall out of the southern basin.

4.7 Sediment loading is a significant issue in southern Cayuga Lake. Did the water quality model also address sediment?

The water quality model focused on eutrophication, the response of algal growth to nutrient enrichment. The CLMP did not directly address the sediment impairment of southern Cayuga Lake. However, the UFI monitoring effort included measuring the bioavailability of sediment and water entering the lake from the tributaries, which furthered our understanding of the ecosystem impacts of the sediment loading. Among the water quality variables that were measured and modeled is turbidity (a measure of light scattering, directly related to the size and number of particles suspended in the water). Measurement of Total Suspended Solids (TSS) was also part of the study. The Cayuga Lake Water Quality Model tracked the relative contribution of algal cells and sediment particles to water column turbidity. Therefore, to the extent that sediment loading is reflected in water column turbidity, the CLMP has provided insights into the factors affecting water clarity in the lake. This information furthers our understanding of the linkages between the watershed and the lake, particularly in association with storm events.

The water quality model could potentially serve as a framework for a sediment model at some future point, because a significant task of the CLMP was to develop the hydrodynamic framework (the equations predicting how lake water moves in response to the weather and seasonal factors). The hydrodynamic framework could be used to address other issues, such as sediment.

5. The Lake Source Cooling facility

5.1 What is the LSC facility?

Cornell's Lake Source Cooling (LSC) facility supplies chilled water to air condition and dehumidify buildings on the university's Ithaca campus, and cool research equipment and spaces. The LSC process uses the renewable resource, naturally cold water deep in Cayuga Lake, in a non-polluting heat exchange process. This process draws water from deep in Cayuga Lake, where temperatures remain cold year-round, and circulates lake water through a heat exchange facility, located on East Shore Drive in Ithaca. The lake water transfers its chill to a second closed loop of water that is connected to the campus cooling system. Slightly warmed water is returned to southern Cayuga Lake through an underwater diffuser. The lake water and campus chilled waters never mix. For more information, and photos of the LSC facility, visit
http://energyandsustainability.fs.cornell.edu/util/cooling/production/lsc/default.cfm

5.2 Why did Cornell build the LSC facility?

The LSC facility uses a renewable resource (the deep cold water of Cayuga Lake) and a non-polluting cooling technology (noncontact plate and frame heat exchangers) to cool buildings and equipment on Cornell's Ithaca campus. By investing in the LSC facility, Cornell was able to decommission six electrically-driven chillers, and accelerate the phase out of ozone-depleting CFC chemicals used as

refrigerants. Since the facility came on line in 2000, the urgency of reducing fossil fuel consumption has only become more pronounced, spurring discussion and debate at the national, state and local levels.

This innovative approach to energy management is part of a sustainable future. The LSC facility is a successful project – the peak summer electric demand of the entire campus would be about 40% higher with conventional chillers instead of the LSC system. That is, without the LSC facility, the electric peak would be 14 MW higher than the actual peak of about 36 MW. The facility reduces the need for electricity to run the campus chilled water system by 86%, with concurrent reductions in carbon air emissions of about 5,000 metric tons CO_2 equivalent per year, and other air pollutants from fossil fuel-fired electric generation. This savings is about 12% of the total campus electric use or about 25 million kWhr/year.

5.3 What is the history of the LSC facility?

Cornell uses a central chilled water cooling system to provide campus buildings with air conditioning and dehumidification. Until the LSC facility came on line in 2000, the university relied primarily on electrically-driven chillers to remove heat from the circulating chilled water. In the early 1990s, Cornell utilities engineers began planning to replace these chillers, which were reaching the end of their 35-year service life. At the time, several factors encouraged the university to examine alternative cooling technologies. The 1990 Clean Air Act Amendments legislated the phase-out of refrigerants (CFCs and HCFCs) known to deplete atmospheric ozone; these refrigerants were used in the university's chillers. Cornell was also committed to reducing overall campus energy consumption and its associated carbon footprint; this commitment was challenged by the projected growth in demand for campus cooling. The use of Cayuga Lake's deep, cold water as a renewable resource was considered, and the university decided to take on the detailed assessment and permitting required to make this innovative approach a reality.

Extensive monitoring and assessment began in late 1993, and culminated in a Final Environmental Impact Statement in 1997. The SPDES permit for the facility was issued in 1998. With this key permit in hand, construction commenced and the facility came on line in July, 2000. As a condition of its permit, Cornell was required to implement an extensive monitoring program in Cayuga Lake's southern basin. Biweekly water quality monitoring at a network of lake sites was conducted from 1998 through 2012.

In 2002, NYSDEC placed southern Cayuga Lake on its list of impaired waters—as a category 1 waterbody, meaning that a TMDL approach was required to bring the lake into compliance with water quality standards. NYSDEC has long stated their intent to complete a TMDL allocation for southern Cayuga Lake.

5.4 Has the LSC facility been recognized for its "green" approach to campus cooling?

The LSC project has been recognized as an outstanding example of pollution prevention and environmental sustainability. In 2001, the LSC facility won the New York Governor's Award for Pollution Prevention. The Governor's Award recognizes institutions and companies that voluntarily go beyond the

requirements of compliance with anti-pollution legislation. NYSDEC also honored the LSC project because of its highly innovative nature, and because the technology can be transferred to other institutions. In addition to multiple awards from the engineering community, the project was honored in 2002 with an Award of Special Recognition and Merit from the Ecological Society of America. The Society cited the engineers in the Department of Utilities and Energy Management at Cornell for "extraordinary vision and effort in proposing and carrying through to realization a major contribution to the wise sustainable use of a renewable natural resource."

5.5 Are there other deep water cooling systems in operation?

The City of Toronto partnered with Enwave to construct a Deep Lake Water Cooling (DLWC) facility, drawing cold water from deep in Lake Ontario and using the chill to cool private and public buildings in downtown Toronto. This project came on line in 2004, and is the world's largest lake source cooling system. Water is drawn from a depth of 83 m in Lake Ontario, pumped through a heat exchange facility connected to a closed loop chilled water distribution system, and then enters the City's potable water supply system. District cooling in Toronto has allowed the City to reduce its electricity demand for cooling by 90%, decommission a coal-fired power plant, and provide higher quality potable water. http://www.enwave.com/district_cooling_system.html

The City of Stockholm has used the cold water from the Baltic Sea for district cooling since 1994, with great success, and is evaluating expansion of the system.

A feasibility study for district cooling of the medical complex in the City of Syracuse, drawing cold water from Lake Ontario or Skaneateles Lake, was completed in 2011. The report includes a detailed comparison of the Cornell LSC system and Toronto's Enwave DLWC system. http://www.cnyrpdb.org/docs/reports/CNYCWP_Final_Report_June_6_2011R.pdf

6. The LSC Permit Renewal/Modification

6.1 What is a SPDES permit?

The State Pollution Discharge Elimination System (SPDES) permit process is used to regulate all discharges to NY waters. Permits set limits on the quantity of materials discharged from regulated facilities. SPDES permits are issued for a five year term. Other facilities discharging to Cayuga Lake, including the Ithaca Area and Cayuga Heights Wastewater Treatment Plants, and Cayuga Operating Company coal-fired power plant (formerly AES Cayuga), hold SPDES permits.

6.2 Is this a new permitting requirement for the LSC facility?

No, the LSC facility has always operated under the terms of a SPDES permit. Cornell was issued a SPDES permit for the LSC facility in 1998, once the State Environmental Quality Review Act requirements were completed. The facility came on line in 2000. In 2002, the southern basin of Cayuga Lake was placed on the state and federal list of impaired waters [the 303(d) list] in Category 1 – meaning that a TMDL

approach was needed to bring water quality into compliance and meet the lake's designated use. Note that the TMDL process is explained in question 2.

The LSC facility's SPDES permit was renewed in 2003, with no modifications. Cornell applied for permit renewal in the fall of 2007, and in 2008 the existing permit was extended until final terms of a permit renewal could be finalized. The LSC facility continued to operate under the terms of the 2003 permit, which remained valid because Cornell met all the required deadlines associated with the renewals. The NYSDEC issued a draft permit renewal and modification on October 16, 2012, and set a 60 day period for public comment. The Tompkins County Environmental Management Council convened a public information session on the draft permit in December, 2012. Representatives of NYSDEC and the project modeling team discussed their approach and responded to community questions. There were 21 comments submitted to NYSDEC on the draft permit renewal.

The current SPDES permit for operation of the LSC facility became effective on May 1, 2013. SPDES permits extend over a five-year period; the current permit will expire on April 30, 2018. NYSDEC also released updated Fact Sheets for the permit, and a responsiveness summary detailing how each of the comments on the draft permit was addressed. These documents are available on the NYSDEC web site http://www.dec.ny.gov/lands/88250.html

6.3 Where can I review the permit?

The NYSDEC has developed a web page http://www.dec.ny.gov/lands/88250.htmlto share information regarding the many Cayuga Lake initiatives underway. The SPDES permit, associated fact sheets, and summary of responses to comments on the draft permit are available at this site.

6.4 What conditions were placed on the LSC facility under the 2013 permit renewal?

The 2013 SPDES permit for the LSC facility included several important modifications and new conditions, as summarized below.

- A phosphorus limit on the return flow of Cayuga Lake water. ONGOING
- A requirement for Cornell to fund development of a water quality model of the lake and watershed that will enable NYSDEC to complete a TMDL allocation for phosphorus inputs to the lake's southern shelf (the impaired segment), or identify other effective measures to improve water quality conditions. COMPLETED DECEMBER 2016
- A requirement for Cornell to complete a preliminary design study for a modified outfall (in the event that modifications to the LSC outfall are a cost-effective means to comply with future phosphorus TMDL allocation). COMPLETED NOVEMBER 2016
- A requirement for additional biological monitoring to evaluate whether fish eggs and larvae are being drawn into the LSC system, and whether additional mitigation technologies are warranted. This condition was included to comply with new state-wide requirements for Best Practices for cooling waters. COMPLETED OCTOBER 2015

- A requirement for Cornell to investigate and document Best Management Practices for managing their campus cooling load, with an objective of minimizing the need to draw water from Cayuga Lake. COMPLETED JANUARY 2017

One condition that was part of the 1998 SPDES permit was discontinued. Once the data gathering for the lake and watershed model was completed in 2013, water quality monitoring of southern Cayuga Lake will no longer be required of Cornell as part of their SPDES permit. However, the water temperature, flow rate, pH and concentrations of total and soluble phosphorus in the LSC return flow will continue to be measured and reported to NYSDEC as part of the 2013 permit requirements.

6.5 Why was in-lake monitoring discontinued?

Cornell was required to fund an extensive water quality monitoring program of southern Cayuga Lake as a condition of their original permit to operate the LSC facility. This requirement was in place for 15 years, from 1998 to 2012, and called for biweekly monitoring between April and October at eight locations within the southern region of the lake. The monitoring program was designed to support a statistical analysis of water quality conditions, before and after the LSC came on line as well as close to and remote from the return flow. This analysis was completed and submitted to NYSDEC (additional discussion is included in FAQ section 6). Annual reports of the lake monitoring program, including the data, are available at http://energyandsustainability.fs.cornell.edu/util/cooling/production/lsc/annualreports.cfm

Note that the latest permit renewal required monitoring of the entire lake and significant tributary streams from April – October 2013. This rich data set was used to support development of the coupled lake and watershed model.

The question of why intensive monitoring of the southern shelf area would no longer be required was raised during the public comment period on the draft SPDES permit. The NYSDEC response is available at http://www.dec.ny.gov/docs/water_pdf/cornelllscresp.pdf; the response reiterates that there is no justification for continuing to require Cornell to monitor southern Cayuga Lake once the model is completed.

7. Lake and Watershed Monitoring

Cayuga Lake and its tributary streams are monitored by multiple organizations. While each monitoring program is designed to meet specific objectives, taken together they provide data and information to assess water quality of the lake ecosystem, particularly with respect to trophic state indicators (nutrients, water clarity, and phytoplankton abundance) as well as track changes and trends over time. **Four programs are active in southern Cayuga Lake: the City of Ithaca/Ithaca Area Wastewater Treatment Facility, the Community Science Institute, the Floating Classroom, and the Citizens Statewide Lake Assessment Program (CSLAP).** As evident from the following program summaries, each

is a collaboration of many stakeholders. The Cayuga Lake Monitoring Partnership strives to coordinate the various monitoring efforts in the southern end, and the Cayuga Lake Watershed Network encompasses the entire lake. Note that other lake regions are monitored as part of the CSLAP program, as well as by researchers associated with the Finger Lakes Institute.

7.1 City of Ithaca/IAWWTF

Environmental professionals from the Ithaca Area Wastewater Treatment Facility (IAWWTF) have been monitoring Cayuga Lake water quality for the last decade and plan to continue. The IAWWTF is owned and operated by three municipalities: the City of Ithaca, Town of Ithaca, and the Town of Dryden. The IAWWTF team samples southern Cayuga Lake monthly at multiple locations for a suite of limnological parameters, including total and soluble reactive phosphorus, chlorophyll-*a*, ammonia nitrogen, nitrate+ nitrite nitrogen, and fecal coliform bacteria. Field measurements include water temperature, dissolved oxygen, pH, and oxidation-reduction potential. Data from this program enable an assessment of trends as well as current trophic state conditions.

In addition to the trophic state parameters listed above, the IAWWTF leads programs to identify and track other important components of lake health. Since 2013, a monitoring platform (PISCES) has been deployed between March and October on the southern shelf where Cayuga Inlet enters the lake. The platform is equipped with sensors and probes to provide data for multiple objectives:

- Tracking changes in carbon dioxide, pH, conductivity, water temperature, and dissolved oxygen concentrations over daily and seasonal cycles to document the lake's metabolism (level of productivity).
- Characterizing the bidirectional flow regime of Cayuga Inlet and thus improving the estimate of net phosphorus loading to the lake (using an Acoustic Doppler Current Profiler to measure current velocity and multiple depths)
- Measuring wind speed and direction at the lake surface
- Monitoring concentrations of chlorophyll-a and indicators of cyanobacteria

Some of the PISCES data are accessible at http://www.ithacawaters.org/; IAWWTF maintains this site. Ultimately, the City and partners intend to archive all the data on ecommons.

Another significant initiative to analyze water samples for hundreds of emerging contaminants is underway. This effort is part of program to measure ambient levels of Endocrine Disruptors/Persistent Organics within the south end of Cayuga Lake. This effort is a collaboration among the City of Ithaca/IAWWTF, Cornell University, Ithaca College, USGS, NYS Dept. of Health, Cornell Cooperative Extension and the Floating Classroom.

Contact Dr. Jose Lozano, Director of the IAWWTF Environmental Laboratory jll13@cornell.edu or Roxanna Johnston RJohnston@cityofIthaca.org for more information about the programs led by the City of Ithaca/IAWWTF.

7.2 The Community Science Institute (CSI)

CSI plans to continue, with financial support from local governments in Tompkins County, to monitor Cayuga Lake and post the results on the CSI website, as follows:

- Nine "synoptic" locations are sampled twice each summer from the Floating Classroom in partnership with their 4-H2O youth group. Four locations are on the southern shelf of Cayuga Lake and three are in the general vicinity of Salmon Creek, including two that are sampled in both the epilimnion and the hypolimnion. The following parameters have been measured since 2007: total coliform bacteria, E. coli, soluble reactive phosphorus, total phosphorus, nitrate, total hardness, alkalinity, pH, dissolved oxygen, chloride, and conductivity. Other water quality parameters have been monitored sporadically, including total Kjeldahl nitrogen, total suspended solids, total dissolved solids, chemical oxygen demand, gross alpha and beta radioactivity, barium, and strontium. Chlorophyll-a will be monitored as well. A map, the latitude and longitude coordinates of the "synoptic" sampling locations, and graphs of average values for each location are available at: http://database.communityscience.org/monitoringsets/9.

- Fifteen locations along the southwestern shoreline of Cayuga Lake are sampled four times a year by the West Shore Homeowners' Association for E. coli and total coliform bacteria. A map of locations, latitude and longitude coordinates, and graphs of average values for each location are available at: http://database.communityscience.org/monitoringsets/39.

- In addition to in-lake monitoring, CSI plans to continue to collect samples from the major tributary streams flowing into Cayuga Lake including Fall/Virgil Creek, Sixmile Creek, Cayuga Inlet, Cascadilla Creek, Taughannock Creek, Trumansburg Creek, Salmon Creek, and Canoga Creek. The data are posted at http://database.communityscience.org/monitoringregions/1.

7.3 The Floating Classroom

The Floating Classroom collaborates with CSI to support their in-lake programs. Bill Foster www.floatingclassroom.net and floatingclassroom@gmail.com directs the Floating Classroom. Students and interns on the Floating Classroom collect the following lake data:

- Secchi Disk transparency: Approximately 50 dates between May and October from multiple locations, including standard sites between Bolton Point and the Ithaca Yacht Club, and a mid-lake station between Myers and Taughannock.

- Temperature profiles: The Floating Classroom has access to the City of Ithaca's field instrumentation (Hydrolab) and has been measuring thermal profiles in order to construct a heat budget for the lake.

- The Floating Classroom also collects plankton samples on a regular basis (at least weekly) and reports the relative abundance of diatoms, green algae and cyanobacteria, plus various zooplankton taxa. They plan to develop capacity to perform ELIZA tests for microcystins.

7.4 CSLAP

Since 1985, NYSDEC and the New York Federation of Lake Associations (CSLAP) have collaborated on a volunteer lake monitoring program to evaluate lake heath using standardized metrics and protocols. In 2017, NYSDEC expanded the CSLAP program to include all 11 Finger Lakes, including Cayuga. Two monitoring locations were sited on Cayuga Lake, one in the northern Class A segment (regulatory segment 2), and one off Taughannock Falls in the Class AA segment (regulatory segment 3). NYSDEC anticipates adding two additional stations, one in Segment 1 and one in Segment 4 (the southern shelf) in 2018 if funding allows.

Samples are collected from the upper waters and lower waters and analyzed for the following suite of parameters: temperature, Secchi disk transparency, conductivity, pH, color, Total Phosphorus, Nitrogen (nitrate, ammonia and total dissolved N), chlorophyll-a, and calcium. In addition, samplers are asked to observe whether the lake is suitable for recreational use. Samplers are trained in surveillance for invasive species, as well as harmful algal blooms.

Finger Lakes water samples collected by CSLAP volunteers are also being analyzed for soluble phosphorus and two parameters that may affect water treatment: dissolved organic carbon and uv254. This is a pilot program to gather data that NYSDEC may use as they develop numerical nutrient limits designed to reduce the risk that public water supplies may be affected by disinfection byproducts.

Samples are analyzed in a certified laboratory and interpreted by professional lake scientists, who prepare annual reports. The web link to the program is http://www.dec.ny.gov/chemical/81576.html

8. How does the LSC facility affect phosphorus cycling in Cayuga Lake?

The LSC facility does not add phosphorus to Cayuga Lake. The transfer of water by the LSC facility brings deep water—containing low concentrations of soluble reactive P—to the shallow, sunlit region of the lake where plants and algae can grow. The soluble reactive P is available to phytoplankton, and the concern was that this new supply could stimulate algal growth. The CLMP model provided the tools to analyze the impacts. Despite the transfer of phosphorus to the upper waters, there is no impact on phytoplankton. The explanation lies in the very short water residence time of the southern shelf; water flushing rate is faster than the algal growth rate. The LSC facility contributes to the very short residence time. Water swept off the shelf is replaced by water from the main lake.

8.1 Does the phosphorus cycling affect the lake ecosystem?

The issue of whether this phosphorus transfer is ecologically significant has been under review since the LSC facility was first conceived. As a condition of their permit to operate the LSC facility, Cornell was

required to measure water quality conditions at a network of eight (8) monitoring stations on the lake's southern shelf. The monitoring program was in place from 1998 to 2012, and resulted in an extensive data set. These monitoring data have been reviewed and analyzed by numerous experts in lake ecology, statistics, and hydrodynamics (water movement), in order to assess whether the return of water drawn from deep in Cayuga Lake to the lake's southern shelf affected water quality conditions.

Scientists from the Upstate Freshwater Institute (UFI) completed a statistical evaluation of the lake monitoring data. They employed a statistical approach, termed a Before-After-Control-Impact (BACI) analysis, to determine whether the observed changes in lake water quality were related to operation of the LSC facility. The BACI analysis and findings were formally submitted to NYSDEC for their review in accordance with the requirements of the facility's SPDES permit. This analysis concluded that there is no scientifically credible evidence that the LSC facility's water circulation has harmed the lake.

8.2 Was the conclusion of the statistical analysis reviewed by outside experts?

NYSDEC requested an EPA review of the BACI analysis. Statistical expert John Fox completed a review of the UFI report and responded to NYSDEC with his comments in 2004. The major conclusion is as follows:

> "Overall, this is a careful and thorough analysis which addresses nearly all of the pertinent concerns regarding statistical analysis. The comparison methodology is sound and well-reasoned. Some deficiencies are identified below; these can be remedied with a modest investment of time and effort. Despite these deficiencies, the general conclusion of no impact appears to be supported convincingly, within the resolution permitted by the variability of data." John Fox, EPA November 2004

Mr. Fox suggested that the Upstate Freshwater Institute be asked to address three deficiencies he identified in the report.

1. The authors should describe the results of testing the additivity assumption.
2. The authors should report the confidence interval of the estimated effect.
3. The authors should calculate and report the statistical power of the analysis.

This EPA report was not shared with UFI or Cornell at the time, and the NYSDEC did not request UFI or Cornell to respond to the EPA comments, or revise the BACI analysis to address the three points raised by the EPA statistical expert.

In a parallel effort, three Cornell University scientists, Dr. Stephen Ellner, Dr. Nelson Hairston, and Dr. Clifford Kraft, were intrigued by the challenge of designing a robust statistical approach to detect change in southern Cayuga Lake, given the spatial and temporal variability of the response variables (chlorophyll, total phosphorus, and turbidity). These investigators used the extensive data set generated by the LSC-required monitoring, and took an alternative statistical approach, avoiding the use of multiple comparisons. This alternative analysis considered the southern Cayuga Lake data set as a whole and conducted only a few scientifically-motivated analyses representing different hypotheses

about the system. The alternative analysis reached the same conclusion as UFI's BACI analysis and the EPA review: the LSC return flow has no significant impact on Cayuga Lake's water quality.

The monitoring data, two statistical evaluations using different methods, and the EPA critique of the BACI analysis all confirm the findings. Circulation of Cayuga Lake water by the LSC facility has not had a statistically significant adverse impact on the water quality of the southern shelf. The findings of the CLMP confirm this conclusion.

8.3 How do the various forms of phosphorus affect the potential impact of the LSC return flow on algal growth in the southern basin?

Phosphorus is present in various chemical forms in lake water, and these chemical forms differ in their ability to stimulate algal growth. Over the years, the scientific community has come to define these various phosphorus fractions in an operational manner, that is, according to the specific procedures used during sample handling and analysis. The procedures incorporate (1) passage through a 0.45 micron filter, which differentiates between soluble and particulate fractions, and (2) digestion with an acid, which liberates phosphorus that is bound to or incorporated into particles, both organic and inorganic. As part of the 2013 monitoring effort, UFI completed three distinct analytical procedures on water samples, to yield five phosphorus fractions (two are calculated by subtraction).

- Total Phosphorus (TP)= particulate + dissolved (unfiltered, digested)—everything in the sample
- Soluble Reactive Phosphorus (SRP) = dissolved (filtered, not digested)
- Total Soluble Phosphorus (TSP) = dissolved (filtered, digested)
- Particulate Phosphorus (PP)= TP-TSP (calculated)
- Soluble Unreactive Phosphorus (SUP), previously referred to as dissolved organic P,= TSP-SRP (calculated)

To evaluate the ecological impact of phosphorus loading, scientists evaluated "biologically available phosphorus" which indicates the potency of various waters to stimulate algal growth. The UFI team tested five tributary streams and three point sources that flow into Cayuga Lake for the bioavailability of the various phosphorus fractions. This specialized testing provided important information relating the operationally-defined phosphorus fractions to their ecological impact.

The results of the testing indicate the following:

- Essentially all SRP is bioavailable from all sources (consistent with limnological literature)
- The individual sources (various tributaries and point sources) have different bioavailability of the PP and SUP fractions.
- The more agricultural land use in a subwatershed, the more bioavailable is the particulate P and soluble unreactive P fractions measured in the streams draining that subwatershed.
- Tributaries contributed approximately 95% of the bioavailable P, and point sources contributed 5% during the 2013 monitoring period.
- The Ithaca Area Wastewater treatment plant has very low bioavailability of the particulate fraction of the phosphorus in their effluent, which is attributed to the Actiflo® process used to

remove phosphorus from the wastewater. Actiflo® is a physical/chemical process using micro-sand particles and chemical coagulants. The Syracuse Metro wastewater treatment plant also uses this treatment technology, with similar results for bioavailability of the particulate P in their effluent stream.

- SUP in the LSC return flow has very low bioavailability. It is hypothesized that the hypolimnetic water has been in the lake so long that the easily available SUP has already been taken up by the algal and bacterial communities.

8.4 Does phosphorus in the LSC return flow make the weeds worse in the southern basin?

Most of the rooted aquatic plants (weeds) that are in the southern basin of Cayuga Lake draw phosphorus from the lake sediments. There is no evidence that the LSC return flow or the discharges from the two wastewater treatment facilities have had any impact on the density or types of weeds found in Cayuga Lake. Sediment is carried into the lake from the tributary streams, Cayuga Inlet, Sixmile Creek and Fall Creek. As the streams enter the lake, water velocity slows and the sediment falls to the lake bottom. Aquatic plants will grow where sunlight reaches the sediment surface.

8.5 What would it take to convert the LSC system over from the "once-through, non-contact cooling water" to a "closed-loop" system"?

A closed-loop system with heat exchangers placed in the lake's deep, cold waters was evaluated during the LSC project design, and was dismissed as impractical in the Final Environmental Impact Statement. Cornell facilities staff are not aware of any successful examples of this technology application anywhere in the world for a system such as LSC. Significant unknowns—such as the heat exchange efficiency, the potential for fouling by sediment, mussels, and other forms of aquatic life, and the methods required to build, maintain and clean such a system—precluded serious consideration of this option. Any leaks that might occur in the piping or heat exchangers would be very difficult to detect or repair, and could result in discharge of treated water to the lake. There would have been no comparable means of spill or leak detection and containment as is currently provided at the Heat Exchange Facility.

9. Why does the 2013 SPDES permit for the LSC facility include a phosphorus limit?

The LSC facility returns water to the lake's southern shelf, which is listed as impaired by excessive phosphorus. NYSDEC considered the transfer of water, and its associated phosphorus content, from an unimpaired region of the lake into the impaired southern basin as a "source", and thus subject to a regulatory limit.

9.1 How did NYSDEC set the phosphorus limit in the SPDES permit for the LSC facility?

The interim limit, 6.4 pounds per day (ppd) is intended to insure that the phosphorus cycled into southern Cayuga Lake by the LSC facility does not increase while the lake-wide monitoring and model development are underway. This limit was based on current conditions of the volume and quality of water circulated by the LSC facility. As described in the Fact Sheet issued with the permit, http://www.dec.ny.gov/docs/water_pdf/cornelllscprmt.pdf the interim limit of 6.4 ppd was calculated using a flow rate equal to 95% of the current flow and a phosphorus concentration set at 0.020 mg/l, which is the NYSDEC current phosphorus guidance value. The cited final limit, 4.8 ppd or as modified by the TMDL, was calculated using the 95th percentile of the measured loading (from July 2000-December 2009). NYSDEC selected this date range.

A final limit will be determined based on the outcome of the TMDL process. However, if there is delay in completing the TMDL that is attributed to the Cornell project team (not caused by NYSDEC or public review), then a phosphorus limit of 4.8 ppd will be imposed. As described in the fact sheet and noted above, this limit was determined based on a statistical calculation of the amount of phosphorus actually cycled by the LSC facility.

9.2 Does the permit renewal allow Cornell to increase phosphorus loading from the LSC facility?

The mass of phosphorus transferred by the LSC facility from one segment of Cayuga Lake to another is governed by two factors: (1) the volume of water circulated, and (2) the concentration of phosphorus in the lake water flowing though the facility. The LSC facility has control over only one of these factors, the flow rate through the facility. The system does not add phosphorus to the lake water. Flow rate remains capped at 2 cubic meters per second (m^3/sec); NYSDEC did not propose any changes to the current flow limit in the draft permit renewal.

However, the permit renewal places a phosphorus limit on the LSC return flow for the first time. The interim limit—during the period of monitoring, modeling and TMDL development—is 6.4 pounds per day. NYSDEC enforces this limit as a monthly average.

The limit was calculated using LSC facility performance data from 2000 to 2009. The upper 95% of the statistical distribution around the facility's discharge rate was calculated to be 1.6 m^3/sec (37.5 million gallons per day). The maximum allowable phosphorus concentration was set at the NYSDEC guidance value, 20 mg/m^3 (parts per billion).

The nature of the LSC facility and the demand for cooling on the Ithaca campus are such that the monthly phosphorus limit may affect the facility's operations during the warm summer months. The volume of water circulated by the LSC facility varies in direct response to the demand for cooling on campus. Flow rates are highest on warm summer days, and decrease to low levels (less than 20% capacity) during the winter. Moreover, between November and late May, Cayuga Lake is completely

mixed, and the LSC facility does only what the winds and water currents are doing naturally—moving water from one segment of the lake to another.

The facility operates to meet current demand for campus cooling; increased circulation rate above the campus cooling demand would be additional energy consumption for no benefit. Therefore, it is not meaningful to project the potential impacts of operating the LSC facility at peak year-round.

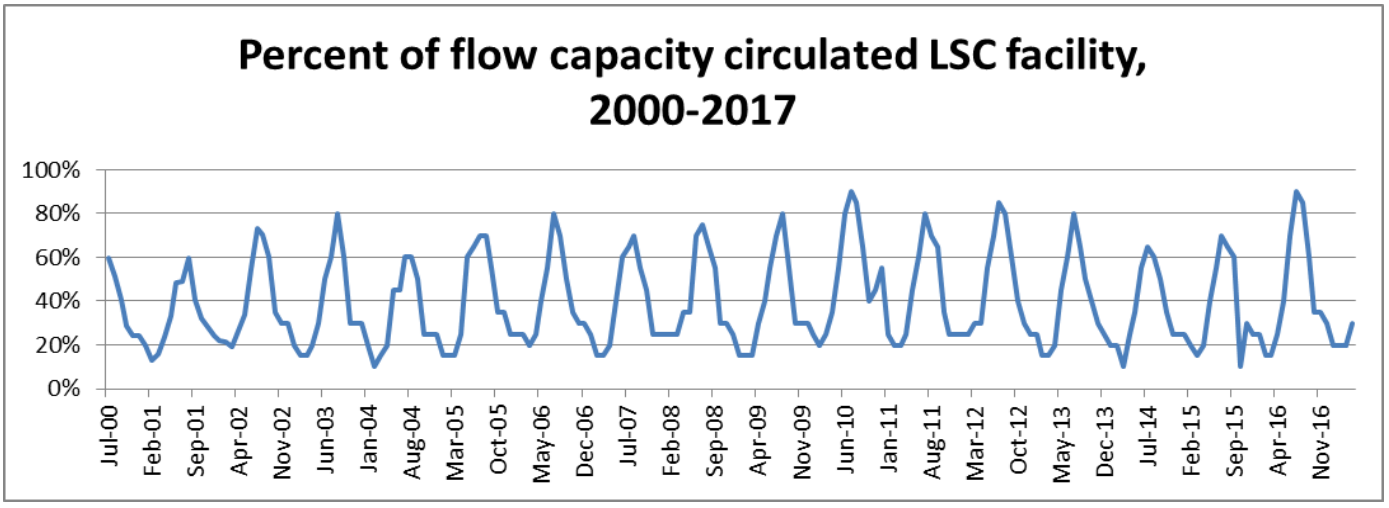

Figure 9.1 Volume of Cayuga Lake water circulated through the LSC system as a percentage of the permitted volume

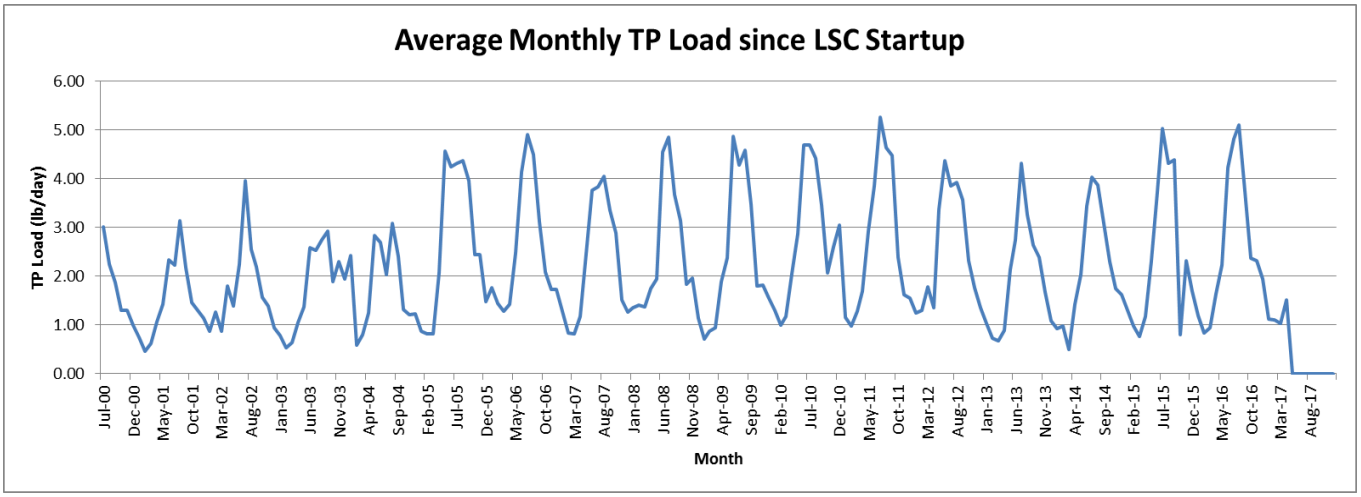

Figure 9.2 Mass of phosphorus circulated through the LSC facility, 2000-2017

10. Has the water quality of Cayuga Lake changed since the LSC facility started up in 2000?

10.1 Phosphorus and chlorophyll-a

Cayuga Lake water quality conditions change from year-to-year. As plotted in Figure 10.1, summer average (June 1- September 30) total phosphorus concentrations in the waters of Cayuga Lake's southern shelf have varied over the 1998 – 2012 period of intensive monitoring required by the Lake Source Cooling SPDES permit. The highest concentration was 26.3 ug/L in 1996, and the lowest was 14.4 ug/L in 2003. The summer average phosphorus concentrations are influenced by the weather and performance of the wastewater treatment facilities. An objective of the Cayuga Lake Modeling Project was to help managers understand this year-to-year variability.

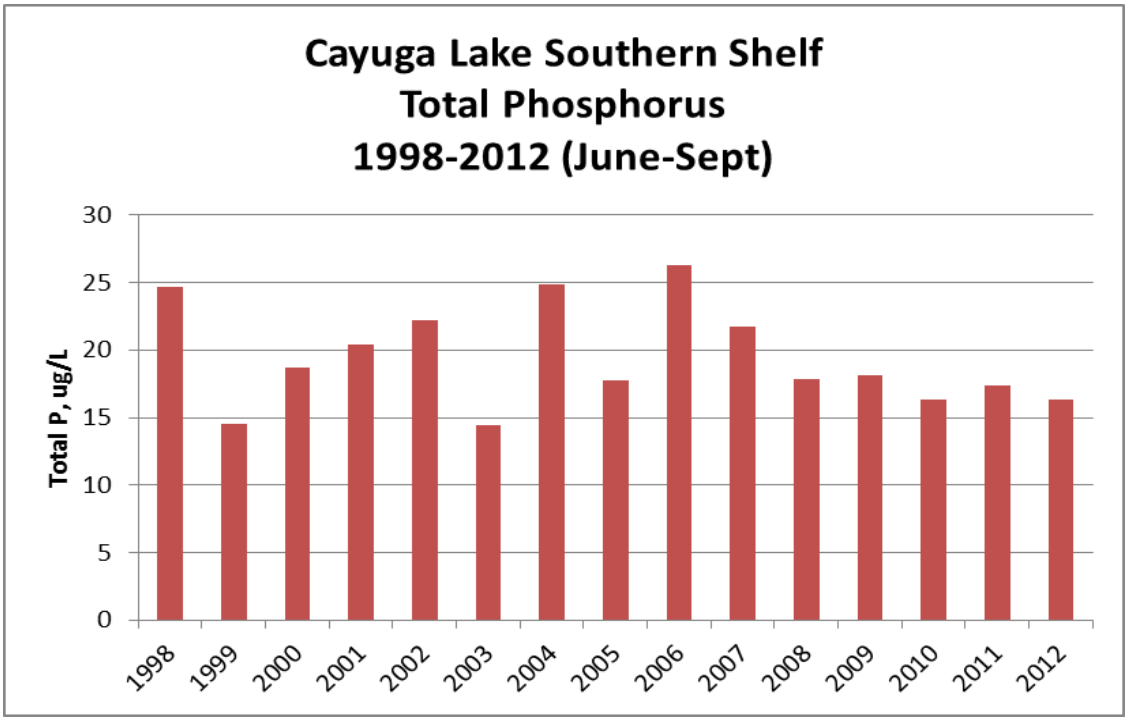

Figure 10.1 Summer average Total P

The summer (June 1 through September 30) chlorophyll-a concentration (an indicator of algal abundance) are also highly variable on the lake's southern shelf, as displayed in Figure 10.2

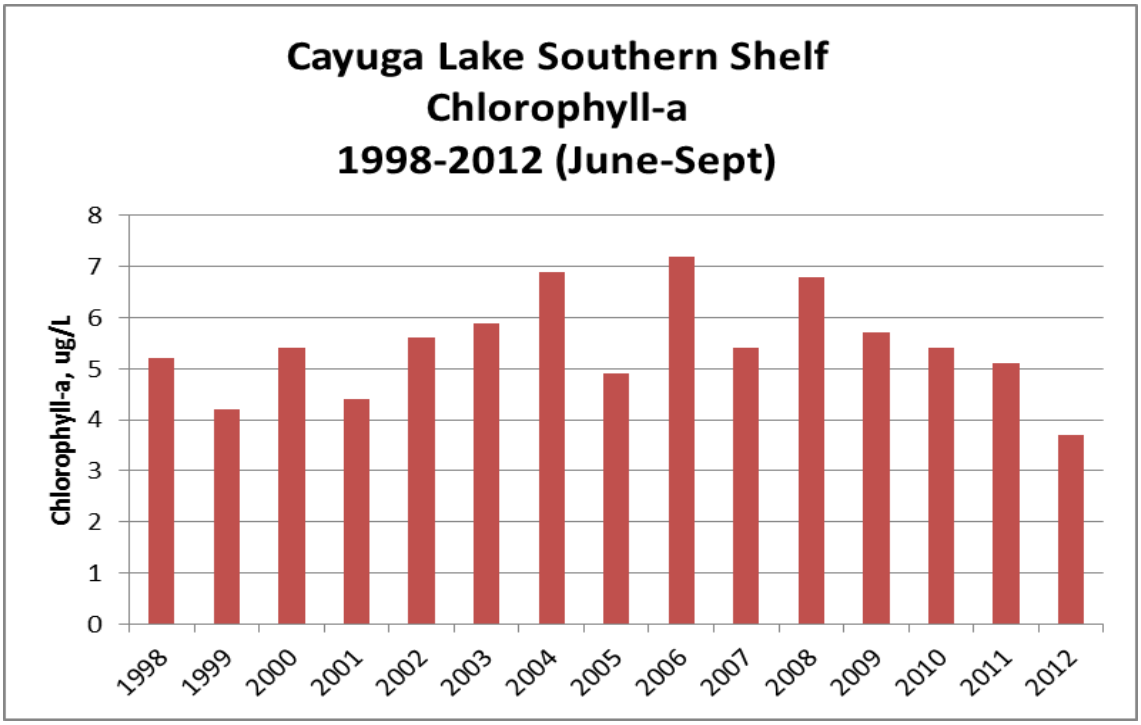

Figure 10-1B Summer average chlorophyll-a

Since 2000, the two wastewater treatment facilities discharging to southern Cayuga Lake have accomplished a significant reduction in phosphorus discharge. This reduction is illustrated in the Figure 8.1C. The lack of a corresponding decline in chlorophyll-a illustrates the complexity of water quality and hydrodynamics conditions affecting the lake's southern shelf. Moreover, it has led Cornell and NYSDEC to work together to improve our collective understanding of factors influencing phosphorus dynamics in the lake. The CLMP will enable NYSDEC to use a scientifically-defensible approach to determining whether a phosphorus limit on the LSC facility would have a positive impact on Cayuga Lake water quality.

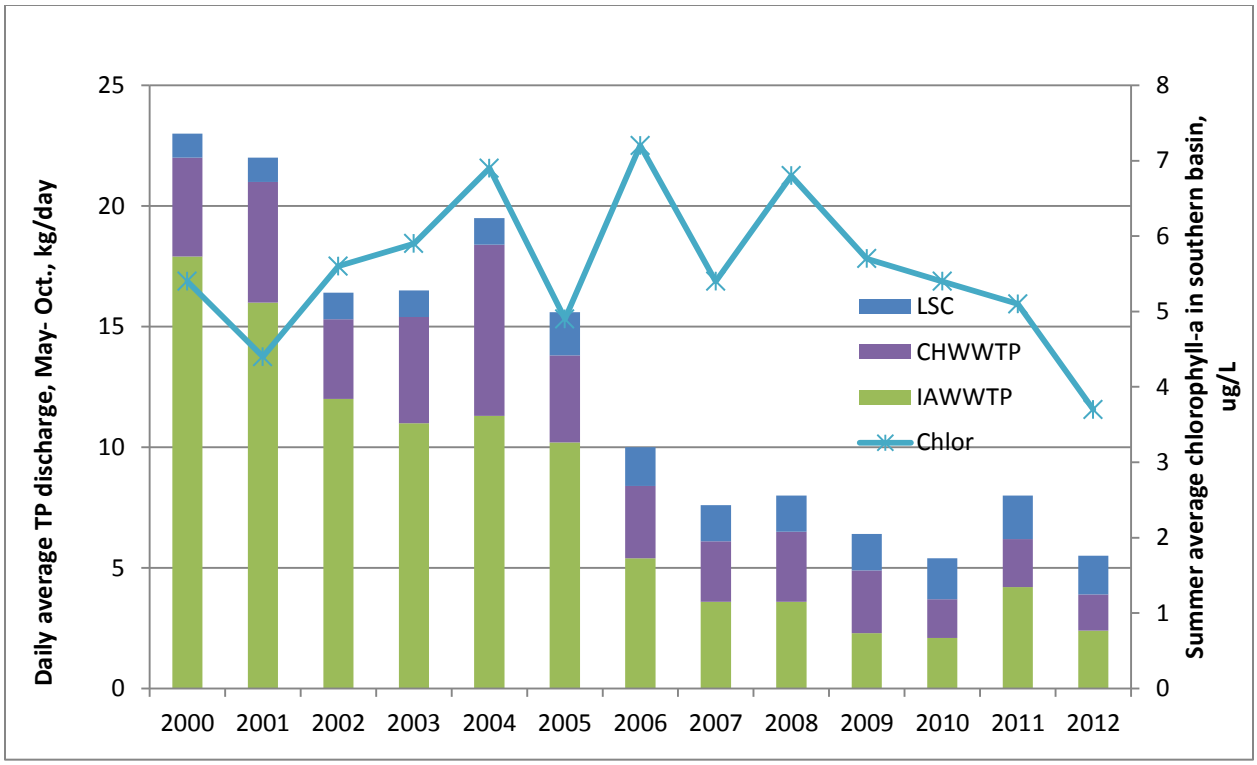

Figure 10.3 Monthly average total phosphorus load (May – October) of three point source discharges to southern Cayuga Lake, and the summer average (June-Sept) chlorophyll-a concentration in the lake's southern shelf.

LSC- Cornell Lake Source Cooling
CHWWTP- Cayuga Heights Wastewater Treatment Plant
IAWWTP- Ithaca Area Wastewater Treatment Plant
Chlor- chlorophyll-a (plant pigment, indicating algal abundance)

Data Source for Figures 10.1, 10.2, and 10.3: Cornell University, March 2013. Cayuga Lake Water Quality Monitoring, Related to the LSC Facility: 2012

10.2 Has the proliferation of dreissenid mussels (zebra mussels and quagga mussels) affected Cayuga Lake?

Part of the 2013 field program was a detailed survey of the distribution and abundance of invasive dreissenid mussels on the bottom of Cayuga Lake. Dr. James Watkins and Professor Lars Rudstam of the Cornell Biological Field Station led this effort, which revealed that quagga mussels dominate the lake's benthic community and are very abundant throughout the entire lake. Mussels were documented present in the deepest part of the lake, over 400 ft., which remains dark and cold year-round. The density and size of the mussels decrease with depth. Filter feeding by these exotic mussels have had clear impacts on phytoplankton biomass and water clarity in the Great Lakes Basin. Their influence on nutrient cycling is less well understood. The CLMP team investigated the potential role of the mussels in the observed increase in hypolimnetic soluble reactive phosphorus (SRP). Experiments to estimate the SRP excretion rate of quagga mussels were completed. In addition, the developers of the lake water

quality model reviewed the scientific literature on excretion rates and how this phenomenon can be incorporated in the water quality model. It appears that the proliferation of the quagga mussels and the expansion of their range into deeper water have contributed to increased hypolimnetic SRP in Cayuga Lake.

11.Opportunities for Collaboration

There is a wealth of information on Cayuga Lake and its watershed, developed over years of monitoring and research. The project team coordinated with local technical stakeholders to capture local data, information, and knowledge so that the lake and watershed models reflected the best available science. The Cayuga Lake Monitoring Partnership, a committee of the Tompkins County Water Resources Council, coordinated local sources of data, information, and knowledge about the Cayuga Lake ecosystem. Chaired by Roxanna Johnston, City of Ithaca Watershed Coordinator, the Monitoring Partnership met regularly with members of the project team to discuss progress and findings throughout the multi-year project.

12.Sedimentation and Use Attainment

12.1 Can a regulatory action such as a TMDL reduce sediments going into Cayuga Lake and the resulting turbidity (cloudiness) and growth of aquatic plants and algae?

There is substantial evidence that Cayuga Lake's large southern tributaries (Cayuga Inlet, Sixmile Creek, and Fall Creek) are the major sources of nutrient and sediment loading to the lake's southern shelf. The Cayuga Lake watershed was cleared of its forests in the 19th and early 20th centuries for agriculture and settlements. Much of the sediment eroded from the cleared landscape during this period is still stored in the streambeds of the lake tributaries. Presently, much of the watershed has been reforested and the sediment loss from the landscape has decreased.

As a consequence, best management practices within the tributary subwatersheds can reduce, but not eliminate, sediment deposition. The Tompkins County Soil and Water Conservation District and other agencies continue to implement projects within the subwatersheds to help reduce soil loss.

12.2 Why is there no swimming at Stewart Park?

Sediment washing into the lake from the main tributary streams- Cayuga Inlet, Sixmile Creek, Fall Creek and Cascadilla Creek, reduces water clarity and makes swimming unsafe. State guidelines for swimming beaches call for a minimum water clarity of four feet. There has been no designated swimming beach at Stewart Park since 1967 (46 years ago). A good overview of recreational uses of southern Cayuga Lake is posted at http://www.cayugawaterfronttrail.com/file_uploads/SPRAP_Report_12-7-09_LowRes.pdf

The article that Professor Nelson Hairston published as an op-ed in the Ithaca Journal in 1999 provides the best answer to the question of why no swimming—here it is again:

The Ithaca Journal
April 12, 1999
Guest Columnist Nelson Hairston, Jr.
Frank H. T. Rhodes Professor of Environmental Science
College of Arts and Sciences Cornell University

The origins of Cayuga Lake's problems

The New York State Department of Environmental Conservation has added southern Cayuga Lake to the, now famous, 303d list. Although the legal and environmental significance of this listing that has been debated at length in this newspaper and elsewhere, the reasons for the designation are well known and relate to levels of nutrients and sediments present in the lake water.

While nutrients have received considerable discussion, the turbidity caused by sediments (particles of silt and clay suspended in the lake water) has received much less attention. It is the sediment that creates such unattractive murky brown water after storms and runoff from spring snowmelt.

It is also sediment accumulation in the near-shore region at Stewart Park that has long-time residents lamenting what they perceive as the worsening conditions in the lake. What are the origins of this problem? The south end of Cayuga Lake, the area now occupied by Stewart, Treman and Cass Parks, was originally and naturally a large marsh. The shallow, muddy sediments that formed the substrate upon which marsh vegetation grew came from the silt and clay particles carried by the tributaries that flowed across the land surrounding the Ithaca area and into the lake: Fall Creek, Cascadilla Creek, and Sixmile Creek.

These particles came from a naturally eroding landscape and were trapped in the marsh where they accumulated. This process led very slowly to an addition of dry land at the shore - much of it now supporting the homes and business of Ithaca. At the same time the deposited sediments extended the marsh edge out into the lake.

The southern Cayuga Lake marsh was filled in by Ithacans early in this century, first to make land for industrial development, and then later converted into the parks that we who live in the Ithaca area enjoy so much. But, the filling of the marsh did not stop the sediment from flowing down the creeks to the lake. Indeed, farming and land development in the watershed no doubt substantially increased the rate of erosion. With no marsh remaining to trap the sediments, the particles now flow largely uninhibited into the lake. When the velocity of the creek water is slowed by mixing with lake water, the sediments fall to the lake bottom, building up near the shores of Stewart and Treman Parks, and creating a large shallow shelf of mud.

Many long-time residents of the Ithaca area recall a wonderful period in the past when swimming was possible at Stewart Park. There is an understandable tendency for these residents to think that swimming at this site was somehow the natural state, that the current condition is unnatural, and that this change must be someone's fault.

In reality, all that is occurring is the inexorable action of natural processes that began when the glaciers receded from the region some ten millennia ago: a marsh is being deposited at the south end of Cayuga Lake - by an accumulation of shallow sediments that will eventually, without our intervention, be occupied by aquatic vegetation such as sedges, rushes and cattails.

The erosion that is depositing these sediments is an accelerated version of the process that formed our beautiful gorges and waterfalls. Those who enjoyed swimming at Stewart Park were lucky. They lived during the period of a few decades between the filling of the natural marsh and the point at which sediment accumulation at the edge of the park became so great that swimming was no longer possible.

The marsh is the natural condition. If the residents of Ithaca and Tompkins County don't like the marsh that is building off the shore at Stewart Park, then it will be necessary to fight back the forces of nature. It is a decision that should be considered only with the knowledge that this really is the action that is being proposed: to keep the lake shoreline in an unnatural state that we as users of the resource prefer.

There is no question that unnaturally high erosion in and along the tributaries should be curtailed by good land-management practices. This will reduce but not stop the rate at which the marsh is being built. We cannot, however, and I assume do not wish to halt farming, building new homes, schools and recreation sites in Tompkins County; some human accelerated erosion will always occur.

Natural erosion can be reduced by better watershed and channel management practices. Whatever our decision as a community, gravity will continue to make water flow downhill, natural erosion will continue, and sediments will continue to enter the lake and accumulate along the shore. We can influence the rates, but at some level we have no choice but to accept the process.

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