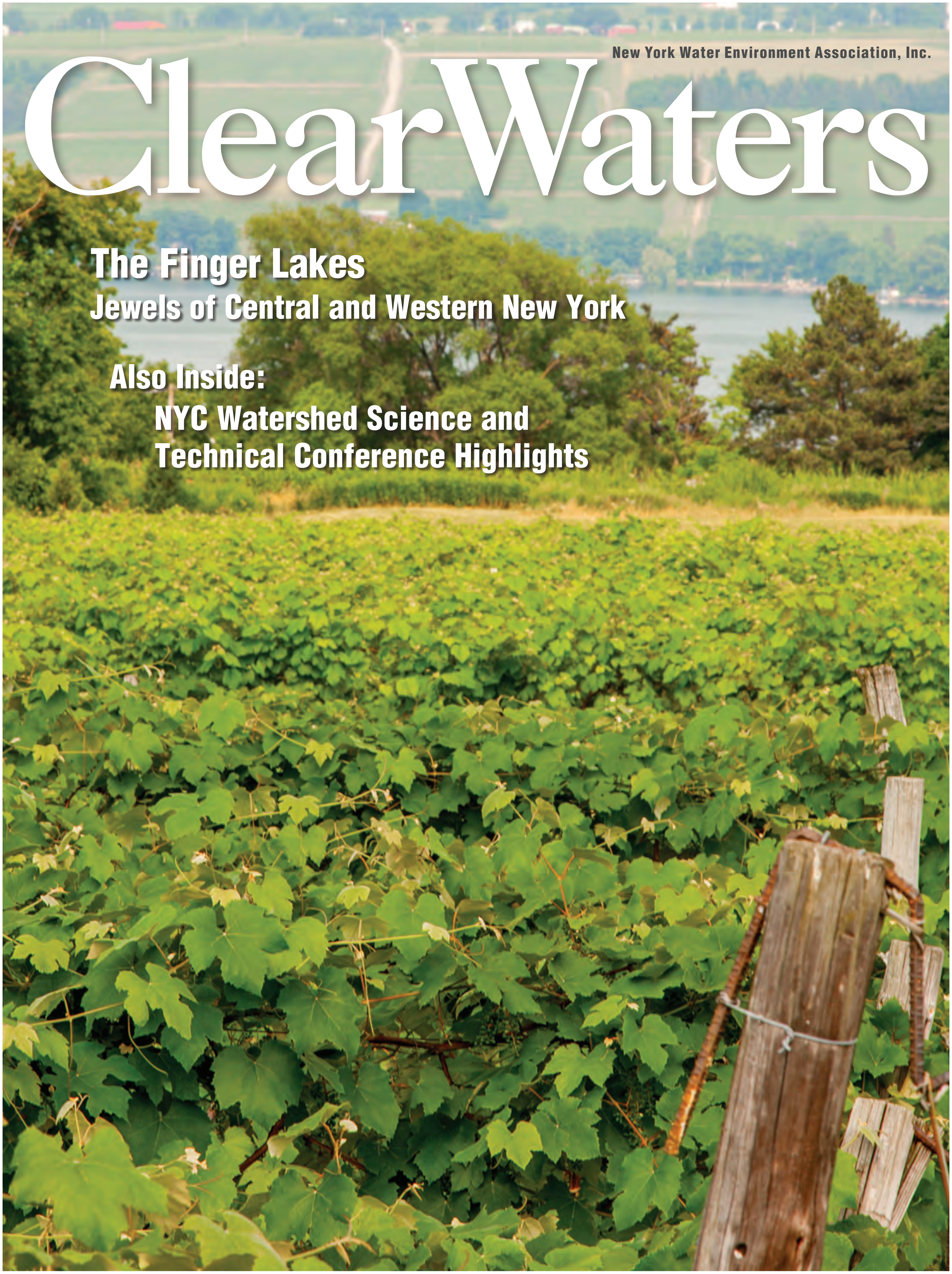
Fall 2017, Vol. 47, No. 3

New York Water Environment Association, Inc.

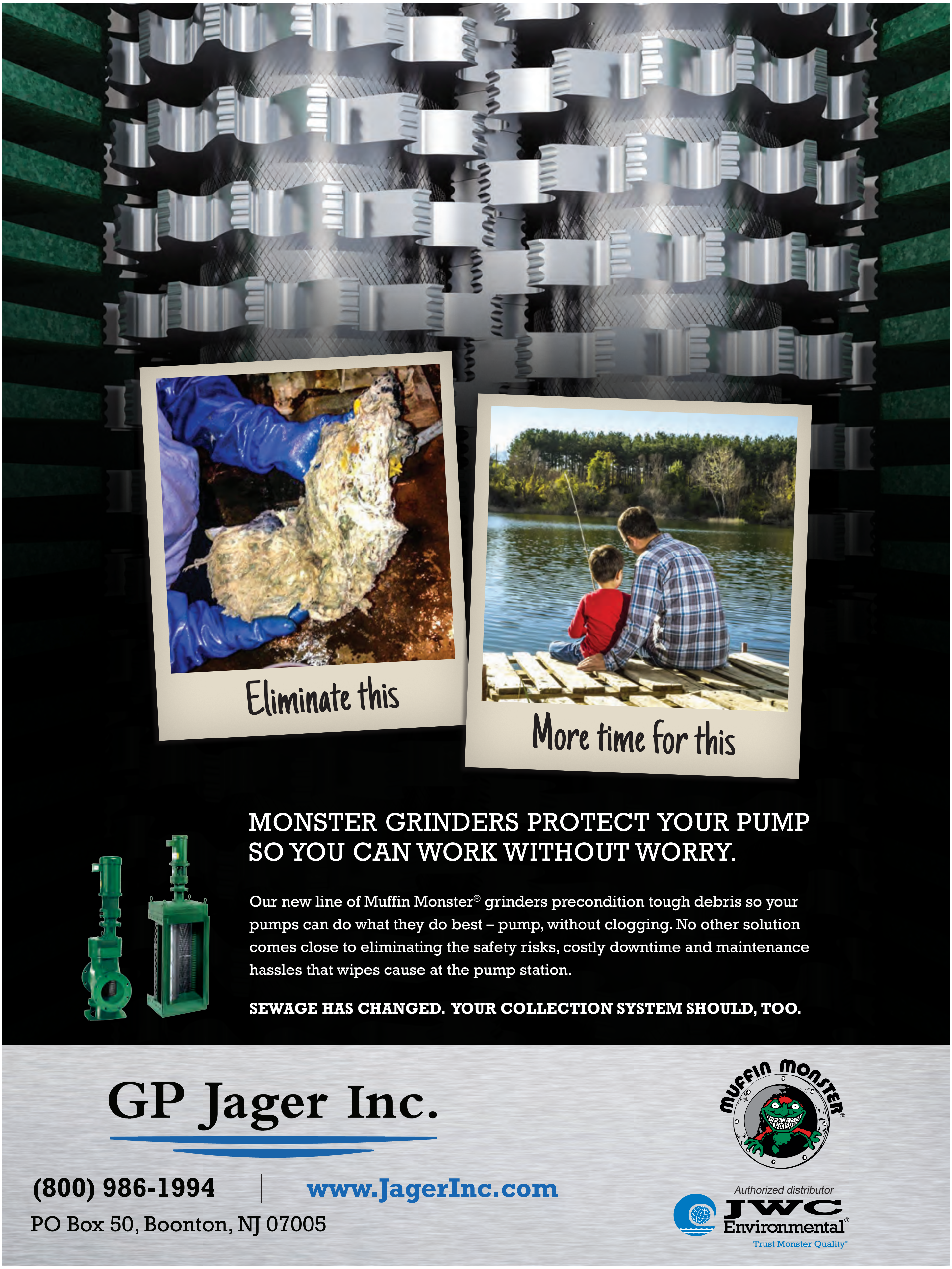
ClearWaters



The Finger Lakes
Jewels of Central and Western New York

Also Inside:

NYC Watershed Science and Technical Conference Highlights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Clear Waters

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Cover: The Finger Lakes, located in the heart of New York state, were carved into the landscape by glaciers over 10,000 years ago. The 11 long, narrow lakes eventually discharge north to Lake Ontario. Outdoor recreational activities abound, from hiking, boating and fishing to snowshoeing and skiing. In addition to the natural beauty of the region, including Letchworth Falls (the "Grand Canyon of the East") and numerous state parks and waterfalls, the area is also a world-class wine region. The lakes provide a moderating influence on the climate of the surrounding watersheds, contributing to growing conditions that are highly suitable for grape production, particularly the cool-climate varieties such as Riesling, Gewürztraminer, Cabernet Franc and Pinot Noir.

Photo: istockphoto.com, by AvatarKnowmad. (Source: New York's Finger Lakes Tourism Alliance)

Clear Waters (USPS 004-595) (ISSN 01642030) is published quarterly with a directory every four years in the fall by the New York Water Environment Association, Inc., 525 Plum Street, Suite 102, Syracuse, NY 13204. Subscription is through membership; public subscription is $25.00/year. PERIODICALS postage paid at Syracuse, NY. POSTMASTER: Send address changes to the New York Water Environment Association, Inc., 525 Plum Street, Suite 102, Syracuse, NY 13204. Ph: 315-422-7811, Fax: 315-422-3851.

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President's Message | Fall 2017

We are getting to my favorite time of the year: fall in New York. I hope that everyone had an opportunity to enjoy time outdoors this summer with friends and family, despite what seemed like rain every other day. It was a busy summer for many NYWEA chapters who hosted social events, picnics and golf outings.

2017 Chapter Exchange

On July 19th NYWEA hosted its fourth annual Chapter Exchange and Financial Best Practices Workshop. CHAPEX 2017 was an enormous success because we had great participation from all seven of NYWEA's chapters. Enthusiastic volunteers from each chapter were eager to share their experiences and learn from others. I want to thank everyone that participated in CHAPEX 2017, for taking time out of your busy schedules to participate in this lively exchange of information.

As many may not be familiar with what happens at CHAPEX, I want to provide a summary of this year's meeting. The event took place on a beautiful day at the Onondaga Lake Visitor Center where a couple of dozen NYWEA volunteers and staff gathered in person or via teleconference.

The first part of the meeting focused on financial best practices, including presentations by Christina Ondrako, CPA from Grossman St. Amour, NYWEA's accounting firm, and John Toepfer of Anderson Insurance, NYWEA's insurance agency. Ms. Ondrako summarized NYWEA's annual reporting procedures, the importance of succession planning in the treasurer position, benefits of chapter annual budget development, reminders of best practices for fraud protection, and the use of W-9 and 1099 forms. This information was particularly useful for the chapter treasurers present.

Mr. Toepfer stressed the need to make sure we have the right insurance policies in place for the various activities of NYWEA and the chapters. The take-away was the need for communication between the chapters and the Executive Office when chapters are planning events. The Executive Office can coordinate review of contract language and insurance needs prior to the event. As we all know, we cannot get coverage after the fact if something unfortunate happens.

The focus of the second half of the CHAPEX meeting was an exchange of lessons learned from chapter to chapter. Some of the stories were about chapter events or programs that were very successful, while other stories were about how we would do things differently next time. The group was enthusiastic, and engaged in back-and-forth dialogue on how chapters can learn from each other's experiences. Everyone came away motivated to try new things in their chapters. By networking with our peers to learn from their experiences, this meeting helps us to make sure we are doing our best to run a non-profit organization efficiently, with the goal of making NYWEA the best it can be.

2017 Watershed Conference

The 2017 NYC Watershed Science and Technical Conference took place on September 13th at Diamond Mills, Saugerties, New York, where NYWEA and its partner organizers – New York City Department of Environmental Protection (NYCDEP), the Watershed Protection and Partnership Council, and New York State Department of State – brought professionals together to exchange the latest science and ideas for protecting the New York City watershed. Lisa Melville and her team have once again organized a great conference with superb speakers. See pictures on pages 6-7.

Upcoming Events

As I write this message, we are looking forward to WEFTEC 2017 in Chicago, Illinois, in the first week of October. Water quality professionals from around the globe will converge for networking and knowledge exchange. NYWEA will be hosting a reception Sunday night, and I hope to see you there.

We are also excited to host a celebration of NYWEA's twentieth anniversary of its Scholarship Program, on October 19th at the Hall of Springs in Saratoga Springs, New York. Co-chaired by longtime scholarship event organizers Bob Butterworth and Fotios Papamichael, this event will honor U.S. Rep. Paul Tonko, Onondaga County Executive Joanie Mahoney and NYCDEP Acting Commissioner Vincent Sapienza, P.E., for their contributions to the water environment. Please plan to join us at what is sure to be a memorable celebration.

New York's Finger Lakes

From Niagara Falls in the west to the Long Island Sound in the east, and everywhere in between, New York has so many areas to explore and enjoy. The Finger Lakes Region is certainly near the top of many lists of places to live and visit. Home to 11 glacial lakes and covering 9,000 square miles, the region has an impressive offering of cultural, historical, culinary and outdoor activities to entertain just about everyone. I was surprised to learn from New York's Finger Lakes Tourism Alliance website that the region has over 1,063 waterfalls and gorges, a 16,036-acre national forest, and over 100 wineries, to name just a few of the region's impressive attributes.

This issue of *Clear Waters* focuses on the Finger Lakes, including articles on long-term water quality trends, algal blooms, modeling for ecosystem-based management, dam restoration and a regional solution to protect water quality. There is also an article on the Finger Lakes Water Hub, established in 2016 and overseen by NYSDEC to address water quality issues, integrate technical knowledge and help identify funding for projects to protect drinking water sources in the Finger Lakes.

The Clear Waters App

Please remember that *Clear Waters* is now available on a mobile app, allowing our members to read the magazine on their smart phones and tablets. For more information on how to log in, see the ad on page 5.

Paul J. McGarvey, PE, NYWEA President

Executive Director's Message | Fall 2017

Change Leads to Progress!

It was while I was in Washington, D.C. at the WEF/AWWA Fly-In, with NYWEA's Legislative Liaison Leah Harnish, that the idea came to mind: Let's strengthen our voice on the state level by having one individual *help all three organizations* – NYWEA, the New York Section American Water Works Association (NYSAWWA) and the New York Rural Water Association – to establish lines of communication with elected officials and help write/research policies affecting water quality. I am so pleased that all three organizations could come to agreement and hire Leah Harnish to be our Legislative Liaison. She has been busy, and I believe she is finding it rewarding to work for three environmental organizations with very important, similar missions.

Continuing on our organizational collaboration, representatives from New York Rural Water, NYSAWWA, Riverkeeper and NYWEA met over the summer with the Deputy Director for Environmental Programs in the Governor's Office to get a better understanding of how monies will be awarded and allocated for the $2.5 billion in the Clean Water Infrastructure Act of 2017 and the $225 million in grants under the Water Infrastructure Improvement Act of 2017. Although we still have some unanswered questions, it is delightful to see the support for water infrastructure in the state budget at unprecedented levels.

Working with Civil Service

I am often contacted by members who have innovative ideas for ways to improve on how things get done. Recently, I was contacted by Tim Murphy, Executive Director of the Albany County Water Purification District. He had recently experienced a 33 percent loss in the labor force at his plants due to a combination of retirements, relocations and (unfortunately) untimely deaths. Civil Service held exams and provided Tim with a candidate list that was quickly exhausted. Not only that, the utility still has six operators on provisional lists waiting for the next exam. Sound familiar? As many of you know, there is a desperate need for operators to train, and it takes time to interview, get approvals and back-fill positions. Tim's example was shared in a meeting with the New York State Department of Civil Service representatives. It is our hope that some changes can be made that will alleviate the burden faced by numerous municipalities. Tim has spearheaded this initiative, and will be working with the members of the Utility Executives Committee on a parallel project to streamline job titles and descriptions to make it simpler for operators to move from one utility to another more easily. Civil Service has indicated they will work with us; however, much work still needs to happen. We will keep you posted on our progress. In the meantime, if you have questions about this please contact Tim Murphy directly at 518-447-1611 or *Timothy.Murphy@albanycountyny.gov.*

Finger Lakes

As you will see from the articles in this issue, water quality in the Finger Lakes region is well-studied, and it is our hope that after digesting the articles, you'll be "in the know" and up to speed on what's been taking place. I'd like to acknowledge the authors and researchers of these articles for their time and effort to study and improve water quality in the Finger Lakes. Our appreciation also goes out to Aimee Clinkhammer, who spearheaded this issue and helped guide the Publications Committee on the author assignments.

As always, thank you for your work to protect public health and the environment! Here's wishing you all a wonderful fall season!

Patricia Cerro-Reehil, pcr@nywea.org

Saugerties, New York

Highlights of NYC Watershed Science and Technical Conference

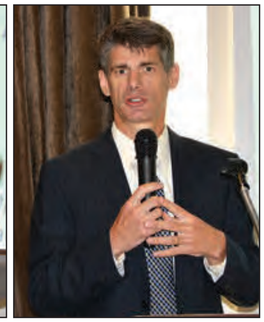
"Water Quality Issues in the NYC Watershed and Beyond"

Over 200 people attended the NYC Watershed Science and Technical Conference in Saugerties, NY, on September 13, 2017. The meeting featured six comprehensive technical sessions that covered water quality issues in New York City's watershed and beyond. NYWEA was joined by its organizing partners: NYC Department of Environmental Protection, the Watershed Protection and Partnership Council and the NYS Department of State. The conference co-sponsors included the Catskill Watershed Corporation, NYS Department of Environmental Conservation, NYS Department of Health, the U.S. Geological Survey, and NYWEA's Lower Hudson Chapter.

NYWEA President Paul McGarvey welcomes everyone to the meeting.

Lisa Melville, NYSDOS, introduces the NY Secretary of State.

Rossana Rosado, NY Secretary of State, shares her thoughts on the importance of water quality.



Paul Rush, Deputy Commissioner for Water Supply, NYCDEP

Chitra Gowda from Conservation Ontario gives the keynote address explaining about how the Government of Ontario has handled water quality issues and the protection of public health.

Elizabeth Denly (left) and Mike Eberle from TRC Solutions talk about PFAS.

Linh Hoang speaks on the Cannonsville Watershed.

Kirk Barrett, Manhattan College Department of Civil and Environmental Engineering

Right: Rakesh Gelda, NYCDEP

Karen Moore, NYCDEP

Steven Schindler, NYCDEP

Kara Pho, CH2M

David Van Valkenburg, NYCDEP

Left: Tim Clayton, Surpass Chemical

All attention is on the speaker at the Opening Session.

(L-r:) Patricia Cerro-Reehil, Maggie Hoose and Lisa Melville


Phil Eskeli, NYCDEP


Rajith Mukundan, NYCDEP


Kyongho Son, NYCDEP


Ira Stern, NYCDEP


Andrew Kricun, Camden County


Dave Tobias, NYCDEP


Jiayu Liu, USEPA


Rich Van Dreason, NYCDEP


Kinsey Hoffman, Hazen & Sawyer


Emmet Owens, NYCDEP


Bill Richardson, NYCDEP


Paul Rush, NYCDEP and Jamie Howard, DN Tanks


Andrew Kricun, Camden County; Janice Whitney, USEPA; William Gilday, NYSDOH; and Mark Wysocki, Cornell University

Jim Hyman, Presby Environmental


Lisa Melville and Dave Warne


Left, David Stahl, HDR and Russ Dudley, Tetra Tech


Above: Members of the NYCDEP Watershed Warriors stand proudly together after their pipe cutting demonstration. (L-r): Matt Burd, Adam Reaves, Erik Coddington (Coach), Eric Albano, Bruce Decker and Kenneth Taylor (Captain)


Right, foreground (l-r): Joe Fiegl, John Fortin and Robert Wither enjoy the good weather.


Robert Wither, NYSDEC, and Deborah DeGraw, NYCDEP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Water Views | Fall 2017

Finger Lakes Stewardship

Home to over a million people, the Finger Lakes region is prized for its beauty, wine, fishing and recreational tourism. All but one of the Finger Lakes are public drinking water supplies. As with many lakes, there are water quality issues that must be understood and addressed. To bring an enhanced, holistic focus to the Finger Lakes, to develop institutional expertise and to expand community collaborations, NYSDEC recently created the "Finger Lakes Water Hub."

The Hub is NYSDEC's center of activity to better understand, protect and address the water quality issues confronting the Finger Lakes. The Hub is composed of four experts stationed in NYSDEC's Syracuse office who operate throughout the region. The Hub takes a collaborative approach, as maintaining water quality and ecology is necessarily a team effort. This past summer, the Hub team met with key stakeholders to learn about the specific issues affecting each lake.

To build on the existing passion and drive for protecting and restoring the Finger Lakes, the Hub staff coordinate with existing NYSDEC water programs, such as the harmful algal bloom program, the Great Lakes program, and watershed-based scientific monitoring and assessment activities. Hub staff are working to connect state agency programs with the work of research institutions, local governments and civic organizations, and will work with key stakeholders to develop strategies for individual Finger Lakes.

Starting this fall, Hub staff will work collaboratively with stakeholders to develop a Finger Lakes Action Agenda to align new priorities with existing environmental, social and economic goals. The Action Agenda will guide conservation, restoration and protection efforts for the Finger Lakes region. Action agendas for priority watersheds are useful tools to ensure stakeholder ideas, interests and concerns are factored into decisions and priorities. The Finger Lakes Action Agenda will be linked to the larger Great Lakes Action Agenda and the national Great Lakes Restoration Initiative, as the Finger Lakes are wholly within the Great Lakes watershed.

The Hub and its collaborators have already made considerable progress. The Hub successfully secured funding for the Finger Lakes to participate in the Citizens Statewide Lake Assessment Program (CSLAP), which monitors two sites on each of the 11 lakes during the summer months. This data will provide lake-specific water quality information to agencies, municipalities and other stakeholder groups. Furthermore, staff are currently overseeing a cover crop project and a pilot soil-loss calculator in the eastern Finger Lakes watersheds to help farmers reduce nutrient runoff from their fields. The team has been hard at work on initial watershed management plans for several Finger Lakes, as well as developing a comprehensive research strategy for the region.

I encourage you to read the article by Hub member Aimee Clinkhammer in this issue of *Clear Waters* to learn more about the Hub function and staff.

– James Tierney, Deputy Commissioner for Water Resources
NYS Department of Environmental Conservation

Focus on Safety | Fall 2017

This Bloom Isn't a Flower

Blue-green algae, or cyanobacteria, is a phylum of bacteria capable of photosynthesis. In high concentrations (blooms), cyanobacteria can discolor the water and cause levels of toxicity that are potentially harmful to people and animals. Known as harmful algal blooms (HABs), these usually occur in nutrient-rich, slow-moving surface waters, particularly during hot, calm weather. The New York State Department of Environmental Conservation (NYSDEC) has an informative Harmful Algal Bloom program, based on 'Know It', 'Avoid It', and 'Report It.'

Members of the public who live, work or recreate on surface waters must be able to identify a bloom by color, pattern and effect on surface waters. The NYSDEC and USEPA websites provide color photos of the various forms of HABs to help in identification. Some blooms look like pea soup, mats, green paint, or have a 'planked' appearance. If you suspect HABs in a lake or pond, do not enter that body of water.

Because it is hard to tell a HAB from non-harmful algal blooms, it is best to prevent accidental ingestion and contact by avoiding swimming, boating, fishing or eating fish, or otherwise recreating in or drinking suspect water. Pets and livestock should also avoid contact with blooms, as their grooming activity will lead to ingesting cyanobacteria, resulting in serious adverse effects. A little due diligence beforehand will help to avoid HABs. NYSDEC has a Notifications Page of waterbodies with HABs. If the waterbody is listed, look at the specific location and plan accordingly. Even if a waterbody is not specifically listed, it cannot be assumed that it is safe. New York state has about 7,000 lakes, and not all of them have a visual monitor.

Water from sources experiencing a bloom must not be used to prepare or cook food, drink, make ice, shower or launder. Surprisingly, the conventional means to disinfect water have no effect on the HAB's toxins. Neither boiling, chlorination nor treatment with ultraviolet light will eliminate the toxins. This is the reason for avoidance as the primary method of protection.

Sometimes, however, a person must enter the water for work-related activities or remediation. In this case, workers must exercise extreme care, using personal protective equipment to avoid water contact, then immediately rinsing/cleaning upon exiting using clean water from a different source. Protective equipment could include tall boots or hip waders, a rain suit and, in some cases, a face mask for protection from aerosol exposure. Rinsing contaminated clothing and skin is paramount to prevent direct exposure.

Summer is a great time to enjoy the lakes and other surface waters of New York, but Mother Nature may have other plans. If you suspect that you have seen a HAB, NYSDEC encourages the public to report the bloom to the HAB Notifications Page. If you have experienced any health symptoms, report that information to both your local and state health departments.

– Eileen M. Reynolds, Certified Safety Professional
Owner, Coracle Safety Management

Two and Half Decades Ago … Revisiting the Finger Lakes

by Robert Brower

I had the privilege to provide an article to *Clear Waters* twenty-five years ago, in 1992 (Volume 22, Issue #2), which began with the words: "The Finger Lakes Region, in the heart of New York state, is the center of innovative institutional and technological efforts to conserve and manage the waterbodies and lakes of the area." The institutional innovation I was writing about was the 18-county Water Resources Board (WRB) that was meeting at the Finger Lakes Tourism Alliance's headquarters in Penn Yan, New York, on the shores of Keuka Lake.

The technological innovation I referred to was the use of geographic information systems (GIS). GIS was being made available through the WRB to support the complicated decision-making required for effective watershed management by its local government (county) members. I was also excited about the potential GIS held for improving our understanding through the use of complex spatial hydrology models, which could help direct our local decision-making. The combination of land-based simulation models and in-lake mixing models would bring an understanding that, in theory, could allow us to project and compare the impacts of various management decisions. This in turn would increase our capacity for generating appropriate public policy decisions, as well as related individual decisions that are made by those of us living throughout the watershed of the Finger Lakes.

In my 1992 *Clear Waters* article, I noted the existence of conflicting watershed land management goals made worse by "… related and very complicated institutional questions …." The counterbalancing potential of "… the first attempts at simulation models …" and the need for "… consensus on the classification of data to characterize watersheds … ." were noted as well. Finally, I emphasized the vital importance of "… organizations, coordinating programs and data exchange between involved entities … ."

The conclusions I drew from these observations included the need for "… increased funding, and recreational industry involvement, and other segments of the private economy, cooperative multi-jurisdictional, multi-disciplinary programs such as represented by the WRB … ." I predicted that the "… technological advantage of GIS integration into watershed management would facilitate an explosion in understanding perhaps equal to that which is required for the stewardship of this magnificent area … ."

I concluded my 1992 article with: "The seeds of these approaches have been planted in the Finger Lakes Area. They will grow if the informed and educated populace nurtures them. They will spread wider if those from other areas borrow what has been started and improve it with additional insight, involvement and effort."

"They will spread wider if …"

In 1996, the 18-county WRB program evolved into the Finger Lakes-Lake Ontario Watershed Protection Alliance (FLLOWPA) and has remained funded, largely uninterrupted, over the past 25 years. The WRB has continued as the managing board for FLLOWPA, although its base of operations has moved to the Oswego County Soil and Water Conservation District's office in Fulton, New York. FLLOWPA's regular meetings, regional workshops and conferences provide forums for county water resource managers to exchange data, information and knowledge. Even after 25 years, the organization's potential is still charged by its interdisciplinary and multi-jurisdictional nature, serving as a mechanism to resolve competing land management goals on a watershed basis, across county boundaries, in a collaborative organizational structure.

Given the current distribution of water resource management responsibilities – and the consequent fragmentation of authority – collaboration is now the only way to protect and restore these magnificent waterbodies. And the institutional landscape in which FLLOWPA now works has become even more complicated since 1992 ***(Figure 1)***. Consider, for example, just five of the governmental and non-governmental entities with which the Owasco Watershed Lake Association (OWLA) routinely interacts. Note also that all but 20 percent of Owasco Lake's watershed is in Cayuga County, and Cayuga County is just one of the 25 FLLOWPA members. ***Figure 1*** shows the five major entities.

Since this organizational chart was created in early 2016, a new entity has joined the group. In October 2016, the newly created and critically important Finger Lakes Hub in the New York State Department of Environmental Conservation (NYSDEC) brings an additional, state-level focus to the Finger Lakes. At the helm is Scott Cook, a highly experienced Program Manager, directing the work of Watershed Coordinator Aimee Clinkhammer, Senior Research Scientist Lewis McCaffrey, and Research Scientist Antony Prestigiacomo.

At the local level, Cayuga County, the City of Auburn and the Town of Owasco have created the Owasco Lake Watershed Management Council (OLWMC). The OLWMC held its first meeting in March of 2011 and, after working for several years, has formalized as a not-for-profit corporation. The OLWMC is comprised of voting policy-makers (elected officials) representing local governments that contribute the resources to support and oversee the activity of the Owasco Lake Watershed Inspection Program (OLWIP). Its membership has been expanding to add local elected officials from the six shoreline and eight additional watershed towns, and now includes the towns of Scipio, Fleming and Niles. In New York, land use control is vested at the municipal (town, village and city) level. Since effective watershed management cannot be done without land use control, local organizations of elected municipal officials are critically important to the success of lake protection. OLWMC joins the Cayuga County Water Quality Management Agency (WQMA) in the current local water management landscape.

The WQMA is a county agency, created in the 1980s, made up of professional governmental program managers with water resource management responsibilities; institutional and academic representatives with related expertise; and citizen-based lake associations such as the Owasco Watershed Lake Association (OWLA). The WQMA includes the critical presence of agricultural program managers, as well as a board member from the Cayuga County Soil and Water Conservation District and representatives from both the Cayuga County Association of Town Supervisors and the Cayuga County Association Villages. Agriculture is the dominant land use in the Owasco Lake watershed and is essentially exempt from complying with the 1972 Clean Water Act. The regulatory and advocacy fabric in which agriculture exists in the Finger Lakes is mature, complicated and extremely powerful at both the State and local governmental levels.

A Look Back at the Problems: Eutrophication

In 1992, we were gauging the condition of the Finger Lakes primarily on a eutrophic, or lake-aging, scale. Limnologists had taught us there were too many nutrients going into the lakes, and from a planning perspective it wasn't much of a leap to discover that nutrients had to be managed in the watershed to prevent them from entering the lake. In the short term, primary point sources, such as the water resource recovery facilities (WRRF) that discharge to the Owasco Lake Inlet, were identified and eventually mitigated. It has been nine years since the Village of Groton installed phosphorus treatment at its WRRF. By that time, the WRRF serving the Village of Moravia had been using a high level of treatment to reduce phosphorus discharge for more than a decade *(NYSDEC 2016)*. The long-term approach was to limit the nutrient loading of the lakes by managing the land in the watersheds. Work was underway throughout the region to monitor the streams and tributaries not just generally for nutrient loading but particularly for phosphorus.

The formula for Owasco Lake was clear: limit the loading of phosphorus, and the aging of the lake (eutrophication) would slow down, hopefully to a natural time scale. In Cayuga County, we were trying to keep our middle-aged Owasco Lake young, hoping perhaps we could even reverse its aging, not just slow it down.

Eventually we learned the importance of measuring phosphorus in two ways: total phosphorus (TP); and the dissolved, or soluble reactive, phosphorus (SRP). We learned that TP sank to the bottom of the lake and was available to rooted lake vegetation, while the SRP dissolved in the water column and was available to floating algae. The goal was to impede and reduce the spread of aquatic vegetation by harvesting as much vegetation as was practical, while at the same time reducing the loading of phosphorus from the streams and tributaries. The vegetation of primary concern was an invasive species, Eurasian watermilfoil *(Myriophyllum spicatum)*. Since SRP was a portion of TP, it seemed logical that if you drove the TP loading down, the SRP loading would also be diminished. We expected that diminished SRP concentrations in the lake would lead to diminished algal blooms.

Hard data that tests this applied logic is difficult to develop. Algal blooms are ephemeral by their nature. They can develop and dissipate in minutes, hours or days. Anecdotal observation is bound to be biased toward the detection of longer-duration blooms, since the likelihood of observation would increase with duration. Of course, this logic assumes an equal vigilance in surveillance over time.

With a surface area of approximately 10.5 square miles, it is similarly difficult to make a comprehensive inventory of aquatic vegetation and assess long-term infestation in Owasco Lake. A 2007 study by Dr. Bruce Gilman and Dr. John Foust references the range of factors correlated with aquatic vegetation growth and the difficulties of interpreting those factors *(Gilman et al., 2008)*. The researchers point out that: "Some substrate conditions were associated with estimated annual production while others were not. Percent organic matter, largely the result of *in situ* growth, was

continued on page 12

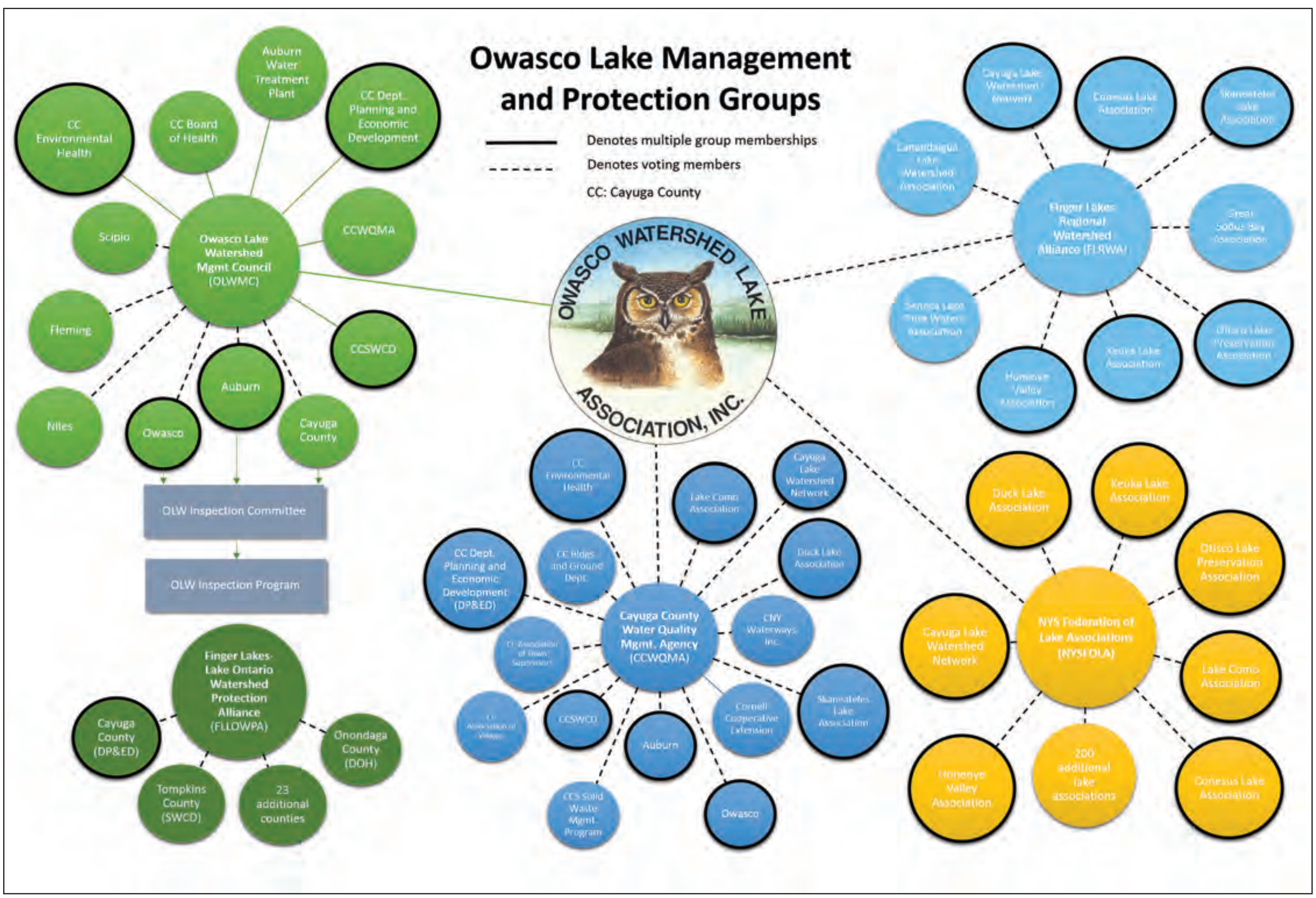

Figure 1. Owasco Lake Management and Protection Groups *Kerry McElroy*

continued from page 11

positively correlated with estimated annual production. The variable pattern in total phosphorus was not correlated to estimated annual production probably due to adequate amounts of this nutrient being available for aquatic plant growth even at the lowest concentrations detected."

A more recent summary assessment of Owasco Lake by NYSDEC, based on the work of multiple limnologists and institutions, does provide some insight. The NYSDEC Owasco Lake Assessment narrative *(NYSDEC 2016)* contains the following reference to such efforts: "These studies indicate that the open water conditions in the Lake continue to be best characterized as mesotrophic, or moderately unproductive. Phosphorus, chlorophyll and clarity measurements are somewhat elevated but typically fall below levels that would suggest impacts to recreational uses. Reports of HABs in portions of the Lake have increased in recent years, though algal blooms in the Lake have long been noted and the increased reports may be at least partially the result of increased awareness." While there is uncertainty about whether the spatial extent and frequency of algal blooms in Owasco Lake have increased, there is no doubt that awareness has increased, particularly around the one type referred to often as a Harmful Algal Bloom (HAB).

The Current Issues: A Case Study of Owasco Lake

Watershed management in the central Finger Lakes is still dominated by legacy resources conceptualized initially to reduce the rate of nutrient loading, mitigate the spread of Eurasian watermilfoil, and slow down the aging of the lake. These legacy resources support the further development of limnological understanding and watershed management techniques. Best management practices (BMPs), for example, serve these purposes when applied in the watershed. Organizational relationships are helping to translate scientific understanding into public policy. Finally, the human and financial resources are continually sought to administer and carefully balance a sustainable blend of authority and assigned responsibility.

However, the institutional and technological landscape has changed dramatically since 1992, along with the physical changes that have occurred throughout the watersheds and consequently in the lakes. These changes, and the emergence of new and very serious management challenges, now face this region. Let's consider the current conservation and restoration challenges by exploring the activities of one lake association – the OWLA – which are representative of the water resource issues confronting many Finger Lakes communities. OWLA is a citizen-based association that works as a catalyst to promote cooperation and leadership in the comprehensive management of land use, water quality, recreation, agriculture and a host of other issues as they pertain to Owasco Lake and its watershed.

OWLA's Stewardship Activities as Related to Cyanobacteria

The increasing frequency of what many call HABs in Owasco Lake has heightened concerns for the future viability of the lake's use as the primary drinking water source in Cayuga County. The HABs in Owasco Lake are actually an organism called cyanobacteria that has bloomed more often in the past few years. The state of New York provided $2 million to add special treatment processes to the pumping stations and filtering processes in the water treatment plants in the Town of Owasco and the City of Auburn. These additional processes became operational in August of 2017.

HABs have also derailed recreational use of the lake; one of the locations affected has been the public beach at Emerson Park. Boaters and shoreline property owners are advised to stay out of the water if it is not clear.

OWLA's stewardship has expanded to include support for the added water treatment processes and repeated efforts to capture more funds for nutrient loading reduction. But now, because of work done in the Cayuga Lake basin over the past five years, OWLA has intensified its focus and changed its approach. Instead of analyzing water samples for TP and SRP, as described earlier, OWLA is working with the Upstate Freshwater Institute (UFI) in Syracuse to estimate Biologically Available Phosphorus (BAP). BAP is a form of phosphorus that is more directly available to cyanobacteria and algae. In other words, it is a subset of the TP and the SRP that can be traced back to sub-basins by sampling at the mouths of the tributaries. OWLA's management goal now is to reduce – and ultimately eliminate – HABs, a decided change from the goal of slowing and then reversing the rate of cultural eutrophication and the expansion of aquatic vegetation that guided public efforts in 1992.

OWLA met in July of 2017 to review the first Owasco Lake BAP estimates with Dr. David Mathews of the UFI. The locational focus of this work includes the tributaries of Dutch Hollow Brook, Vaness Brook and Sucker Brook. The latter two enter the lake at its north end, in proximity to the drinking water intakes for the City of Auburn and the Town of Owasco. Dutch Hollow Brook enters north of the midway point on the east side of the lake. These areas have all experienced HABs that were toxic in 2016, which resulted in the detection of trace amounts of the associated toxin in public drinking water, even after treatment.

OWLA and the Expansion of Citizen Science

OWLA now has an active group of volunteers, trained by NYSDEC Research Scientists in the Division of Water. Under the leadership of Dr. Rebecca Gorney, some 35 members monitor 24 shoreline zones as part of the NYSDEC 2017 HAB Shoreline Surveillance Program. Under the leadership of Scott Kishbaugh, volunteers have been trained to do regular deep-water sampling from boats as part of the Citizens Statewide Lake Assessment Program (CSLAP). Under the leadership of Anthony Prestigiacomo and Scott Cook, of the newly established NYSDEC Finger Lakes Hub, OWLA volunteers are trained to collect tributary samples and undertake flow measurements in accord with the provisions of the applicable Quality Assurance Project Plan. Volunteers also work closely with Tim Schneider and Andrew Snell of the Owasco Lake Watershed Inspection Office, reporting suspected blooms and undertaking special event-based sampling.

A New York state grant, administered by NYSDEC, supports most of these efforts. OWLA collaborators work on grant funding with NYSDEC Research Scientist Karen Stainbrook. The 2015 grant was provided thanks to the leadership of state senator John A. DeFrancisco and a team of Finger Lakes elected officials at the local and state level: Michael Quill, mayor of the City of Auburn; Ed Wagner, Owasco town supervisor; Keith Batman, chairman of the Cayuga County Legislature; and the town boards of all six towns that make up the Owasco Lake shoreline. The resulting grant-supported program dedicates more than half of the grant's $600,000 to land-based efforts designed to reduce nutrient loading.

OWLA's volunteer citizen science work supplements the efforts of other Finger Lakes scientists. For example, a deep-water buoy *(http://fli-data.hws.edu/buoy/owasco/)* has been deployed for the past several years by Dr. John Halfman, professor of geolimnology and hydrogeochemistry at the Finger Lakes Institute at Hobart and William Smith Colleges. In 2016 two shallow-water buoys were deployed under the guidance of Dr. David Mathews at the UFI. The buoys provided data descriptive of a range of geochemical dynamics that are important to the understanding of conditions in the lake and to increasing the understanding of what triggers a cyanobacterial bloom.

OWLA's larger role as a citizen-based organization, representing the voice of the lake, is to bring its growing militia of volunteers forward in support of the long-range goals detailed in the "Owasco Lake Watershed and Waterfront Revitalization Plan," published in 2016 under the thoughtful guidance of Dr. Elizabeth C. Moran and Elizabeth Myers of EcoLogic LLC *(EcoLogic LLC 2016)*.

Local Use of GIS to Target Watershed Restoration Projects

The explosion of understanding that I anticipated in 1992 from GIS deployment in simulation loading/mixing models in the Finger Lakes remains a largely under-realized potential at the local level. Guidance is being provided by the Cayuga County Planning Board, where Principal GIS Analyst Nick Colas has been working with a group comprised of OWLA, the Cayuga County Soil and Water Conservation District and the Owasco Lake Watershed Inspector's Office. Progress is being made on the use of GIS to locate areas at a project level, within the target sub-basins that have the highest potential to reduce phosphorus loading. This has been fueled largely by the availability of more accurate landscape elevation data created from remote-sensing Light Detecting and Ranging (LiDar) and the digital elevation models subsequently created using LiDar data. This provides the detail to identify areas (based on natural features) that must then be field-checked by staff before final determinations can be made on project viability, designs and costs.

This use of GIS as a decision-support tool has just begun. Fifteen candidate sites were delineated using the GIS, then the team contacted land owners. The Cayuga County Soil and Water Conservation District staff visited the sites, designed appropriate BMPs, and the first two projects were completed in the spring of 2017.

GIS use is indeed being deployed throughout the Finger Lakes at the local level for natural resource management, planning, asset management, project design, tax parcel data and a host of other applications. But the single body of Finger Lakes-wide spatial knowledge has not yet been deployed. Agreement has not been reached on the classification of data descriptive of the watersheds. The resulting simulation of loading and mixing that could drive an explosion in understanding has simply not developed, despite the optimism of my 1992 *Clear Waters* article.

But something very special is occurring. In the spring of 2017, NYSDEC announced deployment of the on-line "DECinfo-Locator", described on the NYSDEC website as "… a map-based way … to view and download water permits, water quality data, and information about clean-up activities ..." for a selected location. The Owasco Lake Watershed areas in Tompkins and Cayuga counties were included in this exciting prototype *(http://www.dec.ny.gov/pubs/109457.html)*. Perhaps the simulation models will not be far behind.

Conclusion

The need to understand more about why and how the cyanobacteria bacteria blooms are occurring is important for the development of an effective strategy that eliminates the presence of these HABs in Owasco Lake and in the Finger Lakes. The availability of a safe and reliable water supply is essential to our biological and community survival. Efforts to remove toxins by treating public drinking water when it is first pumped from the lake are being completed in both municipalities that draw from Owasco Lake. As this article is being written, we may be only weeks away from knowing if this first response is to prove effective. Testing for the presence of toxins in the drinking water is, of course, continuing.

The equally important work to understand more completely where and when blooms are happening in the lakes is also developing. Even before the precise cause and effect is completely understood in the lakes, research efforts are establishing correlations with phosphorus in certain biologically available forms. Geospatial technology is helping us learn how to find the source of this type of phosphorus in the sub-basins so best management practices can be applied on the land. The results of sampling at the mouths of the tributaries is providing estimates of the baseline loading so that the effectiveness of targeted land-based efforts can be determined.

The episodic contamination of our drinking water by the toxins released from HABs creates an urgency felt by everyone. So, despite our efforts over the past 25 years to understand and mitigate water resource problems, we now face a new crisis.

There are new and significant resources involved at the state level in the form of the NYSDEC Finger Lakes Hub. There is an expanding volunteer militia of citizen scientists collecting and providing important data. The attention of elected officials at local, state and federal levels has been captured. Will the next 20 years bring further degradation to the magnificent Finger Lakes or will the lessons from our history of collaboration over the past 25 years guide us all to the successful protection of our drinking water?

Robert Brower served as the Program Manager of the WRB from its creation until 1996, leaving to become the Director of Planning and Economic Development for Cayuga County. He retired with 32 years of service to Cayuga County in 2002 to become the CEO of the Institute for the Application of Geospatial Technology (IAGT) at Cayuga Community College. He retired from this position in June of 2017. He is currently the President of the Owasco Watershed Lake Association (OWLA) and serves as a volunteer at IAGT. He may be reached at rnelsonbrower@gmail.com.

References

EcoLogic LLC. 2016. *Owasco Lake Watershed Management and Waterfront Revitalization Plan*. Auburn, New York: Cayuga County Department of Planning and Economic Development.

Gilman, B.A., J.C. Foust, and B. Zhu. 2008. "Composition, seasonal standing crop biomass and estimated annual productivity of macrophyte communities in Owasco Lake." In *A Water Quality Study of Owasco Lake, New York 2007,* edited by Halfman, J.D., M.E. Balyszak, S.A. Meyer, and S. Holland. Finger Lakes Institute, Hobart and William Smith Colleges, Geneva, New York.

NYSDEC. 2016. Waterbody Inventory/Priority Waterbodies List: Owasco Lake (0414020113), revised April 1, 2016. Albany: NYSDEC Division of Water. *http://www.dec.ny.gov/docs/water_pdf/wioswegoowascolk.pdf.*

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NYSDEC's Finger Lakes Water Hub

by Aimee Clinkhammer

Background

The Finger Lakes are a series of 11 freshwater lakes located in central and western New York. These beautiful and unique, glacially-formed lakes are: Otisco, Skaneateles, Owasco, Cayuga, Seneca, Keuka, Canandaigua, Honeoye, Canadice, Hemlock, and Conesus lakes. They range in size from Canadice Lake at 642 acres to Seneca Lake at 43,342 acres. The lakes also vary greatly in maximum depth, from 30 feet in Honeoye Lake to 650 feet in Seneca Lake.

Hemlock Lake *NYSDEC*

The Finger Lakes include three of the 10 largest lakes in New York state, and represent a significant asset to the Finger Lakes region as well as to the state of New York. Except for Honeoye Lake, the Finger Lakes are all used as public drinking water supplies. The Finger Lakes region is also a well-known tourist destination, generating an estimated $2.9 billion annually and supporting almost 60,000 jobs. The lakes and surrounding landscape of the region are a primary focus for tourism activity.

Like the rest of New York's waterbodies, the Finger Lakes are affected by nutrients, sediments, priority organics, micro-organisms and salts. These pollutants have the potential to impact the desired uses of these waterbodies: drinking water supply; swimming and recreation; and fish consumption. Although water quality conditions within the Finger Lakes are generally good, several Finger Lakes are on the New York State Section 303(d) List of Impaired/TMDL Waters. This list identifies waterbodies that are not fully supporting the appropriate uses and may require development of a Total Maximum Daily Load (TMDL) or a Nine Element (9E) Watershed Plan. These plans identify and quantify sources of pollutants, determine the water quality goal(s) or target(s) and the pollutant reductions needed to meet the goal, and describe the actions (best management practices) needed to achieve the reductions that will improve water quality. The New York State Department of Environmental Conservation (NYSDEC) is actively engaged in developing TMDLs for Conesus Lake, Honeoye Lake and Cayuga Lake, and a Nine Element Watershed plan for Owasco Lake. Furthermore, the state and NYSDEC have prioritized funding through the Clean Water Infrastructure Act to protect drinking water sources that may be threatened.

Creation of the Finger Lakes Water Hub

Microcystin, a Harmful Algal Bloom (HAB) toxin, was found in the City of Auburn's finished drinking water in September of 2016. The detection was below the U.S. Environmental Protection Agency (USEPA) guidance values but its presence still underscored the need for a team to focus on HABs and other water quality threats in the Finger Lakes region. Recognizing this need, Governor Andrew Cuomo announced the establishment of the Finger Lakes Water Hub in the fall of 2016.

The creation of the Finger Lakes Water Hub furthers the efforts of the governor's Water Quality Rapid Response Team to swiftly address water quality issues and develop new policies, programs and technologies to ensure clean water for all New Yorkers. This action also enhances state efforts to implement the state-funded Great Lakes Action Agenda and the federally-funded Great Lakes Restoration Initiative Action Plan, both of which geographically encompass Central New York's Lake Ontario/Finger Lakes region. Additionally, the Finger Lakes Water Hub will integrate technical knowledge and program resources with the adjacent Susquehanna River/Chesapeake Bay Watershed Implementation Plan and Mohawk River Action Plan. The Finger Lakes Water Hub will not only develop the watershed management plans, but will also help identify and prioritize funding for Finger Lakes projects to safeguard drinking water resources.

Harmful algal bloom on Canadice Lake in August 2017 *NYSDEC*

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Staffing

The Finger Lakes Water Hub's staff of four is based in NYSDEC's Region 7 office in Syracuse, but works throughout the Finger Lakes in NYSDEC Regions 7 and 8. Each staff member brings unique expertise to the team.

Scott Cook is a research scientist, and as supervisor oversees the activities in the Finger Lakes Water Hub. Scott has over 33 years working with NYSDEC. His past roles included direct oversight and administration of the regional Nonpoint Source Programs, which include the Stormwater Construction and MS4 Permit programs; the Ambient Water Quality Monitoring Programs; Concentrated Animal Feeding Operation (CAFO) permit compliance program; the Water Quality Improvement Grants Program for Non-Agricultural Nonpoint Source Abatement and Stormwater projects; Lake Management programs and Watershed Management initiatives and programs in Region 7.

Aimee Clinkhammer is the Watershed Coordinator. She coordinates stakeholder involvement for all the Finger Lakes Water Hub's activities. She is also assigned as the point of contact for Skaneateles, Hemlock and Canadice lakes. Aimee brings a diverse background in stakeholder coordination and project management, having worked as the Onondaga Lake watershed coordinator and as a project scientist at the Syracuse Center of Excellence at Syracuse University.

Lewis McCaffery, Ph.D. is a research scientist providing expertise in mapping, monitoring and water chemistry for the Finger Lakes Water Hub. Lew is assigned as the point of contact for Otisco, Seneca, Honeoye and Conesus lakes. He has a background in geology with over 25 years of experience in hydrogeology and water chemistry.

Anthony Prestigiacomo is a research scientist providing expertise in monitoring and assessment of the lakes, rivers and streams in watersheds. He is assigned as the point of contact for Owasco, Cayuga, Keuka and Canandaigua lakes. Tony has over 15 years of experience in the analysis of field and water quality data used for the generation of manuscripts, reports and presentations. He also has experience in the development of external nutrient loading estimates.

Ongoing Work

The Finger Lakes Water Hub is bringing people together to share expertise and find the solutions necessary to protect the Finger Lakes and their watersheds. The Hub will use its scientific expertise to promote enhanced collaboration and coordination. Early focus of the Hub's work includes:

- Meeting with citizens' groups, researchers, and academics who live and work in the Finger Lakes watershed to learn more about the specific issues affecting each lake and its watershed.
- Linking NYSDEC's existing water programs, including the HAB program, the Great Lakes Action Agenda and watershed-based monitoring with the work of research institutions, local governments and organizations in the Finger Lakes area.
- Developing a Finger Lakes Action Agenda to combine new priorities with existing environmental, social and economic goals. The action agenda will guide conservation, restoration and protection efforts for the entire Finger Lakes region.
- Identifying funding opportunities to conduct research and implement best management practices in high priority areas.
- Coordinating research through the collection, analysis, and validation of data; identify and fill data gaps; and promote relevant research to understand challenges facing the Finger Lakes.
- Establishing TMDL Plans for Cayuga, Honeoye and Conesus lakes, and a Nine Element Watershed Plan for Owasco Lake.
- Working with the HABs Enhanced Surveillance Monitoring Program on Owasco, Otisco, Cayuga, Honeoye and Seneca lakes to increase knowledge about HABs.
- Working with stakeholders to develop or update watershed management plans for each lake.
- Coordinating the Citizens Statewide Lake Assessment Program (CSLAP) for all 11 Finger Lakes.

Citizens Statewide Lake Assessment Program (CSLAP) volunteer collects samples for water quality analysis. *NYSDEC*

The creation of the Finger Lakes Water Hub will lead to new investment and coordinated action that will help improve and protect water quality throughout the region. We will continue to strengthen partnerships in the region and engage stakeholders to help accomplish our work, which will yield important benefits for the cities and communities throughout the Finger Lakes watershed.

Resources

For more information about the following, please visit the designated NYSDEC web site:

- Clean Water Plans: *www.dec.ny.gov/chemical/23835.html.*
- Waterbody Inventory Factsheets: *http://www.dec.ny.gov/chemical/36730.html.*
- Harmful Algal Blooms: *www.dec.ny.gov/chemical/77118.html.*
- Citizen Statewide Lake Assessment Program (CSLAP): *www.dec.ny.gov/chemical/81576.html.*
- Sign up for DEC Delivers: *http://www.dec.ny.gov/public/65855.html.*

Aimee Clinkhammer is the Watershed Coordinator for the Finger Lakes Water Hub of the New York State Department of Environmental Conservation. She may be reached at aimee.clinkhammer@dec.ny.gov.

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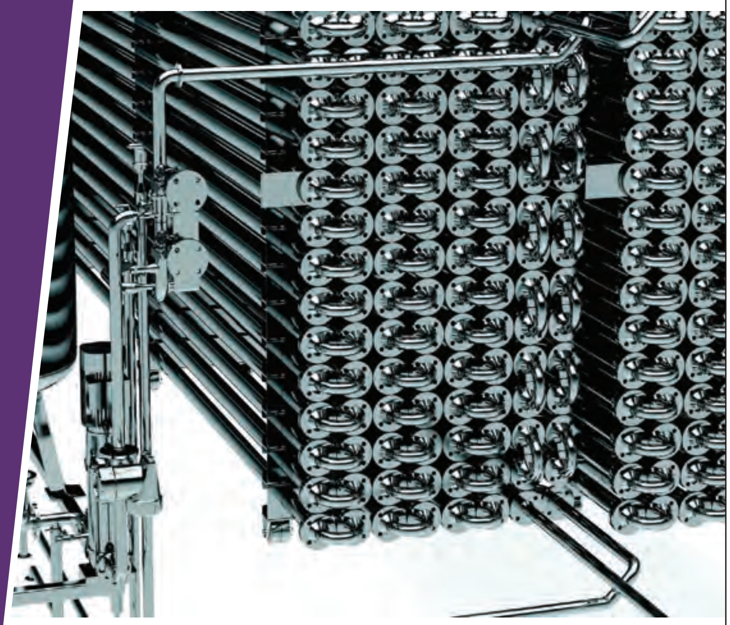

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Decade-Scale Water Quality Variability in the Eastern Finger Lakes, New York

by John D. Halfman

Introduction

The Finger Lakes of central New York are critical to the health, well-being and economy of the region. The 11 lakes – Conesus, Hemlock, Canadice, Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles and Otisco – hold a combined 8.1 trillion gallons of water (30.8 cubic kilometers), and their watersheds occupy a 2,630 square-mile (4,970 square-kilometer), 14-county region ***(Figure 1)***. These lakes are a source of Class AA drinking water to 1.5 million residents in the surrounding communities. For example, Skaneateles and Otisco lakes provide drinking water to the City of Syracuse, while Hemlock and Canadice lakes provide drinking water to the City of Rochester. In the late 1990s, total municipal withdrawals from Finger Lakes sources were approximately 190 million gallons of water per day *(Callinan, 2001)*.

Since 2005, the eight easternmost Finger Lakes of central New York – Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles and Otisco – have been monitored monthly during the summer field season by the Finger Lakes Institute. The surveys collected conductivity-temperature-depth (CTD) profiles, plankton tows and Secchi disk depths at a minimum of two deep-water, mid-lake sites at each lake. Surface and bottom water samples were analyzed for major nutrients, major ions, total suspended sediment (TSS) and chlorophyll-a concentrations. Furthermore, analyses of selected streams in the Seneca and Owasco watersheds augmented the data collected in Seneca and Owasco lakes.

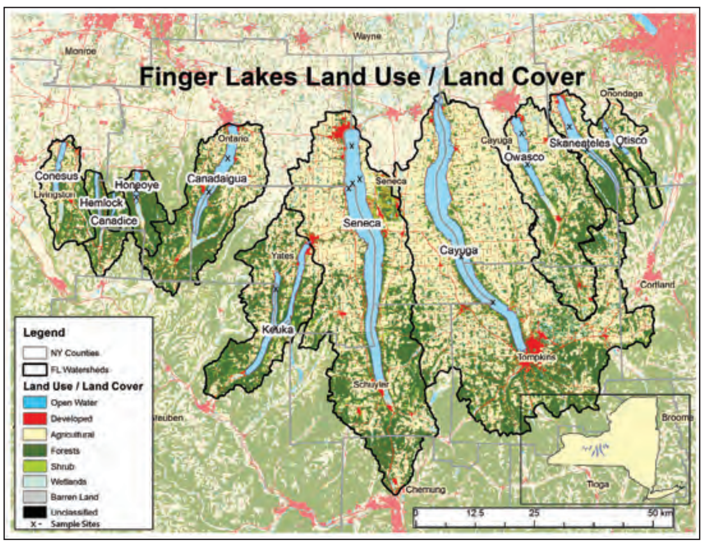

Figure 1. The Finger Lakes, site locations, and land use activities of central New York *Updated from Halfman, 2016*

Characteristics of Trophic States

Oligotrophic lakes have low nutrient concentrations, resulting in low algal growth and clear water; Secchi disk depth measurements are high. Dissolved oxygen is also abundant. Such lakes may be used as sources of drinking water with minimal filtration.

Mesotrophic lakes have a moderate concentration of nutrients, moderate algal growth, and moderate water clarity. May still be used as drinking water source, but filtration is required. Conditions usually suitable for contact recreation.

Eutrophic lakes are enriched in dissolved nutrients (such as phosphates) that stimulate the growth of algae. The algae cloud the water, resulting in shallow Secchi disk depth measurements. Dissolved oxygen is depleted in these lakes. Low water clarity, scums of algae and odors make recreational use unpleasant. Harmful blue-green algal blooms are more likely to occur.

The 2005 survey results indicated that Otisco and Honeoye lakes were eutrophic systems, while Skaneateles, Canandaigua and Keuka lakes were oligotrophic systems, and Cayuga, Seneca and Owasco lakes fell in-between as mesotrophic *(Halfman and Bush, 2006; Halfman and O'Neill, 2009)*. In this report, we present an update of our understanding of water quality parameters of the Finger Lakes. This update includes a summary of the monitoring results for these eight Finger Lakes since 2005 to assess the long-term changes in water quality in these lakes. Stream segment and event vs. base flow analyses are used to highlight the nutrient loading issue in the Finger Lakes region. This report focuses on nutrient loading issues, a potential trigger for the recent rise in blue-green algal blooms in several Finger Lakes.

Methods

Field Methods

Water quality was routinely monitored at Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles and Otisco lakes at a minimum of two deep-water, mid-lake sites on at least a monthly basis during the May to September field season ***(Figure 1)***. Otisco Lake was added to the monitoring program in 2008. CTD (SeaBird SBE-25) water quality profiles, Secchi disk depth, vertical plankton tow, and surface (less than 1-meter depth) and bottom (within a few meters of the lake floor) water samples were collected at each site.

The CTD electronically measured temperature, specific conductance (salinity), dissolved oxygen, pH, turbidity, photosynthetic active radiation intensities (PAR) and fluorescence every 0.2 meters along the surface-to-lake-floor profile. The plankton net (20-centimeter diameter opening, 80-micrometer mesh) integrated the plankton community within the upper 20 meters of water, and each sample was preserved in an alcohol-formalin solution. Water samples were analyzed on-site for temperature, specific conductance, pH, dissolved oxygen, and alkalinity (HCO_3^-) using hand-held probes and field titration kits. Laboratory analyses were performed for major nutrients [total phosphorus (TP), soluble reactive phosphorus (SRP), nitrate (NO_3) and silica (Si)], chlorophyll-a, major ions and TSS concentrations.

Laboratory Methods

Nutrient, chlorophyll-a, and TSS concentrations were analyzed following standard limnological techniques *(Wetzel & Likens, 2000)*. These are summarized in ***Table 1***.

Results

The results over time for the eight monitored Finger Lakes for selected parameters are summarized in ***Table 2.*** Additional data are presented in these graphics with accompanying text:

Table 1. Summary of Laboratory Analytical Methods and Precision for Selected Parameters

Parameter	Analytical Method	Laboratory Precision*
TP	Samples digested in hot (100ºC) persulfate for 1 hour. Analyzed by spectrophotometer.	±0.1 µg/L (both TP and SRP)
TSS	Water samples were filtered through oven-dried (100ºC), pre-weighed, 0.45 micrometer (µm) glass-fiber filters. Concentrations were determined by weight gain volume filtered.	±0.2 mg/L
Chlorophyll-a	Water samples were also filtered through a Gelman HA 0.45-µm membrane filter, and the filtered residue was kept frozen until analysis. Acetone extraction was performed, then analyzed by spectrophotometer at a suite of wavelengths.	±0.5 µg/L
SRP, NO_3, Si	The filtrate was stored at 4ºC until colorimetric analysis of dissolved phosphate (SRP), nitrate (NO_3) and silica (Si) by spectrophotometer.	SRP (see TP) NO_3 ±0.1 mg/L Si ±5 µg/L
Major ions: sodium (Na^+) potassium (K^+) calcium (Ca^{2+}) magnesium (Mg^{2+}) chloride (Cl^-) sulfate (SO_4^{2-})	Analyzed by Ion Chromatograph	±0.5µg/L
Plankton	At least 100 plankton (colonies were counted as one individual) from each tow were enumerated, typically to species level, under a microscope and reported as relative abundance (percentage of the population sampled).	±20%

**Note: mg/L = milligrams per liter; µg/L = micrograms per liter*

Table 2. Mean, Maximum and Minimum of Annual Mean Data – 2005-2016*

	Honeoye	Canandaigua	Keuka	Seneca	Cayuga	Owasco	Skaneateles	Otisco
Secchi Mean (m)	3.0	6.2	5.6	4.3	3.8	4.1	8.0	2.8
Max	4.6	7.7	7.3	5.3	4.5	5.6	9.7	3.8
Min	1.6	4.2	3.7	3.1	3.0	3.2	6.9	2.1
N of means (years)	12	12	12	12	12	12	12	9
Chlorophyll-a Mean (µg/L)	15.6	2.0	1.7	3.4	3.3	3.0	0.9	4.1
Max	37.9	4.2	2.7	4.7	5.4	4.1	1.4	5.7
Min	2.7	1.2	0.8	2.4	2.0	1.9	0.6	2.8
N of means (years)	12	12	12	12	12	12	12	9
TSS Mean (mg/L)	4.3	1.3	1.3	1.7	1.7	1.8	0.8	3.1
Max	8.3	2.2	4.5	2.3	2.6	3.5	1.2	5.9
Min	1.4	0.8	0.7	1.3	1.2	1.2	0.5	1.5
N of means (years)	12	12	12	12	12	12	12	9
TP Mean (µg/L, P)	33.8	9.8	8.5	12.4	13.0	11.0	7.1	18.2
Max	52.4	18.0	14.4	19.6	23.9	17.7	15.5	36.1
Min	16.0	5.2	4.3	6.5	6.8	7.4	2.7	8.6
N of means (years)	11	11	11	11	11	11	11	9
SRP Mean (µg/L, P)	5.8	0.8	0.9	0.9	1.3	1.1	1.1	2.5
Max	16.9	3.0	4.1	3.1	4.4	5.8	5.3	15.7
Min	0.5	0.3	0.2	0.4	0.4	0.4	0.0	0.3
N of means (years)	12	12	12	12	12	12	12	9
NO_3 Mean (mg/L, N)	0.3	0.5	0.4	0.6	1.0	0.9	1.0	0.4
Max	2.8	5.3	4.0	3.8	3.3	3.7	7.3	2.1
Min	0.0	0.0	0.0	0.1	0.6	0.4	0.3	0.2
N of means (years)	12	12	12	12	12	12	12	9
**P:N Ratio (TP:NO_3)	7.6	54.9	46.8	45.5	79.8	78.0	141.8	24.6

**Note: Otisco results represent the 2008 through 2016 annual means.*
***Note: The P:N Ratio is presented as the average of the ratios calculated for each sample date.*

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- ***Figure 2a:*** CTD profiles, Seneca Lake 2015.
- ***Figure 2b:*** CTD surface and bottom water average data, Seneca and Owasco lakes, 2005 through 2016.
- ***Figure 3:*** CTD turbidity profiles, Keuka, Canandaigua, Seneca and Skaneateles lakes.
- ***Figure 4:*** Annual precipitation totals at the Ithaca Airport.
- ***Figure 5:*** Box and whisker plot of Secchi disk depths.
- ***Figure 6:*** Box and whisker plot of chlorophyll-a concentrations.
- ***Figure 7:*** Box and whisker plot of TSS concentrations.
- ***Figure 8:*** Box and whisker plot of surface TP concentrations.

Nitrate, dissolved silica, major ions, additional CTD profiles and other data, as well as numerous annual reports and various data summaries, are available elsewhere *(Halfman, 2016; http://people.hws.edu/halfman/)*.

Selected Highlights

Temperature Profiles and Stratification

The CTD temperature profiles revealed the expected onset and decay of the summer-season stratification ***(Figure 2a;*** *Halfman 2016)*. For example, in Seneca Lake the epilimnion (warmer surface waters) warmed from about 4ºC (39ºF) in the early spring survey to nearly 25ºC (about 75ºF) by mid-summer, cooling again by the last survey date in late September ***(Figure 2b)***. Surface water temperatures warmed quicker in the smaller lakes such as Owasco ***(Figure 2b)***. The hypolimnion (colder bottom waters) remained at or slightly above 4ºC throughout the survey, especially in the deeper lakes.

A few lakes revealed different thermal responses. Persistent summer stratification was not observed in Honeoye Lake. Mixing by wind-driven waves was apparently sufficient to maintain polymictic conditions in this shallow lake (5.0 meters average depth, 11 meters maximum depth). The same wind events established and mixed the epilimnion to depths of 10 to 20 meters in the deeper lakes. In Otisco Lake, and occasionally other shallower lakes, the hypolimnion was typically warmer than 4ºC in the summer. Presumably, wind stress in these relatively shallow lakes maintained isothermal conditions throughout the entire water column as it warmed above 4°C (in some cases up to 10°C) in the early spring, until thermal stratification commenced sometime later in the spring. The hypolimnion temperatures remained constant throughout summer.

Specific Conductance and Salinity

Specific conductance CTD data ranged from 230 micro-siemens per centimeter (μS/cm) (approximately 110 mg/L) in Honeoye Lake to 730 μS/cm (approximately 350 mg/L) in the hypolimnion of Seneca Lake ***(Figure 2b)***. None of the salinities measured preclude these lakes from being viable drinking water supplies (USEPA's Maximum Contaminant Limit is 500 mg/L for total dissolved solids). The differences observed in specific conductance between lakes can be attributed to differences in bedrock geology. Limestones weather more easily, and thus watersheds overlying limestones contribute more dissolved ions (calcium and bicarbonate) to their lakes than do other bedrock in the region *(Halfman, 2014)*. For example, Honeoye and Keuka lakes revealed a smaller specific conductance and both lakes have much less limestone underlying their watersheds than the other lakes. The extensive de-icing salt use in the watersheds is another major source of dissolved ions to the Finger Lakes *(Wing et al., 1995; Halfman et al., 2006)*.

Seneca Lake, and to a lesser degree Cayuga Lake, have the largest salinities among the Finger Lakes. The source of extra sodium and chloride to Seneca Lake was previously hypothesized to originate from the influx of saline groundwater due to the lake floor's connection to the rock-salt Salina Formation *(Wing et al.,*

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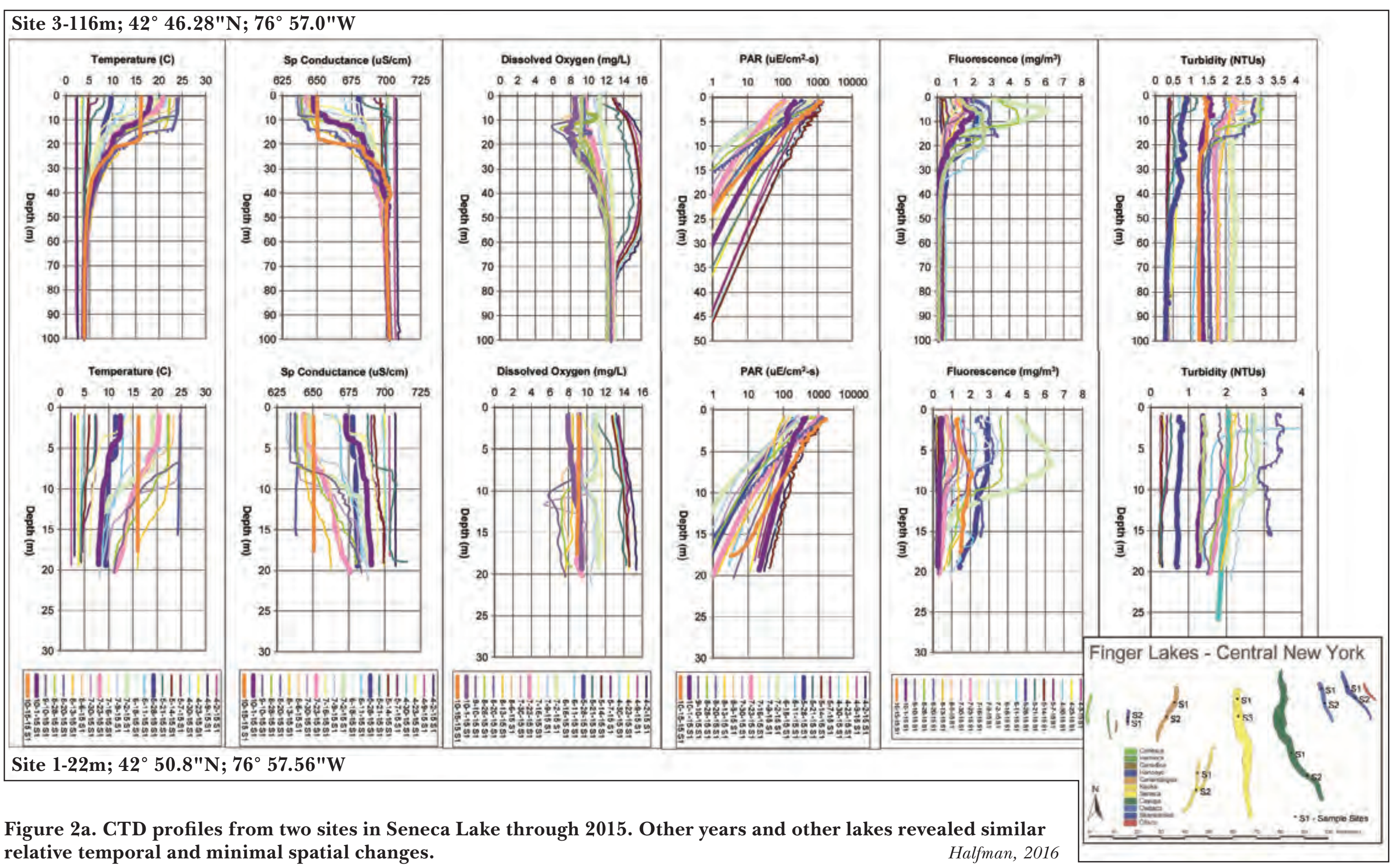

Figure 2a. CTD profiles from two sites in Seneca Lake through 2015. Other years and other lakes revealed similar relative temporal and minimal spatial changes. *Halfman, 2016*


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1995; Halfman et al., 2006). However recent data from Seneca Lake, along with modeling efforts in Cayuga Lake, refute this groundwater source theory *(Effler et al., 1989; Halfman, 2014)*. In summary, the specific conductance of Seneca Lake has steadily decreased, from a high of 730 µS/cm in 2005 to a low of 635 µS/cm in the fall of 2015 ***(Figure 2b)***. This decrease is consistent with the lake's overall decrease in salinity, from a high in the 1960s to 1970s of about 200 mg/L Cl^-. This decrease over several decades is likely due to the regulation by the NYSDEC and USEPA of previously unregulated probable discharge of salt mine wastes (mostly sodium chloride) *(Halfman, 2014)*. More importantly, since the hypolimnetic (deep water) salinity has been relatively uniform each stratified season since the early 1990s, a lake floor (groundwater) source of excess sodium and chloride ions appears to be lacking in Seneca Lake.

Overall, in the Finger Lakes epilimnetic specific conductance gradually decreased by 10 to 50 µS/cm (approximately 5 to 25 mg/L) through the stratified season ***(Figure 2b)***. It suggests that the epilimnion was increasingly diluted by less saline precipitation directly onto the lake and runoff to the lakes. In support of this hypothesis, a large decrease in epilimnetic conductivities was detected between two surveys that straddled heavy rains. The tail end of Hurricane Katrina, in 2005, dropped three inches of rain in Geneva, New York, over a 48-hour period. Katrina's impact was especially pronounced in Owasco Lake, probably because this watershed has the largest watershed-area-to-lake-surface-area ratio of the eight lakes in the survey. Thus, Owasco Lake received a relatively larger volume of fresh water to its relatively smaller epilimnion from the same amount of rainfall. Over longer time scales, the largest epilimnetic decreases in Seneca and Owasco lakes occurred in 2011, 2014 and 2015; these three years had the most spring through fall rainfall measured *(Halfman et al., 2016)*.

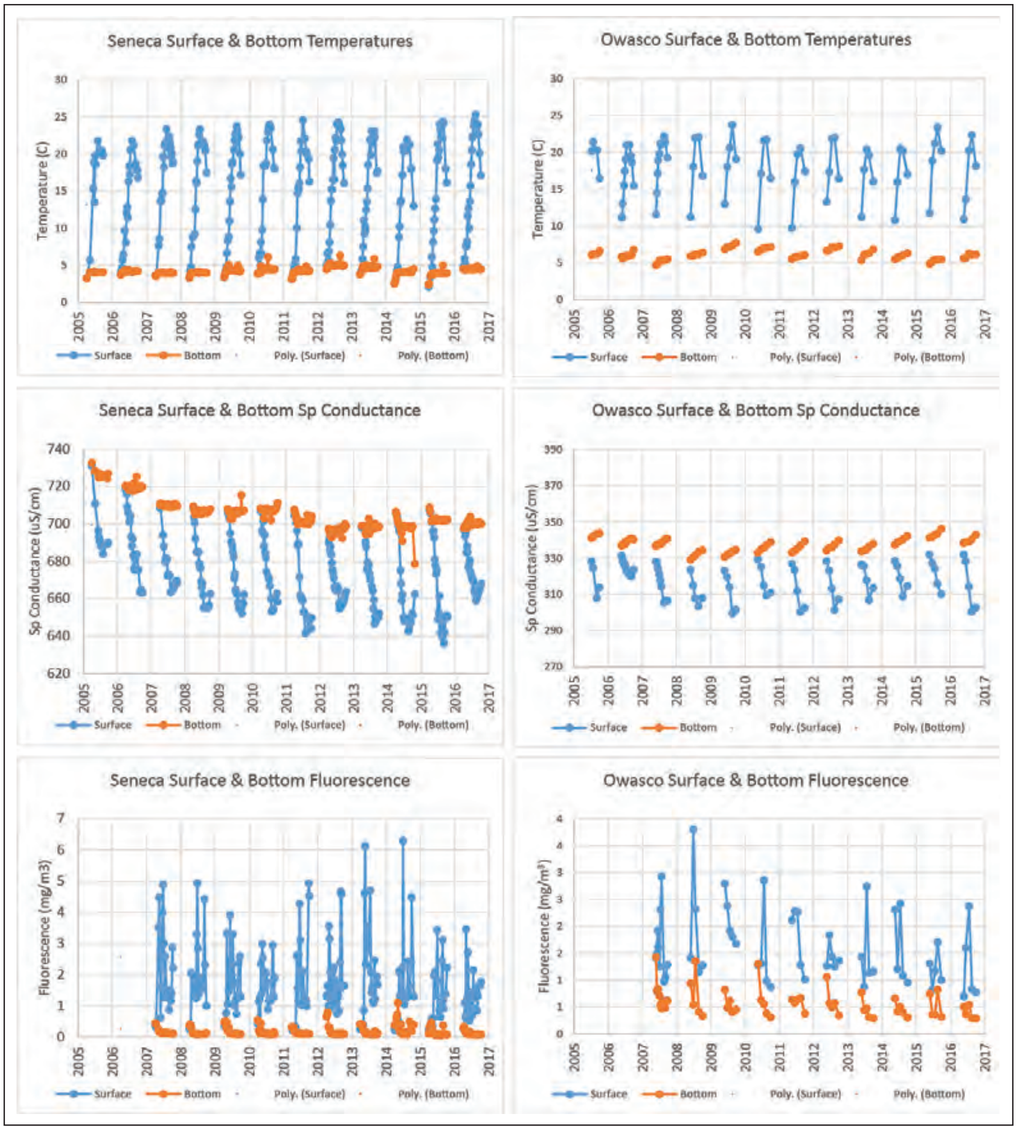

Figure 2b. Surface and bottom water averaged CTD temperature, specific conductance (salinity) and fluorescence (algae) data integrating over a 10-meter thickness from two representative lakes: Seneca (left) and Owasco (right). *Updated from Halfman, 2014*

Turbidity

Surface water zones of increased turbidity were observed in the CTD profiles from many of the Finger Lakes ***(Figure 3)***. Parallel increases were observed in the epilimnetic fluorometer data, which indicates that the epilimnetic turbidity was primarily due to algae blooms. Algal peaks of 3 to 10 µg/L were detected in the epilimnion of Seneca, Cayuga, Owasco and Otisco lakes. Smaller peak concentrations were detected in the metalimnion of Keuka and Canandaigua, and into the upper hypolimnion of Skaneateles.

Benthic (lake floor) nepheloid layers were observed in all the surveyed Finger Lakes, except for Honeoye and Seneca. Years with larger benthic nepheloid turbidities typically corresponded to years with more precipitation, thus presumably more sediment laden runoff. The benthic nepheloid layers were best developed in Cayuga Lake, where hypolimnetic turbidities increased from 1 to 2 nephelometric turbidity units (NTUs) to 10 or more NTUs near the lake floor. Higher lake floor turbidities were detected at the southern monitoring site, where the largest subwatersheds empty into the lake. In contrast, Honeoye mixed too frequently for persistent nepheloid layers. The absence of benthic nepheloid layers in Seneca, even in the occasional profile from the deepest and southern locations, is perplexing but may reflect the presence of smaller tributaries in proportion to the lake's larger size as compared with Cayuga Lake.

Two years, 2014 and 2015, revealed larger turbidities throughout the entire water column for many of the lakes, as compared to the other years in the survey, especially during the early portion of the field season ***(Figure 3)***. Turbidities were typically larger than 2 NTUs in a few profiles in 2014 and 2015, while in other years turbidities were smaller in the same lakes. These larger turbidities were coincident with years with the largest precipitation totals, especially

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precipitation during the early spring ***(Figure 4)***. Spring rains supply proportionally more runoff and suspended sediments because fields are bare. Agricultural fields have just been tilled for planting, and thus the soils are loosened and exposed, maximizing the potential for soil erosion by runoff. The ratios of runoff to infiltration and evapotranspiration are also larger in the spring, due to more saturated soils and inactive plant growth. Both factors increase the percentage of rainfall diverted to runoff. The change in turbidity is not consistent across all the surveyed lakes, most likely because rainfall totals and intensities are not uniform over the 14-county region, and the watershed-area-to-lake-volume ratios vary across the region.

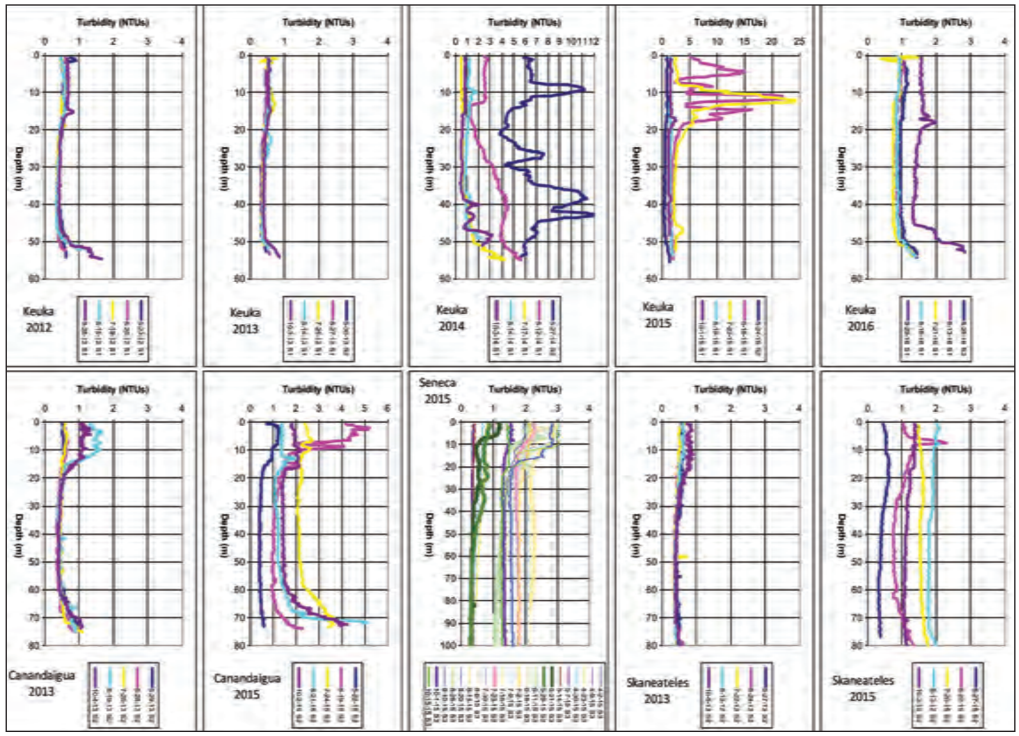

Figure 3. Turbidity profiles from 2012 through 2016 at Site 1 in Keuka Lake; 2013 and 2015 at Site 2 in Canandaigua Lake; 2015 at Site 3 in Seneca Lake; and 2013 and 2015 at Site 2 in Skaneateles Lake. Profiles reveal the changes in water column turbitity between survey dates and from one year to the next.

Updated from Halfman, 2016

Secchi Disk Depths

Annual mean Secchi disk depths ranged from 1.6 to 9.7 meters, and were deepest (least turbid) in Skaneateles Lake, and shallowest (most turbid) in Honeoye, Cayuga, Owasco and Otisco lakes ***(Table 2, Figure 5)***. Annual mean Secchi disk depths in Seneca Lake revealed the largest multi-year change, of about 4.5 meters, as compared to the other lakes. The transition to deeper Secchi disk depths from 1992 to 1998 was due to the invasion and establishment of the filter feeding zebra (dreissenid) mussels. Zebra mussels came into the lake starting in 1992, and the population expanded until their first population crash in 1998 (*Halfman et al., 2012*). Since 1998, Secchi disk depths have slowly declined back to 1992 levels, reflecting increasing concentrations of algae despite the addition of another dreissenid species, quagga mussels, to the filter-feeding mussel community in the early 2000s. The other seven lakes were not sampled until 2005; therefore, this survey could not detect the impact of the 1990s zebra mussel invasion on their water clarity.

Honeoye Lake has also experienced a significant shift from deeper to shallower Secchi disk depths starting in 2009; the reason is unknown. More recently, Honeoye, Canandaigua, Keuka, Seneca, Cayuga and Otisco monitoring revealed shallower Secchi disk depths – thus more turbid water – in 2014 and 2015, the two years with more spring precipitation as compared to other years in the survey.

Chlorophyll-a

Annual mean surface chlorophyll-a concentrations ranged from less than 1 µg/L in Skaneateles Lake to about 10 µg/L in Honeoye Lake ***(Table 2, Figure 6)***. Cayuga, Owasco and Otisco revealed the second largest chlorophyll-a concentrations, while Canandaigua and Keuka showed the second smallest chlorophyll-a concentrations. Some of the variability between surface chlorophyll-a concentrations reflect the variable depth of the algal peaks in these lakes and the coincidence (or lack thereof) between the survey dates and algal blooms.

Annual average chlorophyll-a concentrations were larger in the epilimnion than the hypolimnion for all the lakes except for the well-mixed Honeoye, as algae thrive in the sunlit epilimnion. Surface chlorophyll-a concentrations in Seneca Lake declined from 1993 through 1998, and paralleled deeper (clearer water) Secchi disk depths during this time due to grazing pressures by zebra mussels. Since then, chlorophyll-a concentrations have increased and paralleled the decrease (cloudier water) in Secchi disk depths. Of note, surface chlorophyll-a concentrations were larger in Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, and Skaneateles in 2014 and 2015 than in other years, consistent with the spike in turbidity data and rainfall totals.

Total Suspended Solids

Annual mean surface total suspended solids (TSS) concentrations were proportional to the chlorophyll-a concentrations and inversely

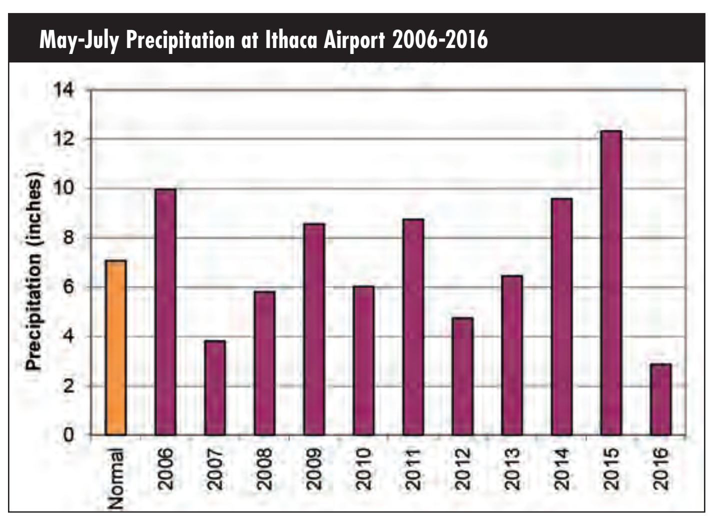

Figure 4. Annual precipitation totals from the Ithaca Airport during the 3-month, May through July, spring season, from 2006 to 2016

Updated from Halfman et. al., 2016

proportional to the Secchi disk data *(Table 2, Figure 7)*. The largest concentrations were detected in Honeoye Lake and the smallest in Skaneateles Lake. Honeoye Lake revealed the largest date-to-date and year-to-year variability in TSS, most likely reflecting the presence or absence of algal blooms on the dates sampled. Surface TSS concentrations were relatively larger in 2014 – and to a lesser extent in 2015 – than other years in Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco and Skaneateles lakes.

Total Phosphorus

Surface total phosphorus (TP) concentrations were largest in Honeoye Lake, with annual means up to 52 µg/L as P ***(Table 2, Figure 8)***. Honeoye continues to be impaired based on NYSDEC's 20 µg/L TP numeric guidance threshold. Otisco Lake revealed the next largest TP concentrations, with annual means between 10 and 35 µg/L and thus was occasionally above the 20 µg/L impairment threshold. TP concentrations were smallest in Skaneateles, Canandaigua and Keuka lakes, with annual means ranging from 5 µg/L to 15 µg/L. Concentrations in Seneca and Cayuga lakes were between these high and low ranges. The largest TP concentrations in each lake were detected in 2014. The mean concentration in 2014 was typically twice the mean from the preceding year in each lake.

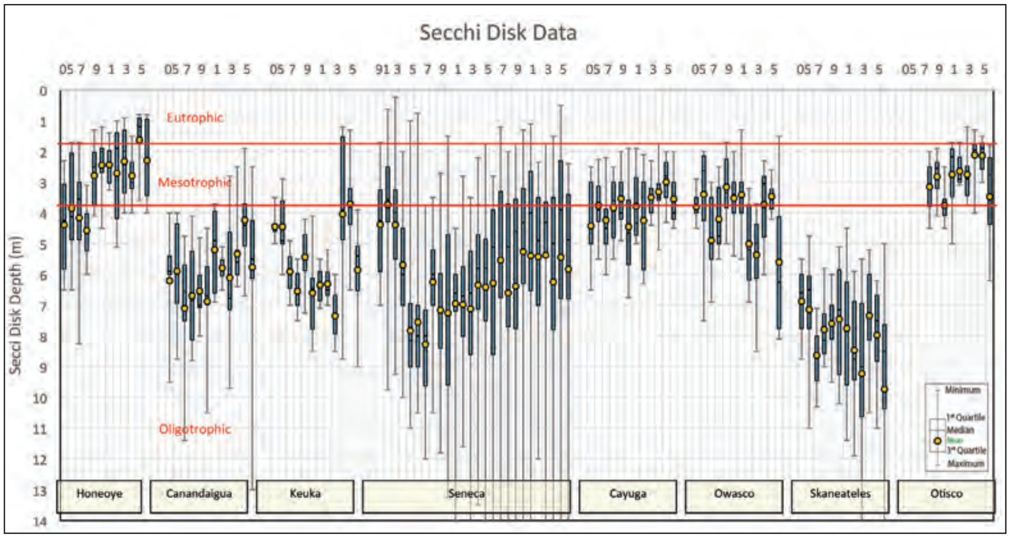

Figure 5. Box and whisker plot of Secchi disk depths. The numbers on the x-axis identify the year, e.g., 05 is 2005 and 91 is 1991. *Halfman, 2016*

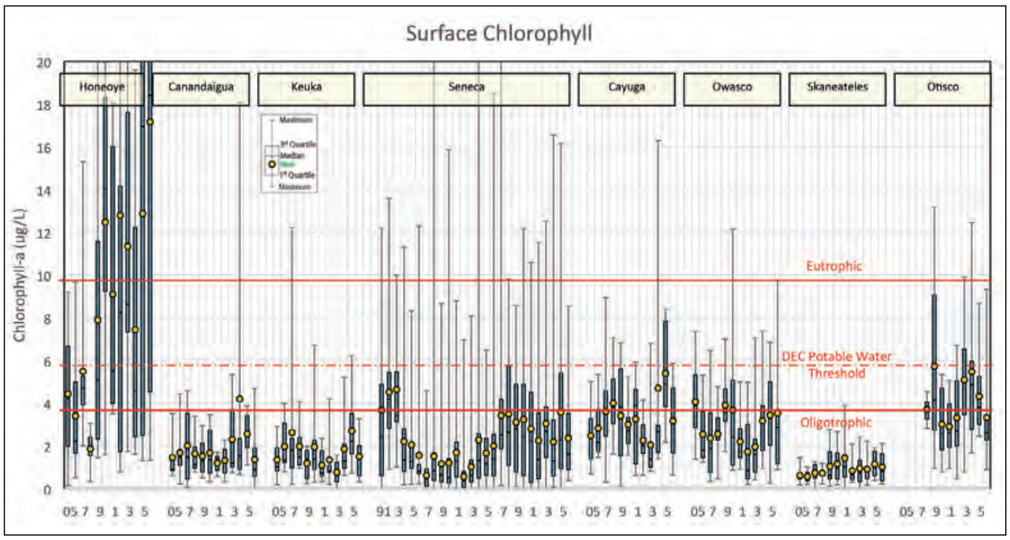

Figure 6. Box and whisker plot of surface water chlorophyll-a concentrations. The numbers on the x-axis identify the year, e.g., 05 is 2005 and 91 is 1991. *Halfman, 2016*

P:N ratios using the TP and NO_3 data indicate that, except for Honeoye Lake, the surveyed lakes are phosphorus-limited, meaning that the ratios are above the 1:7 Redfield Ratio *(Halfman, 2016)*.

Plankton and Algal Communities

Plankton populations were dominated by diatoms in all the eight Finger Lakes monitored ***(Figure 9)***. Seneca, Cayuga and Keuka consistently had the largest percentages of diatoms (50 percent to 80 percent of the taxa) whereas Otisco and Skaneateles had the least (20 percent to 30 percent). Dinoflagellates and blue-green algae were the next common plankton groups with annual percentages ranging from 5 percent to 20 percent. Of dinoflagellates, Canandaigua, Keuka, Owasco and Otisco had the largest percentages (greater than 10 percent), while Cayuga and Seneca had the least (less than 5 percent); Skaneateles was in-between. More green algae were detected in Honeoye, Cayuga, Skaneateles and Otisco lakes, up to 5 percent of the plankton community; Canandaigua, Keuka, Seneca and Owasco had the least, at only a few percent of the plankton community.

Definition: Redfield Ratio

Redfield measured the ratio of P:N in algae across the globe and always got the same answer, 1:7. The implication is simple: algal photosynthesis requires phosphorus and nitrogen in a fixed ratio, 1:7. If the supply of these two nutrients in the water column is skewed above or below this ratio, then the skew direction highlights which nutrient limits algal growth, because when the lake runs out of the under-supplied nutrient, photosynthesis stops.

The plankton net mesh (80 µm) was too large to trap significant quantities of cryptophytes. Recent Finger Lakes Institute Fluoroprobe data revealed that cryptophytes are major parts of the plankton community in Skaneateles, Keuka, Canandaigua and Cayuga *(Halfman, 2016)*. Specifically, the genera *Fragilaria, Tabellaria, Diatoma, Asterionella, Synedra, Melosira, Rhizosolenia* and *Cymbella* dominated the diatom taxa. *Dinobryon* and *Ceratium* dominated the dinoflagellate taxa. *Closteriopsis* and *Closterium* dominated the green taxa. *Anabaena, Stichosiphon, Gomphosphaeria* and *Microcystis* dominated the blue-green taxa.

Honeoye, Canandaigua, Keuka and Skaneateles had the largest percentage of blue-green algae (cyanobacteria) taxa (greater than 20 percent), and Seneca and Cayuga the least (less than 5 percent, ***Figure 9***). *Microcystis* was the most common form of cyanobacteria. It is surprising that three oligotrophic lakes had the largest relative

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continued from page 27
abundance of blue-green taxa, as these cyanobacteria were thought to only impact eutrophic systems. Please note, relative abundances reported here do not dictate large concentrations of algae, just dominance of the taxa as a percent of the overall algal population. Cyanobacteria have been detected at the same relative abundance in these lakes since the start of the Finger Lakes Institute survey in 2005. In fact, blue-green species were detected in the Finger Lakes as long ago as 1914 *(Bloomfield, 1978)*. Only some of these Finger Lakes experienced significant nearshore blooms of cyanobacteria. It suggests that localized perturbation(s) must have triggered the recent and large nearshore blooms in selected lakes.

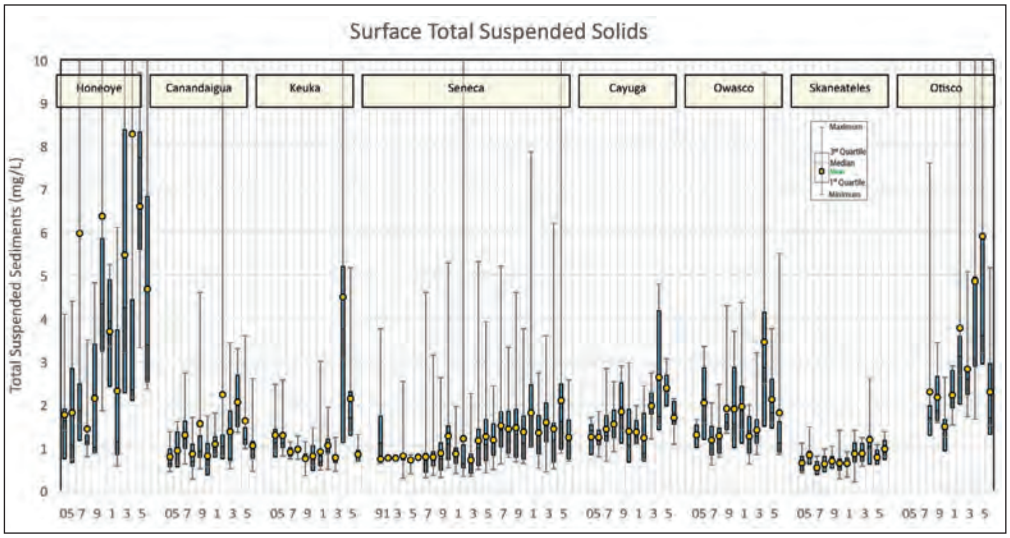

Figure 7. Box and whisker plot of surface water total suspended solids concentrations. The numbers on the x-axis identify the year, e.g., 05 is 2005 and 91 is 1991. *Halfman, 2016*

Finger Lakes Trophic State and Water Quality

The eight surveyed Finger Lakes ranged from oligotrophic to eutrophic systems ***(Table 2)***. Since Callinan's water quality survey of the Finger Lakes in the late 1990s *(Callinan, 2001)*, the trophic states of Keuka and Otisco lakes improved. Keuka's trophic state changed from mesotrophic to oligotrophic, while Otisco shifted from eutrophic to mesotrophic. The trophic status declined in Cayuga, Seneca and Owasco lakes, from borderline oligotrophic to mesotrophic. The trophic states of Skaneateles and Honeoye remained the same: oligotrophic and eutrophic, respectively.

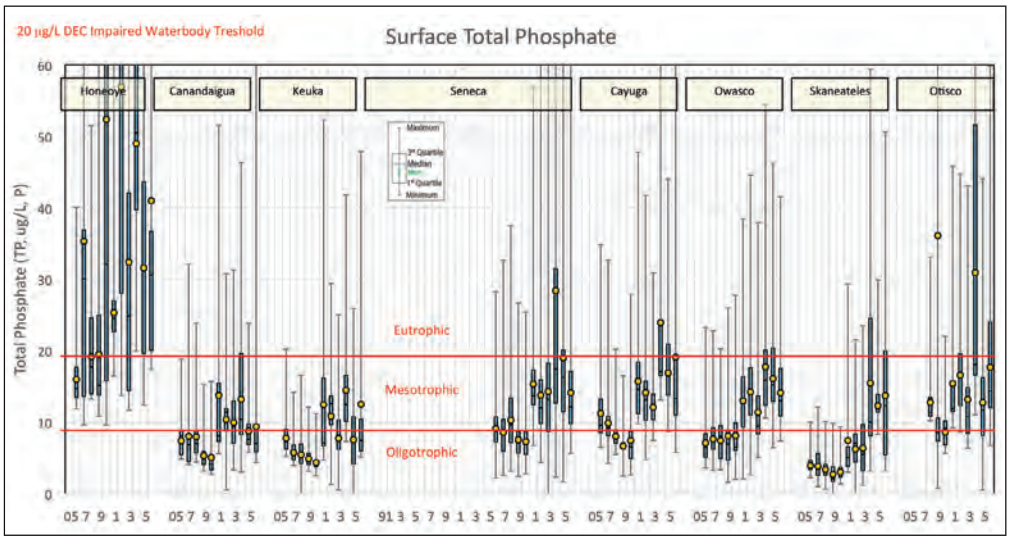

Figure 8. Box and whisker plot of surface water total phosphorus concentrations. The numbers on the x-axis identify the year, e.g., 05 is 2005 and 91 is 1991. *Halfman, 2016*

To increase the sensitivity of the water quality analysis, an independent annual water quality rank was calculated for each lake based on surface water concentrations of TP, SRP, NO_3, chlorophyll-a, TSS and Secchi disk depths *(Halfman and Bush, 2006)*. These independent ranks are consistent with a mean Carlson's Trophic Status Index (TSI) that mathematically manipulates surface concentrations of chlorophyll-a, TP, and Secchi disk depths *(Carlson, 1977)*. ***Figure 10*** plots the average (±1 standard deviation) of the annual mean TSIs. A mean annual TSI for each lake calculated the average of the annual mean Secchi disk (SD), total phosphorus (TP) and chlorophyll-a (Chl) TSIs using the

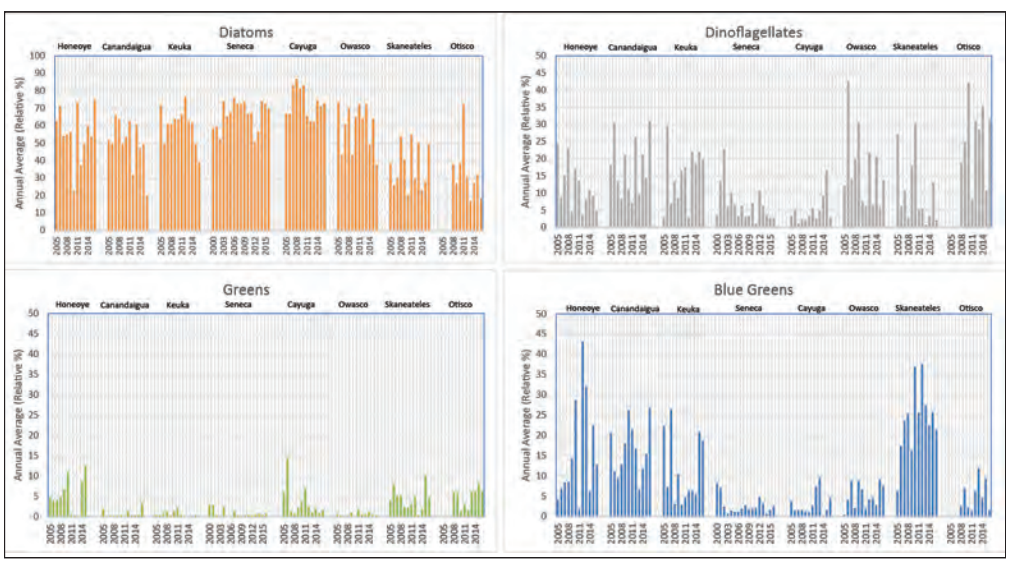

Figure 9. Annual average plankton relative percentages *Halfman, 2016*

Table 3. Trophic status of the Finger Lakes: Late 1990s, 2015 and 2016

Lake	Secchi Depth (m)	TP (µg/L)	Chlorophyll-a (µg/L)	Trophic Status	Callinan's Designation
Trophic Classification Boundaries					
Oligotrophic	> 4	< 10	< 4		
Mesotrophic	2 to 4	10 to 20	4 to 10		
Eutrophic	< 2	> 20	> 10		
Late 1990s *(Callinan, 2001)*					
Honeoye	3.7	24.2	8.4		Eutrophic
Canandaigua	7.7	6.2	1.0		Oligotrophic
Keuka	5.6	8.0	2.8		Mesotrophic
Seneca	6.0	9.8	2.4		Oligotrophic
Cayuga	4.0	9.7	3.5		Oligotrophic
Owasco	2.8	12.0	3.8		Oligotrophic
Skaneateles	7.6	4.0	0.7		Oligotrophic
Otisco	2.0	13.0	5.3		Eutrophic
2015					
Honeoye	1.6	31.6	19.0	Eutrophic	Eutrophic
Canandaigua	4.2	8.7	2.6	Oligotrophic	Oligotrophic
Keuka	3.7	7.6	2.7	Oligotrophic	Mesotrophic
Seneca	3.6	13.8	3.7	Mesotrophic	Oligotrophic
Cayuga	3.0	16.9	5.4	Mesotrophic	Oligotrophic
Owasco	3.3	15.5	3.8	Mesotrophic	Oligotrophic
Skaneateles	8.0	12.3	1.1	Oligotrophic	Oligotrophic
Otisco	2.1	12.7	4.3	Mesotrophic	Eutrophic
2016					
Honeoye	2.3	41	22.7	Eutrophic	Eutrophic
Canandaigua	7.7	18	1.8	Oligotrophic	Oligotrophic
Keuka	5.9	12.5	1.5	Oligotrophic	Mesotrophic
Seneca	4.3	15.1	2.7	Oligotrophic	Oligotrophic
Cayuga	3.5	16.5	3.0	Mesotrophic	Oligotrophic
Owasco	5.6	14.1	3.5	Mesotrophic	Oligotrophic
Skaneateles	9.7	13.7	1.0	Oligotrophic	Oligotrophic
Otisco	3.2	16.1	3.0	Mesotrophic	Eutrophic

Eleven Years of Water Quality Annual Ranks

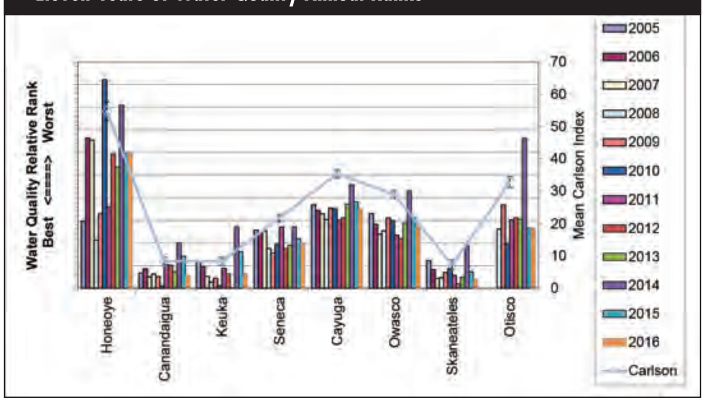

Figure 10. Annual water quality ranks and the mean Carlson's trophic status index *Halfman, 2016*

formulas below:

TSI (SD) = 10 [6 – ln (SD) / ln 2]

TSI (TP) = 10 [6 – (ln (48/TP) / ln 2)]

TSI (Chl) = 10 [6 – (2-04 – 0.68 ln (Chl)) / ln 2]

Two years – 2014 and 2015 – stand out in the year-to-year changes in water quality. Water quality declined in 2014 and 2015 for Canandaigua, Keuka, Cayuga, Owasco, Skaneateles and Otisco compared to other years in the record. These two years correspond to the larger concentrations of suspended sediments, TP, dissolved phosphates and chlorophyll-a mentioned previously, and were also the two rainiest springs in the recent past ***(Figure 4)***.

The mean water quality ranks were compared to the percentage of agricultural land, watershed area, lake volume, lake-volume-to-surface-area ratio, watershed area, water residence time, total population and population served with drinking water *(Halfman and O'Neill, 2009)*. Rank vs. watershed area revealed a correlation when the smallest lakes – Honeoye, Otisco and Owasco – were excluded from the analysis. When all eight of the surveyed lakes were included, none of these variables revealed a correlation ($r^2 <= 0.1$).

The percentage of agricultural land within each watershed revealed a strong correlation to the water quality ranks ($r^2 = 0.92$), but only when Honeoye was excluded from the comparison ***(Figure 11)***. This analysis suggests that runoff from agricultural landscapes is more nutrient-rich, fertilizing the algal populations and thus degrading the receiving lake. Excluding Honeoye Lake from this analysis is reasonable because its watershed history, shallow depth and small size set this lake apart from the other Finger Lakes in this survey. In the 1800s, the timber industry clear-cut the Honeoye watershed, resulting in severe soil erosion and nutrient transport to the lake. The nutrients transported historically exist today in the sediments of the lake. The lake's polymictic status (it is well-mixed from surface to bottom) induces significant internal nutrient

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Mean Rank vs. Agricultural Land Use

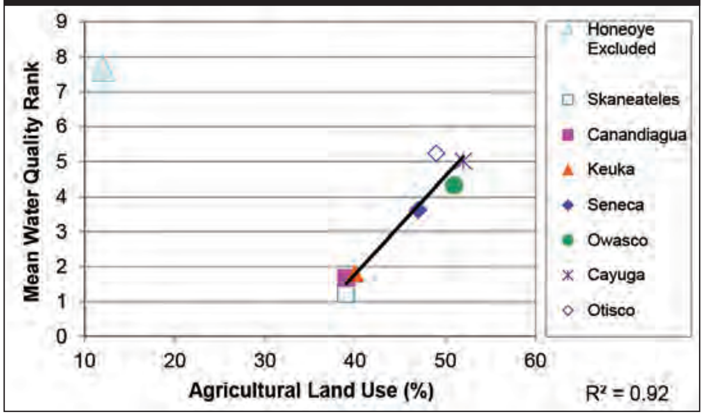

Figure 11. Mean water quality rank vs. agricultural land use. The best-fit correlation excluded Honeoye Lake. *Halfman, 2016*

loading to the water column from the sediments. Honeoye is also unique in that algal growth is limited by nitrogen, not phosphorus, as in other lakes in this survey.

Nutrient Loading Issues

Evidence from several Finger Lakes watersheds studies linked nutrient loading to water quality degradation (refer to *Halfman et al., 2008; Makarewicz et al., 2009; Effler et al. 2010; Halfman et al., 2012; UFI et al., 2014; Halfman et al., 2016;* and *Halfman 2016*). For example, each year's SRP concentrations in the Seneca Lake watershed are consistently 10 to 100 times larger in tributaries draining the watershed than in the lake, indicative of a nutrient loading problem (***Figure 12;*** *Halfman et al., 2012*). The phosphorus sources to Seneca Lake were multifaceted and included:

- Runoff from agricultural land, including both crop and animal farms, especially from Concentrated Animal Feeding Operations (CAFOs).
- Municipal wastewater treatment facilities.
- Soil, road ditch and stream bank erosion.
- Construction activities.
- Lakeshore on-site septic systems.
- Atmospheric deposition.

Another phosphorus source unique to the Reeder Creek tributary of Seneca Lake is residue from exploded munitions at the former Seneca Army Depot. The nutrient loads over time paint a consistent scenario with the decline in water clarity and water quality in Seneca Lake since the late 1990s (***Figure 5***).

Research in the Owasco watershed highlights the importance of precipitation events on nutrient loads (*Halfman et al., 2016*). Event vs. base flow measurements at Dutch Hollow Brook, an agricultural-intense subwatershed of Owasco Lake, revealed that over 90 percent of the nutrient and sediment loads were transported during precipitation-induced runoff events as compared to base flow inputs, especially in the spring season (*Halfman et al., 2016*). Comparable results were found in other Finger Lakes watersheds. This difference was less staggering in 2016, a relatively "dry" year. Annual nutrient and sediment loads positively correlated to precipitation totals as well, especially precipitation totals during the spring months ($r^2 = 0.81$, *Halfman et al., 2016*). Thus, rainfall events and runoff from agricultural areas are significant to the delivery of nutrient and sediments to the lake. Other, but quantitatively less important, sources of phosphorus include effluent from municipal wastewater treatment facilities, on-site wastewater systems, stream bank and road ditch erosion, construction activities and atmospheric deposition (*Halfman et al., 2016*).

Estimated annual phosphorus budgets for Seneca and Owasco lakes confirmed a nutrient loading problem (*Halfman et al., 2012; Halfman et al., 2016*). In Seneca Lake, inputs exceeded outputs by 45 metric tons of phosphorus per year or about one-third of the total amount of phosphorus in the lake (*Halfman et al., 2012*). This annual load likely underestimated the actual load because most of the stream samples were collected during base flow. Annual phosphorus budgets for Owasco Lake from 2011 through 2016 (***Figure 13***) revealed a persistent net addition of phosphorus to the lake as well (*Halfman et al., 2016*). A positive balance was probably also true for 2009 and 2010; as only base-flow stream data were used in these two years, therefore their phosphorus inputs lacked event contributions. Those years with significantly larger inputs than outputs experienced more spring rainfall.

Nutrient loading is an obvious "bottom up" ecological stressor to aquatic ecosystems by stimulating algal blooms and degrading water quality in the lake. But nutrient loading is not the only stressor controlling water quality in these lakes. "Top down" ecological perturbations can remove algal predators, and thus enhance algal populations and decrease water quality. For example, grazing of herbaceous zooplankton by the carnivorous zooplankton *Cercopagis pengoi* induced a mid-summer algal bloom in Owasco Lake (*Brown and Baulk, 2008*). In contrast, the filter-feeding zebra and quagga mussels increased water clarity in the 1990s. Thus "top down" alter-

Dissolved Phosphate (SRP) Average (1999-2014) Concentrations

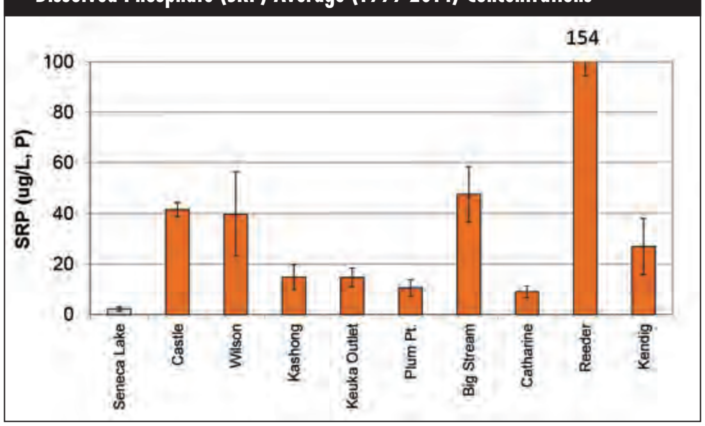

Figure 12. Average dissolved phosphate (SRP) concentrations in the major Seneca Lake subwatersheds (orange) compared to SRP concentrations in the lake (green-left side) *Halfman, 2016*

Phosphate Inputs and Outputs

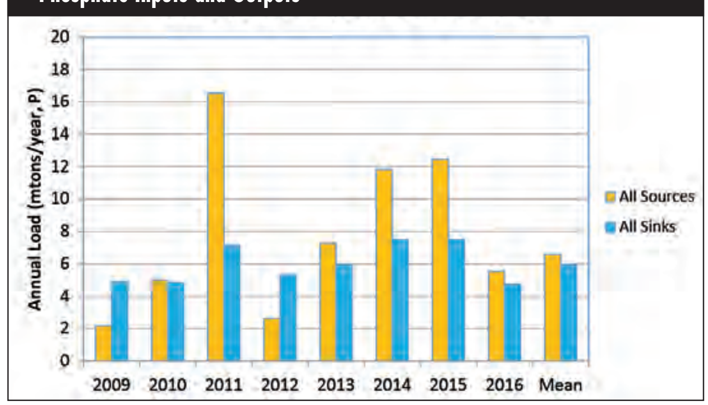

Figure 13. Estimated annual total phosphorus inputs and outputs for Owasco Lake *Halfman et. al., 2016*

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ations probably influenced some of the year-to-year variability in water quality and water clarity, as well.

Implications for Blue-Green Algae (Cyanobacteria)

The recent rise in blue-green algal (cyanobacterial) blooms and their associated toxins, with concentrations occasionally above toxic thresholds in many Finger Lakes, is disturbing *(**Table 4;** R. Gorney and S. Kishbaugh, NYSDEC, personal communication 2016)*. The Finger Lakes were not unique in having more recent cyanobacteria blooms; 95 lakes in New York had confirmed blooms in 2016, and 38 of those also had confirmed high toxin concentrations. The number of impacted lakes throughout the state has grown from 58 lakes in 2012 to 172 lakes in 2016. However, the trend over time may reflect that, in more recent years, there have been an increasing number of people looking for blooms. The most disturbing aspect is that cyanobacterial blooms were detected in some oligotrophic (Canandaigua) and mesotrophic (Cayuga, Owasco, Otisco and Seneca) lakes as well as the expected eutrophic (Honeoye) systems. By the end of 2016, cyanobacterial blooms have not been reported by the NYSDEC for Hemlock, Canadice, Keuka and Skaneateles lakes. Unfortunately, by the end of the summer of 2017, cyanobacterial blooms had been confirmed for all 11 of the Finger Lakes. *(NYSDEC)*.

All of the affected Finger Lakes revealed suspended sediment and nutrient perturbations in 2014 and 2015. Those years paralleled the first detection of cyanobacteria blooms in many of the impacted lakes. Those lakes lacking cyanobacterial blooms have less agricultural land and more forested land in their watersheds, and/or have stricter watershed protection legislation, thus less runoff of nutrients during events. The temporal association suggests that nutrient loading may have provided a trigger for these blooms in the Finger Lakes. It also implies critical remediation strategies must be established now to reduce and hopefully reverse the disturbing trends in water quality.

Table 4. Harmful algal blooms (HABs) reported in the Finger Lakes, 2012-2016
(Source: Gorney and Kishbaugh, personal communication 2016)

Lake	2012	2013	2014	2015	2016
Conesus	–	–	C (7)	C (3)	C (4)
Hemlock	–	–	–	–	–
Canadice	–	–	–	–	–
Honeoye	S (12)	HT (18)	C (8)	HT (7)	C (9)
Canandaigua	–	–	–	HT (4)	C (3)
Keuka	–	–	–	–	–
Seneca	–	–	–	C (6)	HT (2)
Cayuga	–	–	S (3)	–	C (7)
Owasco	HT (1)	C (7)	HT (12)	HT (9)	HT (9)
Skaneateles	–	–	–	–	–
Otisco	–	–	–	S (?)	–

Note: Bloom status key: S = suspicious, C = confirmed, HT = confirmed with high toxins; The value in parentheses is the number of weeks detected in lake. Harmful Algal Blooms (HABs) Archive Page, NYSDEC Website (http://www.dec.ny.gov/chemical/83332.html).

Conclusions

The trophic status ranged from oligotrophic to eutrophic systems across the eight easternmost Finger Lakes. Skaneateles, Canandaigua and Keuka Lakes are the most oligotrophic and exhibit the best water quality. Honeoye is the most eutrophic. The remaining lakes – Seneca, Owasco, Cayuga and Otisco – are in-between, i.e., borderline oligotrophic/mesotrophic to mesotrophic. The trophic status in many lakes has changed since the late 1990s. Nutrient loading can explain the observed degradation in water quality and even some year-to-year variability, especially during 2014 and 2015. This timing coincides with the onset of blue-green algal (cyanobacterial) blooms in many Finger Lakes. It implies remediation efforts to reduce nutrient loading must be established now to reverse the observed water quality degradation of these lakes. Since the sources of nutrients are multifaceted, and everyone contributes in some way to the nutrient loading problem, everyone must also contribute to the nutrient reduction strategies.

The critical roles of the lakes as drinking water supplies and recreational resources are essential to the regional tourism-based economy, so everyone has a stake in protecting and preserving water quality in the Finger Lakes. Therefore, everyone must work together to reduce nutrient sources and cyanobacteria blooms to eventually improve water quality in our lakes.

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Acknowledgements

The research was supported by grants from Hobart & William Smith Colleges, the Kloman Fellowship Fund, The Environmental Studies Research Fund, the Fred L. Emerson Foundation, the Triad Foundation, the Booth Ferris Foundation, the state of New York, the Andrew W. Mellon Foundation and others. Our 25-foot trailerable research vessel, the *JB Snow,* was purchased and outfitted with support from the John Ben Snow Foundation. We especially thank retired New York state Senator Mike Nozzolio, and President Mark Gearan of Hobart and William Smith Colleges, for their unwavering support of the Finger Lakes Institute. We thank Captain John Nichols (retired), Captain Dave Brown, John Abbott (retired) and Anthony Madia for their professional service on the *William Scandling,* our 65-foot research vessel on Seneca Lake. Marion Balyszak, Lisa Cleckner, Roxanne Razavi, Meghan Brown, Bin Zhu, Jay Bloomfield, Cliff Callinan P.E., Scott Kishbaugh, Joe Makarewicz, Bob Brower, Steve Effler, Ed Mills, Bruce Gilman, and numerous others are also thanked for fruitful discussions on water quality issues in the Finger Lakes. Most importantly, special thanks are extended to the 100 or so undergraduate students for their assistance in the field and in the laboratory.

References

Bloomfield, J.A., ed. 1978. *Lakes of New York State.* Vol. 1: Ecology of the Finger Lakes. New York: Academic Press, Inc.

Brown, M.E., and M.A. Balk. 2008. "The potential link between lake productivity and the invasive zooplankter *Cercopagis pengoi* in Owasco Lake (New York, USA)." *Aquatic Invasions* 3 (1): 28-34. *doi:10.3391/ai.2008.3.1.6.*

Callinan, C.W. 2001. *Water Quality Study of the Finger Lakes.* Division of Water, New York State Department of Environmental Conservation, 151 pp. *http://www.dec.ny.gov/lands/25576.html.*

Carlson, R. E. 1977. "A trophic state index for lakes." *Limnology and Oceanography* 22 (2): 361-369.

Effler, S.W., A.R. Prestigiacomo, D.A. Matthews, R.K. Gelda, F. Peng, E.A. Cowen, and S.A. Schweitzer. 2010. "Tripton, trophic state metrics, and near-shore versus pelagic zone responses to external loads in Cayuga Lake, New York, U.S.A." *Fundamental and Applied Limnology* 178 (1): 1-15. *doi:10.1127/1863-9135/2010/0178-0001.*

Effler, S.W., M.T. Auer, and N.A. Johnson. 1989. "Modeling Cl concentration in Cayuga Lake, U.S.A." *Water, Air, and Soil Pollution* 44 (3-4): 347-362. *https://www.researchgate.net/publication/237954365_Modeling_Cl_concentration_in_Cayuga_Lake_USA.*

Halfman, J.D., and K.F. Bush. 2006. *A Preliminary Water Quality Study of Selected Finger Lakes, New York.* Geneva, New York: Finger Lakes Institute, Hobart and William Smith Colleges, 15 pp. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D., and K. O'Neill. 2009. *Water Quality of the Finger Lakes, New York: 2005-2008.* Geneva, New York: Finger Lakes Institute, Hobart and William Smith Colleges, 33 pp. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D., C.M. Caiazza, R.J. Stewart, S.M. Opalka, and C.K. Morgan. 2006. "Major ion hydrogeochemical budgets and elevated chloride concentrations in Seneca Lake, New York." *Northeastern Geology & Environmental Sciences* 28 (4): 324-333. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D., D. Zorn, C. Roberson, L. Cleckner, and S. Meyer. 2012. *Seneca Lake Watershed Management Plan: Characterization and Evaluation.* Hobart and William Smith Colleges, Finger Lakes Institute, Genesee/Finger Lakes Regional Planning Council, Southern Tier Central Regional Planning and Development Board, 155 pp. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D., E.S. Brown, T.F. Ware, K.A. O'Neill, C.K. Franklin, and R.E. Dye. 2008. "Owasco Lake, New York: Water Quality and Nutrient Sources." In *A 2007 Water Quality Study of Owasco Lake, New York.*, edited by J.D. Halfman, M.E. Balyszak and S.A. Meyer, 37 pp. Geneva, New York: Finger Lakes Institute, Hobart and William Smith Colleges. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D., H.A. Simbliaris, B.N. Swete, S. Bradt, M.C. Kowalsky, P. Spacher, and I. Dumitriu. 2016. *The 2016 Water Quality Report for Owasco Lake, New York.* Geneva, New York: Finger Lakes Institute, Hobart and William Smith Colleges, 51 pp. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D. 2014. *A 2014 Update to the Chloride Hydrogeochemistry in Seneca Lake, New York.* Geneva, New York: Finger Lakes Institute, Hobart and William Smith Colleges, 27 pp. *http://people.hws.edu/halfman/#Publications.*

Halfman, J.D. 2016. *Water Quality of the Eight Eastern Finger Lakes, New York: 2005-2016.* Geneva, New York: Finger Lakes Institute, Hobart and William Smith Colleges, 52 pp. *http://people.hws.edu/halfman/#Publications.*

Makarewicz, J.C., T.W. Lewis, I. Bosch, M.R. Noll, N. Herendeen, R.D. Simon, J. Zollweg, and A. Vodacek. 2009. "The impact of agricultural best management practices on downstream systems: Soil loss and nutrient chemistry and flux to Conesus Lake, New York, USA." *Journal of Great Lakes Research* 35 (Supplement 1): 23-36.

Upstate Freshwater Institute; Cornell Biological Field Station; Cornell University Department of Biological and Environmental Science; and Cornell University Department of Ecology and Evolutionary Biology. 2014. *Final Phase I: Monitoring and Modeling Support for a Phosphorus/Eutrophication Model for Cayuga Lake.* Ithaca, New York: Cornell University, 288 pp. *https://energyandsustainability.fs.cornell.edu/file/Phase_I_Cayuga_Lake_Final_Report_121914.pdf.*

Wetzel, R.G., and G. Likens. 2000. *Limnological Analyses.* 3rd Edition. New York: Springer-Verlag. *doi:10.1007/978-1-4757-3250-4.*

Wing, M.R., A. Preston, N. Acquisto, and W.F. Ahrnsbrak. 1995. "Intrusion of saline groundwater into Seneca and Cayuga lakes, New York." *Limnology and Oceanography* 40 (4): 791-801. *doi:10.4319/lo.1995.40.4.0791.*

The Cayuga Lake Modeling Project: Tools for Ecosystem-based Management

by Elizabeth C. Moran

The New York Finger Lakes and their watersheds exemplify the concept of a "working landscape": the lands and waters provide habitat and sustenance to a diverse ecosystem, including humans. How human activities – including residential and commercial development, animal husbandry, food production, industry and waste disposal – affect water quality is a question of great interest to the research community, regulatory agencies, and all who live, work and play in the watersheds.

The Cayuga Lake watershed extends across 785 square miles and is home to 134,000 people within 45 municipalities. The 2017 updated *Cayuga Lake Watershed Restoration and Protection Plan* reports that agriculture is a major land use; about half of the watershed lands are currently used for pasture or cultivated fields. Dairy farming is a significant industry, with over 100,000 cattle housed on farms of varying sizes. Although regional lake experts concur that Cayuga Lake's water quality is generally very good, emerging issues in other Finger Lakes highlight the need for a deeper understanding of the impact of wastewater, agricultural practices, invasive species, cooling water discharges and climate change on water quality and aquatic habitat.

In December 2016, Cornell University completed the Cayuga Lake Modeling Project (CLMP) and provided New York State Department of Environmental Conservation (NYSDEC) with sophisticated mathematical models to address key questions regarding Cayuga Lake's water quality. The university and NYSDEC designed the CLMP to provide knowledge and tools for a rational, science-based approach to managing Cayuga Lake and other regional waters. The investment of four years and $3 million has resulted in a deeper understanding of three issues central to managing Cayuga Lake: phosphorus sources; phosphorus bioavailability (i.e., potency for supporting phytoplankton growth); and the impact of water motion on phosphorus and phytoplankton distribution.

NYSDEC and Cornell University embraced the emerging ecosystem-based management approach during the multi-year collaboration on Cayuga Lake. The core principles of ecosystem-based management include: developing site-specific information; building on a strong scientific foundation; engaging with the community; and taking a holistic approach to evaluating impacts of management decisions on lands, water and air.

Cayuga Lake Water Quality and the Role of Phosphorus

Across the 11 Finger Lakes, phosphorus (P) is the nutrient that most frequently limits algal growth. Elevated concentrations of this essential nutrient can lead to problematic increases in phytoplankton (algae and cyanobacteria) that degrade aquatic habitat and affect human uses of the waters for potable supply and recreation. NYSDEC currently regulates nutrient concentrations in lakes using a combination of quantitative and qualitative measures. For phosphorus and nitrogen, the qualitative assessment (known as a narrative standard) states: *"None in amounts that result in the growths of algae, weeds and slimes that will impair the waters for their best usages." (6 CRR-NY 703.2)*. This approach enables the regulatory community to exercise their best professional judgement to determine when nutrients, which are essential for the aquatic food web, have reached unacceptable levels. For recreational uses of lakes, NYSDEC applies a quantitative numeric guidance value for Total Phosphorus (TP), selected to keep phytoplankton and "algal greenness" low enough so that the waters remain attractive for swimming and boating. Compliance with the numeric phosphorus guidance value is calculated as a summer (June-September) average; to meet the guidance value summer average TP must not exceed 20 micrograms per liter (ug/L, or parts per billion). Samples are collected from upper waters of the main body of the lake.

Scientists and lake managers have directed research and monitoring programs to elucidate how phosphorus, which comes from various sources and occurs in multiple forms, affects phytoplankton concentrations. The CLMP was designed to analyze existing data regarding phosphorus and phytoplankton, implement an extensive monitoring program of the tributary streams and the lake, and integrate the information into three mathematical models. These models, once validated for accuracy over a range of conditions, can be used to test various "what-if" scenarios to project future water quality. These modeling tools can help define the most effective ways to protect the lake for future generations.

Statewide Guidance Value for Total Phosphorus in Lakes: What's Behind the Number?

Total phosphorus is a measure of all forms of phosphorus in water: dissolved and particulate; organic and inorganic. The analytical measurement of TP involves an aggressive acid digestion process that converts all these fractions into orthophosphate (PO_4^{-3}), which is then measured colorimetrically. The resulting TP measurement accounts for all forms of P, including that sorbed to sediment particles, incorporated into living and dead biomass, and dissolved in water.

The New York guidance value for TP in lakes is a summer average of 20 µg/L in the upper waters of a mid-lake station. At these sites, most of measured TP is incorporated into algal cells during the summer. NYSDEC issued this guidance value in 1993, based on a statistical analysis of data collected by volunteers from lakes across New York. As volunteers collected water samples for analysis of TP, chlorophyll-a (measure of phytoplankton biomass) and water clarity, they also completed a survey to scale their perception of a lake's suitability for recreation. NYSDEC concluded that lakes are generally attractive for recreational use when the average TP concentration in the upper waters does not exceed 20 µg/L. This value is consistent with that used by many management agencies across the U.S. and the world.

Regulatory Designations

Cayuga Lake is divided into four regulatory segments ***(Figure 1)*** due to substantial differences in depth, aquatic habitat and human uses along the 38-mile lake. Segment 1 is at the north end, where the outflow from Seneca Lake enters Cayuga Lake. This shallow region is compliant with the phosphorus guidance value. In the deep main lake (Segments 2 and 3), phosphorus concentrations are well below the NYSDEC guidance value, and have been for decades. The southern shelf (Segment 4), which includes 965 acres

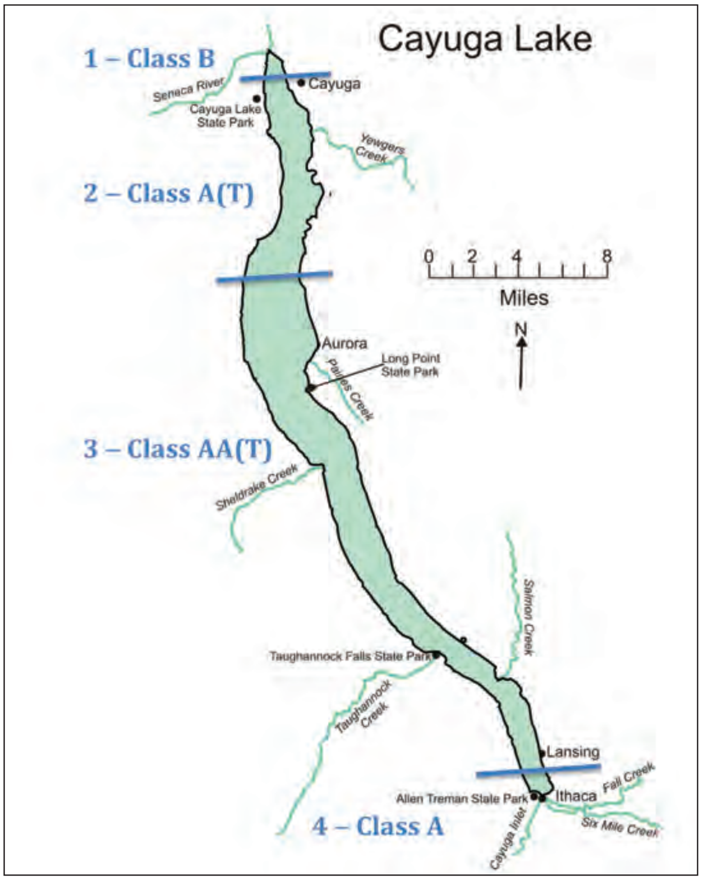

Figure 1. Cayuga Lake and Regulatory Segments. Water quality classifications are based on usage, as defined in *6 CRR-NY 701*. The best usages of Class AA and A waters are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The best usages of Class B waters are primary and secondary contact recreation and fishing. The (T) signifies trout waters. *EcoLogic LLC, based on NYSDEC information*

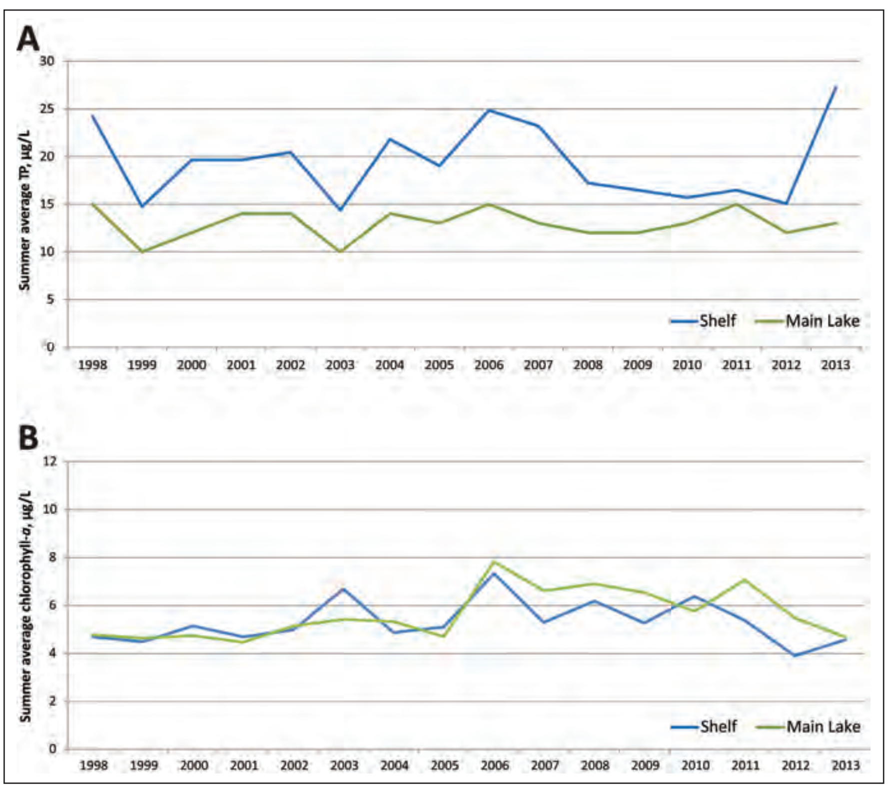

Figure 2. A comparison of TP (Panel A) and chlorophyll-a (Panel B) concentrations in the Cayuga Lake shelf segment and main lake, 1998-2013 *Data courtesy Cornell University*

of mostly shallow water adjacent to the large southern tributaries, was included on state and federal lists of impaired waters in 2002 due to elevated phosphorus, suspended silt/sediment and pathogens (bacteria). Based on a closer examination of bacteria data, NYSDEC concluded that Segment 4 had been listed in error; the segment was delisted for pathogens in 2014.

The summer average TP concentrations in Segment 4 occasionally exceed the guidance value, depending on rainfall patterns ***(Figure 2, panel A)***. In wet summers, turbid waters from the large tributary streams result in elevated TP concentrations after storm events. However, chlorophyll-a concentrations are not systematically different between the southern shelf and the main lake ***(Figure 2, panel B)***.

The 2002 regulatory listing of Segment 4 as impaired required NYSDEC to develop a Total Maximum Daily Load (TMDL) allocation for phosphorus. A TMDL is a regulatory process that identifies all sources of a given pollutant from point and nonpoint sources and determines the loading reduction needed to achieve the in-lake target concentrations. NYSDEC was unable to complete the phosphorus TMDL without detailed water quality models of Cayuga Lake and its watershed. The CLMP was designed to provide NYSDEC with tools needed to develop a phosphorus TMDL for Cayuga Lake.

Central Questions for Lake Management

Periodic elevated TP levels in Segment 4 sparked broad interest in understanding why these increases occurred in the lake's southern shelf. Both the local community and regulators wanted to identify management options that would effectively avoid stimulating algal growth. A quantitative assessment of the sources and fate of phosphorus affecting the southern shelf was needed to answer several key questions that could provide a scientific basis for managing this lake segment:

- What are the point and nonpoint sources of phosphorus to Cayuga Lake, and why is TP elevated in Segment 4?
- How much of the measured TP supports phytoplankton growth?
- How does water movement affect the distribution of TP and phytoplankton?

In addition to receiving inflow from two of the watershed's largest tributaries, the southern end of Cayuga Lake is home to some of its largest communities and is thus more heavily influenced by human uses, including treated effluent from two water resource recovery facilities (WRRFs) and water from deep in the lake circulated through Cornell University's Lake Source Cooling (LSC) facility. The LSC process draws cold water from a depth of 75 meters (approximately 250 feet) through an intake located in Segment 3 and uses it in a non-polluting heat exchange process before returning it, slightly warmed, to the southern shelf *(see Lake Source Cooling inset, page 39)*. The LSC facility, which began operation in 2000, represents a major step forward in the university's commitment to a carbon neutral campus.

While the LSC process does not add phosphorus – or any other chemicals – the deep lake water circulated through the heat exchange facility has mea-

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surable concentrations of dissolved phosphorus. Because this water is returned to the shallow Segment 4, light is adequate for phytoplankton growth. Prior to completion of the CLMP, the significance and environmental impact of the LSC circulation on phytoplankton in Segment 4 was unresolved, despite the required intensive annual monitoring and statistical analysis from 1998 to 2012. An interim TP limit was added to the 2013 State Pollutant Discharge Elimination System (SPDES) permit renewal for continued operation of the LSC facility. Thus, an additional key question is raised relating to one of the point sources discharging to Segment 4: does the Cornell LSC facility affect phytoplankton growth? If so, what final effluent limit would protect the lake for its designated uses?

To develop a final TP limit for the LSC facility – as well as for other point and nonpoint sources of phosphorus to Cayuga Lake – NYSDEC included completion of the CLMP as a special condition of the facility's 2013 SPDES permit renewal. Cornell University's Department of Utilities and Energy Management was required to fund a technical team tasked with developing mathematical models of Cayuga Lake and its watershed, with a focus on phosphorus and phytoplankton. This team of environmental engineers and scientists, led by the Upstate Freshwater Institute (UFI), spent about four years gathering data, developing and testing models, and preparing detailed reports for NYSDEC review. Cornell faculty, research associates and graduate students participated in the effort to develop knowledge and tools for effective management of Cayuga Lake and its watershed, embracing the concept of campus facilities as a living laboratory.

NYSDEC and the U.S. Environmental Protection Agency (USEPA) directed and oversaw the modeling project, which included an extensive public outreach program to ensure that local knowledge was incorporated into the models and that stakeholders could review the data collection program and modeling approaches. NYSDEC assembled a Technical Advisory Committee with representatives of local water resource management agencies, including local Soil and Water Conservation Districts, the city of Ithaca, the U.S. Geological Survey, the Finger Lakes Institute at Hobart and William Smith Colleges and the USEPA. The USEPA brought national and international modeling experts onto a Model Evaluation Group to review the mathematical models.

While managing such a complex, collaborative project team was challenging, NYSDEC and Cornell remained committed to their pledge to provide a scientific foundation for decision making, recognize interconnections within and among ecosystems, to maintain open communication with stakeholders. Over the course of the study, NYSDEC sponsored public meetings and participated in monthly updates with the Monitoring Partnership of Tompkins County's Water Resources Council.

Forms of Phosphorus and Algal Growth Potential

Under NYSDEC's direction and oversight, the CLMP included detailed analyses of the bioavailability (algal growth potential) of the analytically defined components that comprise TP (particulate P, soluble reactive P and soluble unreactive P) in samples from Cayuga Lake's streams, point sources and lake waters. A specialized laboratory at Michigan Technical University partnered with UFI to measure the bioavailability of phosphorus fractions in these sources.

The results for the Cayuga Lake and tributary samples reveal that virtually all soluble reactive P is biologically available, most (67 to 75 percent) soluble unreactive P is biologically available, and only some (6 to 20 percent) particulate P is biologically available

Cornell's Lake Source Cooling

Since July 2000, Cornell's Lake Source Cooling (LSC) facility has supplied chilled water to air condition buildings on the university's Ithaca campus, and to cool research equipment and spaces. The LSC process uses the renewable resource, naturally cold water deep in Cayuga Lake, in a nonpolluting heat exchange process. This process pumps water through a screened intake at a depth of 250 feet to a shoreline heat exchange facility. The lake water transfers its chill to a second closed loop of water connected to the campus cooling system. Slightly warmed water is returned to southern Cayuga Lake through an underwater diffuser ***(Figure 4)***. The lake water and campus chilled waters never mix. Nothing is added to the lake water except heat, and the temperature of the return flow remains relatively constant throughout the year; it is cooler than ambient lake water during the summer and warmer than ambient during the winter. The additional heat added to Cayuga Lake from the campus buildings is equivalent only to an additional 3 to 4 hours of sunlight on the lake's surface over the course of an entire year, which is well within the natural annual variability in annual lake heating. The lake loses heat to the atmosphere during the winter with no carryover from year-to-year.

This innovative approach to campus cooling is part of Cornell's commitment to energy conservation, reduced carbon emissions, and a sustainable future. By investing in the LSC facility, Cornell

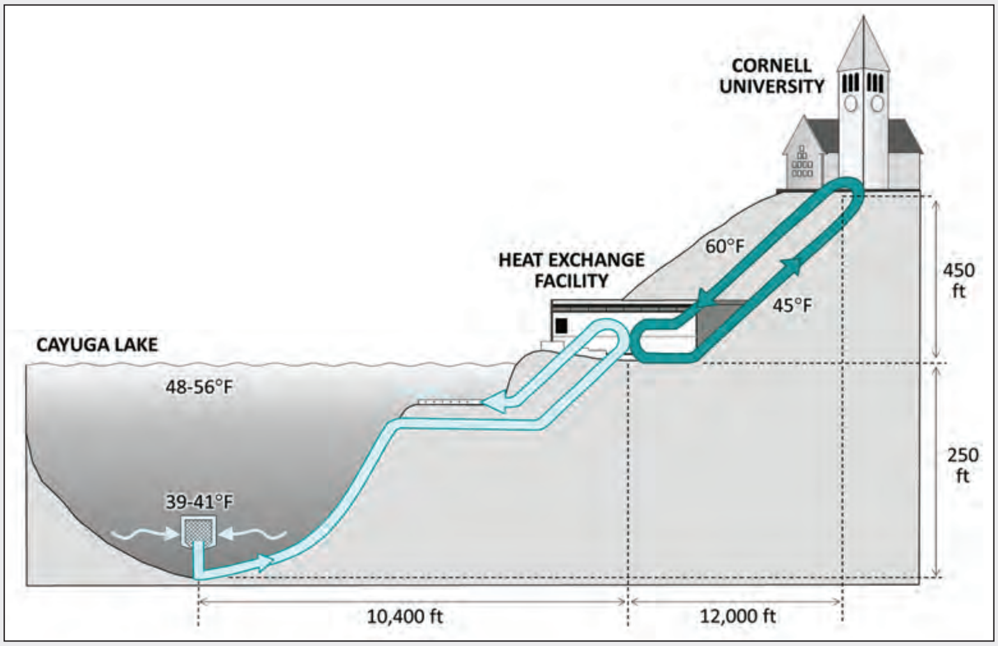

Figure 4. Lake Source Cooling process *Cornell University*

(Prestigiacomo et al. 2016).

The bioavailability of particulate P in tributary samples varies, depending on land use and the nature of the particles. Particles in streams draining agricultural watersheds exhibited substantially higher algal growth potential compared to streams draining forested watersheds. The bioavailability of particulate P from point sources also varies widely, depending on the treatment processes in place.

Three Models to Help Answer the Questions

To quantify linkages between Cayuga Lake's 785-square mile watershed – with its range of environmental conditions and human impacts – and the water quality in the lake itself, the project team developed three models.

- The **watershed model** (Soil and Water Assessment Tool, or SWAT) simulates the flow of water, nutrients and sediment from the landscape based on soils, topography, hydrology, land use, vegetative cover and management practices. The watershed modeling effort was led by Professor Todd Walter, Director of the New York Water Resources Institute. Dr. Walter and his graduate students tailored this publicly available model to the Cayuga Lake watershed after detailed consultation with local experts on land practices and manure management.
- The **lake water quality model** (CLM-2D) projects the impact of point and nonpoint sources on lake nutrients, clarity, phytoplankton growth and other water quality metrics, using a series of differential equations. This model, which is based on an EPA-supported platform (CE-QUAL-W2), applies a two-dimensional grid that incorporates hydrodynamics (water stratification, mixing and transport in response to streamflow, winds and weather). UFI developed this model for Cayuga Lake and worked with Cornell researchers to characterize the abundance and identity of lake phytoplankton species and their pelagic consumers, particularly the abundance and distribution of zebra and quagga mussels.
- The **three-dimensional hydrodynamic model** (Si3D) simulates physical processes that drive the mixing of lake water, with a focus on the lake's southern shelf and, specifically, the influence of the LSC return flow on circulation and water residence time. Professor Edwin A. (Todd) Cowen and Dr. Alexandra King of the Cornell University College of Engineering's DeFrees Hydraulic Laboratory led the Si3D hydrodynamic modeling effort in close coordination with UFI.

The modeling teams collaborated throughout the CLMP to ensure that assumptions and inputs were consistent. Although the three models are distinct from each other, the resulting knowledge has been integrated to enhance the usability of the modeling tools for the TMDL development effort. For example, the watershed model provides detailed phosphorus loading information to the lake water quality model, which tracks phosphorus, adjusted for bioavailability, and simulates phytoplankton growth. The detailed Si3D hydrodynamic model quantifies the complex mixing and water exchange between Segment 4 and the main body of the lake, and elucidates how those processes affect the distribution of phosphorus and phytoplankton.

Major Findings

The findings of the CLMP provide vital knowledge required for

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could decommission six electrically-driven chillers, and accelerate the phase out of ozone-depleting chlorofluorocarbon chemicals used as refrigerants. The LSC facility is a success – the peak summer electric demand of the entire campus would have been 40 percent higher with conventional chillers instead of the LSC system. The facility reduces the need for electricity to run the campus chilled water system by 86 percent, with annual reduction of about 5,000 metric tons carbon dioxide equivalents, and other air pollutants from fossil fuel-fired electric generation. This savings is about 12 percent of the total campus electric use or about 25 million kilowatt-hours per year.

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 State Governor's Award for Pollution Prevention, which recognizes institutions and companies that voluntarily go beyond regulatory requirements. NYSDEC also honored the LSC project because of its highly innovative nature, and the potential for technology transfer. 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, which praised engineers in Cornell's Department of Utilities and Energy Management 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."

More information about the Cornell Lake Source Cooling facility is available at *http://energyandsustainability.fs.cornell.edu/util/cooling/production/lsc/default.cfm.*

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science-based management of the Finger Lakes and other waterbodies.

What are the point and nonpoint sources of phosphorus to Cayuga Lake, and why is TP elevated in Segment 4?

As previously mentioned, the CLMP augmented existing lake and stream data with an intensive monitoring effort. In 2013, UFI's comprehensive water quality monitoring program captured changes in P inputs during storm events to improve the precision of the loading estimates. The loading estimates were used to calibrate and test the watershed model, and to identify both geographic regions and land use practices that contribute most of the phosphorus entering Cayuga Lake.

Results showed that the vast majority of TP entering Cayuga Lake is from the watershed. An estimated 97 percent of the annual TP load enters the lake from the tributaries; the remaining 3 percent is contributed from the regulated point sources. In Segment 4, phosphorus bound to sediment washing down the streams is the driver of the elevated TP measurements and the basis for the regulatory impairment. Cayuga Lake's southern tributaries, which represent about 40 percent of the annual streamflow to the entire lake, deliver a substantial mass of clay particles to the shelf during storm events. As streamflow increases, particles containing tightly bound phosphorus are eroded from the stream beds and banks and transported into the lake. These turbid inflows result in elevated concentrations of TP in the shelf waters following storms.

How much of the measured phosphorus supports phytoplankton growth?

The watershed model and lake model incorporate the detailed analysis of bioavailability into the phosphorus loading calculations. On a lakewide basis, the tributary streams contribute an estimated 95 percent of the bioavailable P to Cayuga Lake. In Segment 4, the elevated TP measured following storm events is associated with clay particles temporarily suspended in the water column; phosphorus bound to these particles has exceptionally low bioavailability (about 3 percent).

How does water movement affect the distribution of TP and phytoplankton?

The answer to this question helps resolve a conundrum: both WRRFs discharging to Segment 4 upgraded their treatment processes to achieve advanced TP removal between 2005 and 2009, yet no subsequent reduction in chlorophyll-a or TP concentrations was observed (*refer to* ***Figure 2, panel A***). The lake water quality model and Si3D hydrodynamic model provide insights as to why the 80 percent reduction in point source phosphorus did not affect trophic state variables. The very short water residence time on the shelf is the key: water residence time is shorter than phytoplankton growth rate *(Gelda et al., 2015*). The models document the extensive water exchange between the shelf and the main lake. Furthermore, the Si3D model quantifies the extent to which the LSC return flow enhances this water exchange. For every gallon of lake water circulated through the LSC facility, an additional ten gallons are swept off the shelf into the main lake by the momentum induced by the return flow's underwater diffuser. Water from the main lake replaces the water carried off the shelf, thus further reducing residence time in this dynamic segment.

Biological interactions

The CLMP evaluated components of the lake's ecosystem, with a focus on grazing organisms that affect phytoplankton. After extensive field and laboratory investigations, researchers confirmed that dreissenid (zebra and quagga) mussels have altered the Cayuga Lake phosphorus cycle by filtering particles and returning bioavailable P to the water column. During the 1990s, Cayuga Lake was home to a relatively small population of zebra mussels; currently, the closely related quagga mussel is the dominant species of invasive dreissenid, and is present at greater depths. This finding highlights the importance of an ecosystem-based approach to lake management and has implications for other Finger Lakes where quagga mussels have expanded their range.

Model Simulations

UFI researchers completed three test computer simulations to demonstrate the capabilities of the lake water quality model. These tests projected the impacts of three management scenarios compared to current Cayuga Lake TP and chlorophyll-a levels ***(Figure 3)***. The model runs were not performed as part of a TMDL analysis; the models have been provided to NYSDEC for use in completing the regulatory TMDL allocation and developing an implementation plan. Nevertheless, the test simulations offer insight into conditions that could influence phytoplankton growth in the lake over time.

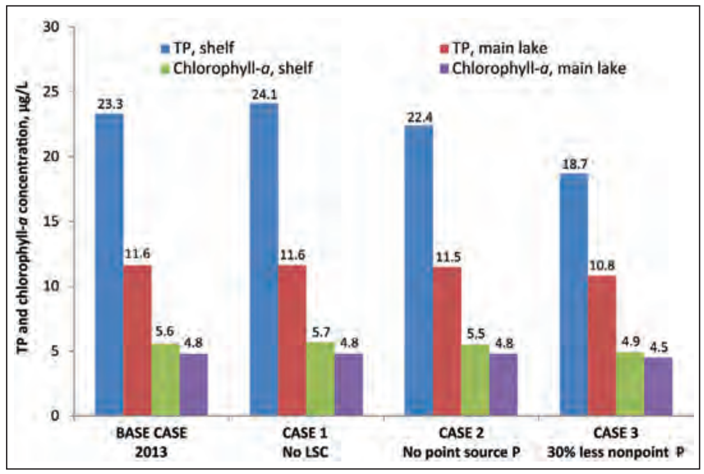

Figure 3. Applying the modeling tools to evaluate impacts of three management scenarios on summer average TP and chlorophyll-a concentrations in the shelf and main lake regions of Cayuga Lake. Model test runs project a decline in TP and chlorophyll-a concentrations in both the shelf and main lake when nonpoint source P is reduced by 30 percent. *Data courtesy Cornell University*

Case 1: Cease Operation of the Lake Source Cooling Facility

Without the reduced shelf residence time created by LSC return flow, phosphorus concentrations on the shelf are projected to remain constant or increase slightly. That is, the introduction of phosphorus to the shelf from the deep waters of the main lake by the operation of the LSC facility has no significant impact on phytoplankton growth. The increased water exchange resulting from operation of the LSC facility appears to provide a slight water quality benefit to Segment 4.

Case 2: Remove Total Phosphorus from WRRF Effluent

This test evaluated the water quality consequences of complete removal of phosphorus from six WRRFs that discharge to the lake or its tributaries. Since these point sources constitute only a small (less than 5 percent) component of both TP and bioavailable P load, it is logical to expect that this simulation would lead to a small (less than 5 percent) reduction in TP and related phytoplankton metrics. Model projections were consistent with this expectation. Notably, the small predicted reductions would be masked by the much higher natural interannual variability in water quality metrics.

Case 3: Reduce Nonpoint Source Phosphorus by 30 percent

The third model run considered the water quality impacts of a 30 percent reduction in nonpoint source TP over the entire watershed (assuming no change in bioavailability partitioning). Because phytoplankton growth is P-limited, a reduction in the supply of bioavailable P would be expected to eventually reduce phytoplankton growth. This third scenario does predict a noteworthy reduction in phytoplankton. It is likely that TP concentrations on the shelf, which are strongly correlated to storm flows, would still periodically exceed the regulatory limits. However, because the great majority of the TP load from storm events is bound to sediments, and hence not bioavailable, phytoplankton growth is not expected to be affected.

Management Implications

Consider Phosphorus Bioavailability

Pioneering work in the 1970s helped develop a central paradigm in lake management that has focused on TP and its strong correlation with phytoplankton abundance and lake clarity *(Schindler 1974)*. This perspective led to major investments and reductions in point source TP that have improved the quality of many inland lakes and reservoirs. Unfortunately, some lakes have not followed this pattern. For example, nuisance algal blooms in western Lake Erie are increasing despite reductions in TP loading; increased bioavailable P loading is implicated *(Baker et al. 2014)*.

In addition, the CLMP findings document that the summer average TP guidance value does not always correlate with phytoplankton abundance, particularly in nearshore shallow waters affected by large, turbid tributary inflows. The Finger Lakes, with major tributaries entering from the south, are vulnerable to sediment-laden inflows during storms, particularly where the tributaries have been channelized and natural wetland complexes filtering the southern tributaries have been removed or altered. Even though suspended sediments contain TP, the clay particles carried into southern Cayuga Lake during high flow conditions exhibit exceptionally low potency for stimulating phytoplankton growth.

Recognize the Magnitude and Importance of Mixing

The Finger Lakes' north-south orientation in deep valleys and the prevailing wind patterns result in strong internal waves and substantial mixing within the lake's waters. The CLMP has documented the major influence of lake hydrodynamics on the distribution of phosphorus and phytoplankton. Both Cayuga and Seneca lakes are classified by NYSDEC in multiple segments, due to differences in aquatic habitat and the designated best use of the water segments. However, these segments do not represent separately manageable water bodies. This became clear over the course of the CLMP; initially, NYSDEC stated their intention to develop a TMDL for Segment 4, the Cayuga Lake shelf. Once the preliminary models were reviewed, the agency correctly determined that a whole-lake TMDL focused on protection was the appropriate path.

Focus on the Watershed

The findings of the CLMP point to the need to understand the sources and nature of TP in tributary inflows, and focus watershed management practices on preventing bioavailable TP sources from reaching the surface water network. Thus, interventions such as buffer zones along streams and improved manure management may be more effective at reducing the risk of excessive phytoplankton than measures such as stream bank stabilization to reduce erosion of particles low in bioavailable P.

The watershed model offers additional site-specific guidance into sub-watersheds where the interactions of soils, topography, hydrology, vegetative cover and land use practices pose the greatest risk of bioavailable P export to Cayuga Lake. This tool can support decisions by agencies such as County Soil and Water Conservation Districts and others as they set priorities for technical assistance and financial support.

Conclusions

This detailed analysis of the sources and fate of phosphorus in Cayuga Lake advances our collective ability to manage lakes and watersheds across New York so that they continue to support multiple uses. The findings of the four-year collaboration between NYSDEC and Cornell provide a scientific foundation to guide policy decisions. The importance of nutrient bioavailability is a key factor in understanding the relative importance of various sources and thus projecting the effectiveness of control. Long-term protection strategies must address these realities.

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Acknowledgements

Dozens of engineers, scientists, NYSDEC staff, graduate students and resource management professionals contributed to this multi-year investigation of Cayuga Lake. In addition to the individuals cited in the text, special recognition goes to Dr. Steven W. Effler, who was proud to lead the Cayuga Lake project as the culmination of his long career. His UFI colleagues, notably Susan O'Donnell and David O'Donnell, persevered to uphold his standards and guide the lake water quality model to completion. Finally, the LSC Faculty Advisors – Nelson Hairston, Cliff Kraft and Todd Cowen – provided expert guidance to the project team.

References

Baker, D.B., R.B. Confesor, D.E. Ewing, L.T. Johnson, J.W. Kramer, and B.J. Merryfield. 2014. Phosphorus loading to Lake Erie from the Maumee, Sandusky, and Cuyahoga Rivers: The importance of bioavailability. *Journal of Great Lakes Research* 40(3): 502-517.

Cayuga Lake Watershed Network. 2017. *Cayuga Lake Watershed Restoration and Protection Plan*. Prepared for the Cayuga Lake Watershed Intermunicipal Organization. Available at *http://www.cayugalake.org/files/all/clwrpp_2017_final_4_30_17.pdf.*

Gelda, R.K., A.T. King, S.W. Effler, S.A. Schweitzer, and E.A. Cowen. 2015. Testing and application of a two-dimensional hydrothermal/transport model for a long, deep, and narrow lake with moderate Burger number. *Inland Waters* 5(4): 387-402.

Prestigiacomo, A.R., S.W. Effler, R.K. Gelda, D.A. Matthews, M.T. Auer, B.E. Downer, A. Kuczynski, and M.T. Walter. 2016. Apportionment of bioavailable phosphorus loads entering Cayuga Lake, New York. *Journal of the American Water Resources Association (JAWRA)* 52(1): 31-47. *DOI: 10.1111/1752-1688.12366.*

Schindler, D.W. 1974. Eutrophication and recovery in experimental lakes: Implications for lake management. *Science* 184:897-899.

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LEADING THE WAY IN
WATER QUALITY MANAGEMENT

The Economic Impacts of Harmful Algal Blooms in Owasco Lake

by Tracy Verrier and Bruce Sherman

Owasco Lake, the sixth largest of the Finger Lakes, is truly the lifeblood of Cayuga County. The health of our lake affects our communities significantly. Owasco Lake is a source of drinking water, production water for businesses, recreation for residents, and is an economic driver for tourism. Concern has been growing throughout the last two decades regarding the overall condition of Owasco Lake, spurring the creation of multiple advocacy and governmental groups monitoring lake levels and nutrient/phosphate levels.

Aerial view of the north end of Owasco Lake, facing south. Emerson Park is visible along the lake shore, along with the Owasco Outlet channel. *Bill Hecht*

During the summer and fall of 2016, microcystin toxins were discovered in the drinking water provided by the City of Auburn and Town of Owasco. These toxins were the result of prolonged harmful blue-green algal blooms (HABs) in Owasco Lake. Although the levels were determined to be safe enough for consumption (drinking), the concerns of local officials, businesses and residents were heightened substantially.

To better understand the economic impacts to the County from HABs in Owasco Lake, the Cayuga County Chamber of Commerce and Cayuga Economic Development Agency sought input from Cayuga County businesses, municipalities, community groups, non-profits, and other organizations via a survey.

The survey covered a series of topics, starting with some basic information about that respondent's organization, such as industry, employment levels, how it utilizes water sourced from Owasco Lake (e.g., general office use, direct production, cleaning, etc.), and whether the organization is supported by tourism. From there, the survey inquired about how the organization was affected by the algal blooms and toxins in 2016. Respondents were asked to indicate whether there was an increase, decrease, or no impact in the following areas in 2016:

- Revenue.
- Costs.
- Employment levels.
- Payroll.
- Employee morale, health and safety.
- Employee recruitment.
- Customer perception, health and safety.

Then the respondent was asked to indicate anticipated impacts in 2017 should there be continued instances of HABs, as well as how a "do not drink" order would affect their organization. Finally, respondents were asked about their personal concerns regarding water quality and their perception of the response by government and community groups. Additional comments were encouraged throughout the survey.

Forty-nine targeted entities responded, with thirty of those completing the survey through the economic impact questions and twenty-nine completing the survey in full. The impacts noted by respondents primarily discussed the costs of procuring water through an alternate source, and revenue losses due to customer perceptions and decreased tourism ***(Table 1)***. The biggest changes between actual 2016 impacts and anticipated 2017 impacts are in the areas of revenue and costs. Fewer organizations expect there to be no impact in these areas, with more expecting decreased revenues and increased costs in 2017 should more severe instances of algal blooms and water quality issues occur.

Anecdotally, one manufacturer noted that costs would increase in 2017 should there be continued water quality issues, due to their need to install additional filtration and treatment systems to ensure consistent water quality.

Of particular concern are two sectors within manufacturing that are a focus of our county's and region's economic development strategies: value-added agriculture and food production. Both of

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Table 1. Results of the Survey Showing Number of Respondents for Each Impact Area

	Question: *Please indicate how the instances of blue-green algal blooms in Owasco Lake and detection of low levels of microcystin toxins in City of Auburn water impacted your organization in 2016 in the following areas:*			***Question:*** *If more severe instances were to occur in 2017 (such as interruption in water supply), how do you believe these instances would impact your organization in the following areas:*		
Impact Area	**Increase**	**Decrease**	**No Impact**	**Increase**	**Decrease**	**No Impact**
Revenue	1	8	21	2	18	8
Costs	12	1	17	20	0	7
Employment levels	1	3	26	2	9	16
Payroll	2	3	25	3	5	19
Employee morale, health and safety	3	16	11	8	18	3
Employee recruitment	1	8	21	1	8	18
Customer perception, health and safety	4	16	10	5	17	6

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The Owasco Outlet channel at Emerson Park. This park is the only public access available on the lake, and includes a beach, boat launch and several boat slips. *Christopher Molloy*

these manufacturing sectors tend to be water-intensive industries, so reliable water sources are key to their success. Ongoing water quality concerns could limit our community's ability to expand and attract these kinds of businesses.

One seasonal recreation company noted a nearly 50 percent decrease in revenue in 2016 following the identification of HABs in Owasco Lake, and they expect that more severe instances in 2017 could close the business altogether. Some organizations also expressed concern about the ability to recruit residents and employees to the area should water quality continue to decline. Their concern is that declining drinking water quality and less recreational access to the lake – or even the perception of these issues – will have a negative impact on quality of life. Furthermore, since microcystin toxins cannot be removed from the water by boiling, businesses will be forced to buy water and have it delivered to their facilities. Consider the cost of this for health care facilities and restaurants. Residents would also need to purchase water, stretching families' budgets and affecting their financial well-being.

There are also serious concerns about the economic sustainability of our communities from a tax revenue perspective. Property tax revenue could be significantly affected should property values decline due to reduced recreational access to the lake or concerns around drinking water quality. School districts in particular would feel the effects of reduced property values.

Tourism generates a significant amount of tax revenue for Cayuga County. For instance, the Great Race, an annual event that is the nation's largest team-only run, bike and paddle triathlon, is highly reliant on the water quality in Owasco Lake for the paddling portion of the race. If boating and swimming were restricted due to HABs and toxin levels in the water, the event would be in jeopardy. This event attracts hundreds of visitors to Cayuga County each year, so there would be a significant impact on sales tax and occupancy tax revenue should the event not occur.

Water quality in Owasco Lake is important on many levels. Cayuga County relies on it as an asset for tourism and recreation, while approximately 50,000 residents rely on it for drinking water. There are obvious implications for quality of life and health should water quality continue to decline in the lake. However, the economic impacts add another level of concern. Continued algal blooms and elevated levels of microcystin toxins could jeopardize the financial health and sustainability of our businesses, non-profits and municipalities. Poor water quality is expected to increase costs and decrease revenue for these entities, and as such could impact their ability to retain jobs. Furthermore, decreased tax revenue related to decreased tourism and property values could strain municipal and school district budgets. Improving our water treatment facilities is a good first step to ensure health and safety of drinking water; however, identifying and addressing the causes of the HABs will be imperative to our community's economic success in the long run.

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Otisco Lake Dam Rehabilitation, Town of Marcellus, New York

by Andrew J. Weiss

Project Description

Over 100 years old, the Otisco Lake Dam has made it possible for the Onondaga County Water Authority (OCWA) to provide drinking water to hundreds of thousands of residents throughout Central New York. The dam is a large, High Hazard, Class 'C' structure, located on the Nine Mile Creek in the Town of Marcellus, Onondaga County, New York.

During the last few years the New York State Department of Environmental Conservation (NYSDEC) has been working with dam owners to verify the condition and safety of large dams throughout the state. The Otisco Lake Dam has been upgraded and improved many times over its long lifespan. In 2014 an engineering assessment was conducted of the dam that led to its rehabilitation in 2015. The overall cost for the project was $1.2 million. On-going inspection and maintenance will provide data to monitor the integrity of the structure under a variety of conditions. The rehabilitation of the dam also provided an educational opportunity for senior engineering students at the State University of New York College of Environmental Science and Forestry (SUNY ESF).

Engineering Assessment

In 2014 OCWA retained CHA Consulting, Inc. (CHA) to perform an Engineering Assessment of the Otisco Lake Dam, per NYSDEC's Guidance for Dam Engineering Assessment Reports *(DOW TOGS 3.1.4, dated March 2011).*

Aerial view of the Otisco Lake Dam in 2017, after completion of the rehabilitation project *OCWA*

During the evaluation of the Otisco Lake Dam, CHA found that the details about the original timber piles, installed in 1903 in the foundation of the dam, were unclear. The stability analysis for the service spillway section of the dam suggested that the dam may not meet the recommended target factors of safety, assuming potentially deteriorated connections between the base of the concrete-and-stone masonry gravity section of the dam and the underlying timber pile foundations. If the connections have deteriorated, it is possible that the timber piles would no longer resist uplift forces (i.e., function as tension piles) on the base of the spillway gravity section.

In the 1960s an upgrade project added a submerged concrete buttressing apron-and-strut system to correct for a potential connection failure between the gravity section and timber pile foundation. While the 2014 Engineering Assessment found that this structure may offer the necessary resistance to sliding failure, the system does not provide the necessary overturning resistance required to bring the structure into compliance with the NYSDEC's current overturning design guidelines.

Based on the findings of the assessment – and the fact that there is no actual way to check the condition of the connections between the dam and the piles – CHA suggested two options to OCWA:

1) perform more testing to measure how well the timber piles work; or
2) strengthen the dam so that the performance of the more than 100-year-old piles becomes less significant in the safety analysis.

To be conservative, as well as to ensure the long-term stability of the dam that is a major component of the regional water supply, OCWA chose to install additional anchors that will secure the dam in place for the long term.

Rehabilitation

OCWA accepted CHA's recommendations and chose to proceed with strengthening the dam. The installation of post-tensioned anchors was designed to achieve both sliding and overturning design criteria in two ways: first, by increasing the factor for safety against sliding failure to values that meet or exceed those recommended in the NYSDEC's *Guidelines for the Design of Dams* (revised January 1989); and second, to bring the resultant overturning moment within the appropriate structural base-middle of the spillway gravity section. The recommended modifications and repairs provided by CHA were intended to improve the overall performance of the dam and bring it into compliance with current NYSDEC *Guidelines.*

A critical success factor for the project was minimal impact to the level of the lake during the work. The community regards the lake as a valuable recreational resource, and lake level changes are a highly sensitive topic. Additionally, lake level directly affects OCWA's ability to produce water for our downstream water treatment plant; lowering the lake level limits the agency's ability to maximize our most efficient water source.

With lake levels in mind, the major part of rehabilitation work was scheduled to occur in the fall, coinciding with the historically lowest lake levels during the year. Over the last 55 years, the level of Otisco Lake has averaged 12 inches below the spillway by mid-August, and dropped to slightly more than 24 inches below the spillway by early December. These levels would be ideal for the work to occur "in the dry" while providing some storage buffer in the lake for rain events; abnormal adjustments to the lake level should not be necessary. OCWA's goal, therefore, was to maintain the lake level between 12 and 18 inches lower than the spillway of the dam during the work.

In late 2015, work began on the dam to install the post-tensioned anchors ***(Figure 1)***, as well as to make other improvements such as repointing of the masonry, sealing of joints in the concrete spillways, and repairing other minor cracks and damage to the dam's surfaces. The work included:

1) Design of a restraint system that would improve the dam's resistance to sliding and overturning. The design had to account

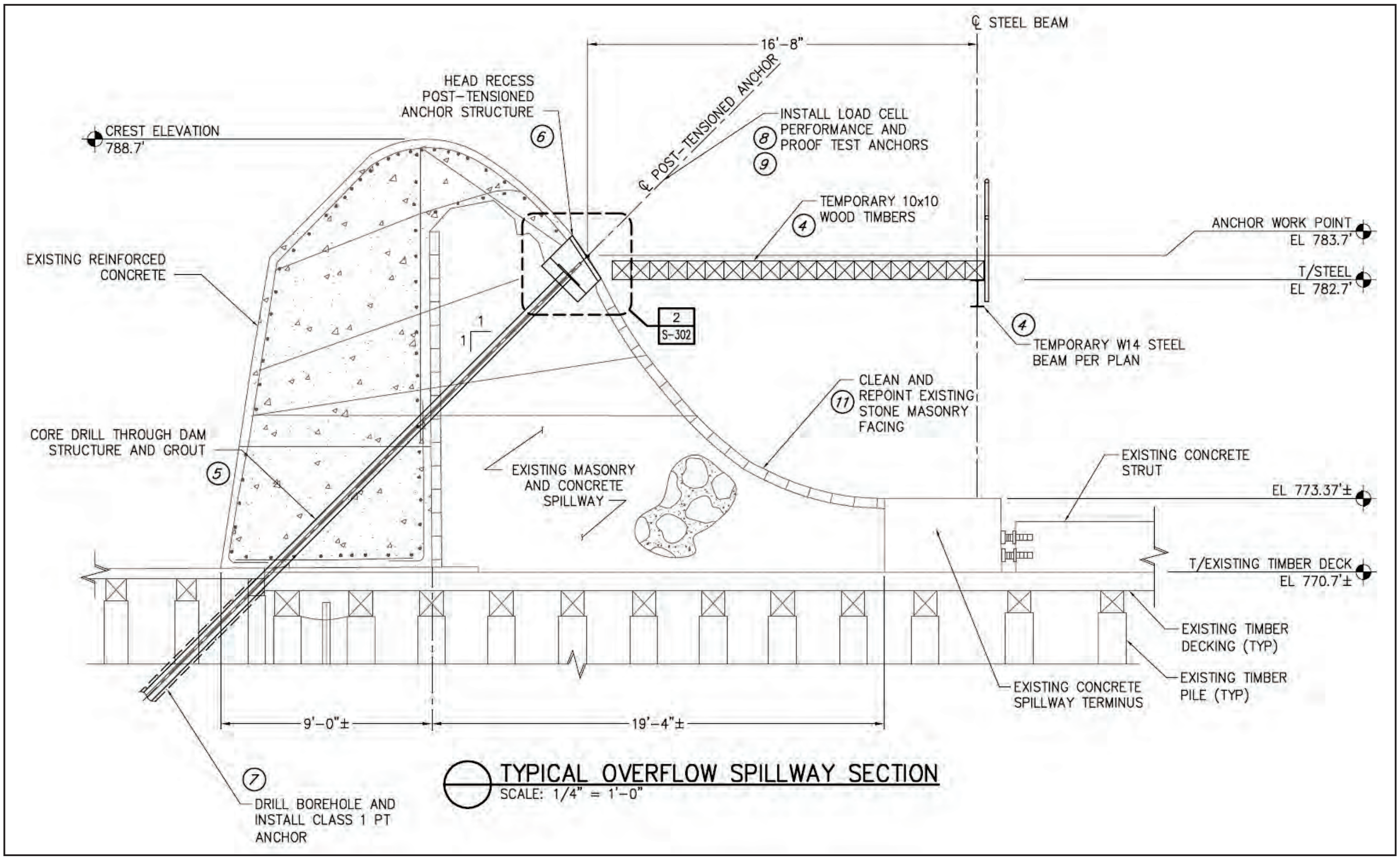

Figure 1. Cross-section diagram of the Otisco Lake dam showing the installation placement of the anchors, the masonry structure and the timber piles *CHA*

for the fact that the dam is comprised of two structures: the original masonry dam from 1908 and the upgraded cast-in-place concrete overpour from 1963. Both structures sit atop the wood piles installed in 1903.

2) Design and construction of a temporary support platform to allow for the precise and stable positioning of the anchor drill rig along the face of the dam.
3) Temporary siphons to maintain the NYSDEC-required discharge of fresh water to Nine Mile Creek while avoiding the cost and adverse environmental effects of pumping the water over and around the dam.
4) Drilling 100-foot-long anchors at an angle through the concrete and masonry dam and into the lake bed below. Precise location and angle of the anchors was necessary to avoid several existing structural features of the dam, including steel sheet pile walls beneath the upstream toe.
5) Installation and grouting of each anchor, including the lifting and insertion of individual 50-foot long sections.
6) Proof loading each anchor to confirm successful installation and curing.
7) Removal and replacement of a single failed anchor. The anchor became separated during installation and the lower 50-foot section was abandoned. A new 100-foot anchor was re-drilled and installed adjacent to the abandoned portion, through the same original hole in the face of the dam. The contractor expedited the procurement of the replacement anchor and worked with the engineer to establish an acceptable reinstallation approach without delay to the project schedule.
8) Installation of load cells to monitor select anchors for confirmation of construction and for the monitoring of long-term stability of the dam.
9) Petrographic analysis of the existing masonry grout to establish the original mix design and replicate it with the goal of achieving similar strength and performance to the original. The replicated grout mix was then used to hand re-point all the dam's exterior masonry joints.
10) Injection grouting of select joints to stop various leaks through the dam structure.
11) Repairing of the expansion joints found throughout the non-overflow sections of the dam.
12) Several meetings and presentations with the Otisco Lake Preservation Association to explain the project and reassure the residents that the lake level would remain adequate for

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The Otisco Lake Dam during the construction phase. Visible in this image are the temporary siphons (blue pipes), the temporary support platform across the face of the dam, and the anchor drill rig. *OCWA*

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their use during the later summer and early fall. Much of this effort revolved around suppressing rumors that OCWA would drain the lake. By the midpoint of construction, the rumor grew to as much as 18 feet of lake drawdown, when the actual target level was 18-inches below the spillway.

13) Monthly updates on the OCWA website to keep the public informed and to also provide updated lake level reports to compare actual level to the historical average. This was an effort to show that despite the work, the lake level was not adversely affected.

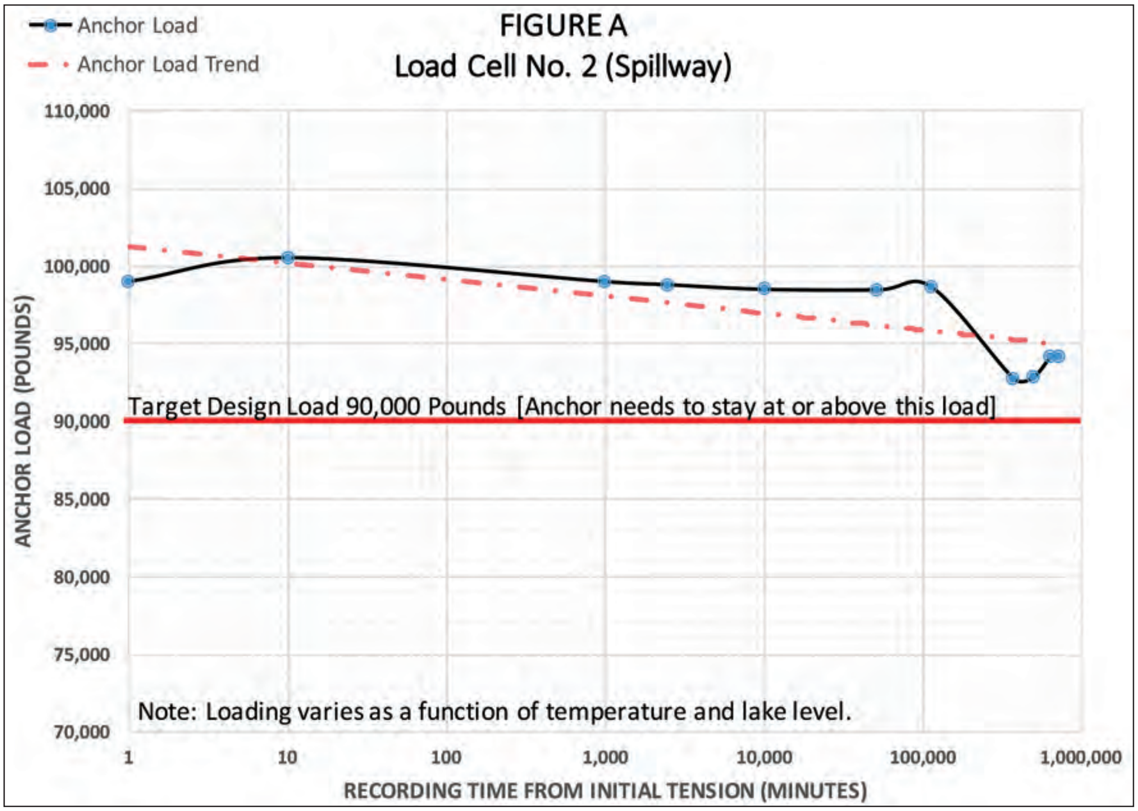

Figure 2. Readings from Load Cell No. 2 (Spillway) measured between January 6, 2016, and April 11, 2017. The data are load cell readings corrected to jack lock-off load, in pounds, with a logarithmic trend line. The x-axis is scaled logarithmic; the y-axis is scaled linear. *OCWA*

The overall project was completed in January 2016, on-time and under budget, and has been performing successfully. Despite the potential for many complications the work progressed smoothly. Strong cooperation between the contractor, OCWA and CHA allowed for steady progress.

Post-Construction

Post-construction, OCWA is performing periodic inspection of the dam, following the Inspection and Maintenance (I&M) Plan prepared by CHA. The I&M Plan was developed in conformance with the New York Codes, Rules and Regulations Title 6, Chapter 10, Part 673.6 *(6 CRR-NY 673.6) Inspection, Operation and Maintenance*, and the NYSDEC's *An Owners Guidance Manual for the Inspection and Maintenance of Dams in the State of New York (June 1987)*. The I&M Plan has descriptions of operations, monitoring, routine inspections, maintenance, training and notifications associated with the Otisco Lake Dam.

A key component of the I&M Plan is that every six months the load cell readings are taken to verify integrity of the anchors. ***Figure 2*** shows the record of the 6-month readings taken at completion of the project in January 2016 through April 2017, with some additional data points. The anchors are not rigid and their tension will change over time. The short-term tension varies based on water level in the lake, temperature of the anchors, and any other loading imposed on the dam (i.e., ice). Long term, the tension will slowly decrease as the anchors "creep" due to the tension they are providing. Each anchor head can be accessed via a steel cover plate and the locking nut can be re-tightened to restore design tension to the anchors. The downward trend depicted in ***Figure 2*** is consistent with the design intent. The logarithmic scale along the time axis makes the decline appear dramatic. However, the actual rate of change in tension is slow and it is anticipated that retightening will not be necessary for 50 years or more.

As part of the I&M Plan it is also necessary to perform inspection of the dam during events or major changes in lake condition. While no official events have occurred at the dam since project completion, OCWA has been selecting times when conditions deviate significantly from average and recording the values (e.g., during lowest and highest observed lake levels). The intent is to establish a baseline of anchor load data so that in the future, should an event occur, the values measured at that time have greater relevance. Examples of an event include: more than three inches of rainfall in 24 hours; or more than one inch of rainfall within one hour. Additionally, any seismic event in the area would also trigger inspection.

Educational Opportunity

Beyond the actual work performed, the project was used as an Engineering Capstone Project for senior engineering students at SUNY ESF. A project team from the senior design class worked with OCWA and performed a parallel evaluation of the dam and developed engineering solutions of their own. They were provided project documents and were able to visit the project several times during active construction to observe the dam and the work being done firsthand. The students concluded that the approach used by OCWA was the most appropriate and economical.

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OCWA
Central New York's Water Authority

A Regional Water Quality Solution Envisioned for Seneca Lake

by Gregory D. Mosure

The Village of Watkins Glen owns and operates an aging water resource recovery facility (WRRF) located on the shoreline of Seneca Lake, adjacent to a thriving waterfront marina, restaurant and hotel ***(Figure 1*)**. The facility serves the Village of Watkins Glen, as well as sewer districts within adjacent areas of the Towns of Dix and Reading. The Town of Dix Sewer District includes the Watkins Glen International Speedway that, together with local wineries and Seneca Lake's recreational opportunities, brings substantial tourism revenue to the Village each year.

The nearby Village of Montour Falls also owns and operates an aging WRRF which is located on the shoreline of the Seneca Canal, adjacent to a thriving waterfront community comprised of seasonal motor homes, a campground and marina facilities ***(Figure 2)***. The facility serves the Village of Montour Falls with no outside customers in the surrounding towns.

At over 50 years old, both facilities have reached the end of their useful design and service life despite many upgrades over the years. In addition, both facilities sit on prime real estate for waterfront development consistent with both the Villages' and Schuyler County's long-range planning as part of the *Project Seneca* lakefront development effort. *Project Seneca* is poised to be the largest economic development initiative in Schuyler County's history. This partnership of Watkins Glen, Schuyler County and Montour Falls is working in a coordinated effort to invest public dollars to attract private development and spur economic development on the Seneca Lakefront ***(Figure 3)*** and along the Canal to Montour Falls ***(Figure 4)***.

Recognizing their shared problems, the Villages of Watkins Glen and Montour Falls completed a joint Preliminary Engineering Report (PER) for evaluation of alternatives for rehabilitating their respective WRRFs in 2012. The PER considered costs for each Village to repair/replace its own facility, in addition to a "Regional" wastewater treatment alternative. This Regional alternative would replace both existing aging facilities and serve both the villages and the outlying sewer districts.

Schuyler County, a key stakeholder through the Planning and Funding Phases, embraced and strongly supported the Regional WRRF Project. With the support of the county and many others, the $25 million *Project Seneca* Regional WRRF was selected as the most cost effective, long-term sustainable solution for meeting the area's wastewater treatment needs for the next 30 years and beyond.

The Regional WRRF is viewed as the first and most critical component of the overarching *Project Seneca Vision*. The P*roject Seneca Vision* will include ongoing local and private investment in water-

Figure 1: The existing Watkins Glen WRRF, located on Seneca Lake
NYS GIS Clearinghouse Orthoimagery

Figure 3: *Project Seneca Vision* for the Watkins Glen/Seneca Lake waterfront
Image courtesy of Laberge Group

Figure 2. The Montour Falls WRRF is located on the Seneca Canal/ Catharine Creek.
NYS GIS Clearinghouse Orthoimagery

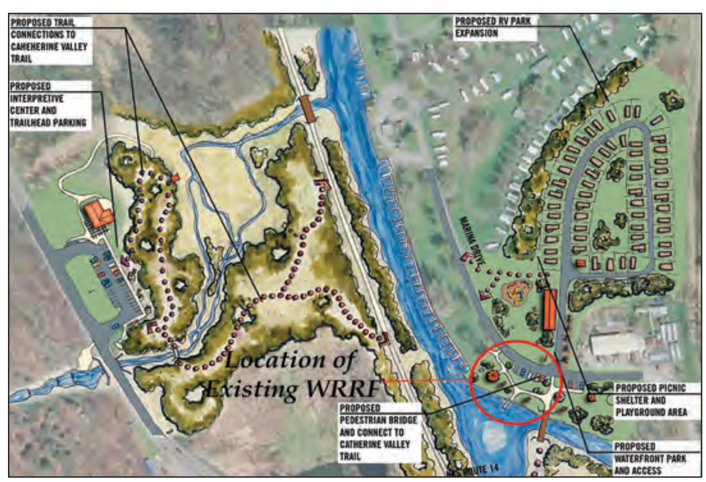

Figure 4. *Project Seneca Vision* for the Montour Falls waterfront
Image courtesy of Laberge Group

front revitalization projects. The vision for the Regional WRRF is a state-of- the-art, modern facility that maximizes energy efficiency opportunities. It will apply the latest in treatment technologies to meet (and potentially exceed) new and increasingly stringent effluent nutrient limits to Seneca Lake. The Regional WRRF will have the capacity to treat the highly variable waste flows and loads generated by the Watkins Glen International Speedway and the area's tourism industry, while building in flexibility for future development and possible extension of public sewers to the Villages of Odessa and Burnett.

The Regional WRRF process, designed by Barton & Loguidice, D.P.C. in Syracuse, New York, will include screening of raw sewage and grit removal, followed by extended aeration in a three-train sequencing batch reactor (SBR) process. The biological process uses the Integrated Surge Anoxic Mix (ISAM™) scheme developed by Fluidyne Corporation. The process incorporates an anaerobic and anoxic mix step at the head of the train, integrated with low-rate anaerobic digestion. Decanted secondary effluent will be dosed with ferric chloride to coagulate residual phosphorus not taken up biologically. Secondary effluent will be filtered through a fabric filter to remove remaining suspended solids and coagulated phosphorus prior to seasonal ultra-violet disinfection and discharge to the Seneca Canal.

Settleable solids and waste activated sludge will be digested in Fluidyne Corporation's proprietary low-rate anaerobic digestion process. This process is a low-energy, low-rate digestion process. Solids are retained within the covered digesters for approximately 120 days, resulting in a 64 percent volatile solids reduction and digested sludge consistency of approximately 3 percent solids. Digested sludge will be dewatered through a volute dewatering press, sized to produce a 20 percent cake solid and approximately 8,600 dry pounds per day.

The Regional WRRF is designed for 1.2 million gallons per day (MGD) average daily flow and 6 MGD peak hourly flow. The facility will occupy a 5-acre parcel along the Seneca Canal midway between the Villages of Watkins Glen and Montour Falls.

The Villages have formed a Joint Project Committee (JPC), under the auspices of an Intermunicipal Agreement (IMA) executed between the two Villages. The IMA outlines the framework for planning, construction, operation and financing of the Regional WRRF. The IMA also includes provisions and monetary incentives for proactive reduction of inflow/infiltration (I/I) within the existing sanitary collection systems as a means of creating and sustaining excess capacity within the new Regional WRRF. The Regional WRRF IMA, as written, does not include any provisions for ownership, operation and maintenance of the four sanitary collection systems that will be tributary to the new Regional WRRF; it assumes that each village and town will continue to own, operate and maintain their respective collection system assets.

To date, the JPC has worked in close coordination with the *Project Seneca* stakeholders, professional consultants, legal counsel and others to secure the funding needed for the Regional WRRF, including a Clean Water State Revolving Fund hardship loan, an Empire State Development grant, and New York State Clean Water Grant Round 1 Award. Construction will be performed under three main contracts, the first of which will be open for bid on November 1, 2017. Substantial completion of the Regional WRRF is anticipated in early 2019.

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N.Y. Students Awarded 2017 Stockholm Junior Water Prize!

Reprinted from NYWEA's Currents Newsletter

Ryan Thorpe and Rachel Chang, both from Manhasset High School, New York, constructed a system that detects and purifies water contaminated with *Shigella, E. coli, Salmonella* and *Cholera* more rapidly and sensitively than conventional methods.

The system detects as little as one reproductive bacteria colony per liter instantaneously and eliminates bacterial presence in approximately ten seconds. In contrast, conventional methods have detection limits of up to 1,000 colonies and take one to two days.

The prize, which attracted teams from 33 countries competing in the 2017 finals, was presented by H.R.H. Crown Princess Victoria of Sweden during the World Water Week in Stockholm.

In its citation, the Jury said: "This year's winning project embodies the fundamental principle of providing safe drinking water. The winner's motivation is to eliminate millions of human deaths each year. The project developed a unique, rapid and sensitive method to identify, quantify and control water contaminants."

As the pair received the prize, Rachel Chang said: "I'm feeling so overwhelmed with emotions. All the projects here are absolutely amazing, truly of the highest quality. So, to be able to win such an achievement, it feels incredible".

Torgny Holmgren, executive director of the Stockholm International Water Institute (SIWI), said: "This is a very inspiring project that takes on one of the world's biggest challenges, providing clean drinking water for all. Methods like these can unlock huge human potential, when access to safe drinking water, and by extension health, improves among hundreds of millions of people."

(L-r) Ryan Thorpe and Rachel Chang are this year's Stockholm Junior Water Prize winners. They pose here with patron of the prize, H.R.H. Crown Princess Victoria of Sweden, and 2017 Stockholm Water Prize Laureate, Professor Stephen McCaffrey.

NYWEA is proud to have sponsored these young students in the Stockholm Junior Water Prize competition. We congratulate Ryan and Rachel on their achievement, and we recognize the mentoring contribution of their teacher, Ms. Alison Huenger, in their success.

Honeoye Lake Restoration: Let Nature Lead the Way

Reprinted with permission from The Nature Conservancy

Last fall, The Nature Conservancy and partners completed a restoration project in the Honeoye Lake watershed that will improve its largest tributary's ability to filter sediment and nutrients before they reach the lake.

Increasingly, blue-green algal blooms are reducing recreational use of the lake, impacting tourism, and even creating conditions that are dangerous for people, pets and wildlife.

Over the years, various control methods have been proposed for different Finger Lakes, but for Honeoye the restoration team relied on one-part green engineering and two-parts ingenuity.

"When confronted with tough problems, we return to first principles. In this case, that meant imagining how the lake used to function prior to the watershed's agricultural boom," says Stevie Adams, Freshwater Specialist with The Nature Conservancy. The result was a "green infrastructure" plan, which restored the stream course into a winding channel that reconnects Honeoye Inlet to its floodplain. This slows the rush of water into Honeoye Lake and allows the floodplain to naturally intercept nutrients and sediment before they reach the lake. Now, even during flood events, the water spills over the floodplain instead of rushing directly into the lake – thus greatly reducing food for blooming algae.

Partnerships are fundamental to how The Nature Conservancy works. Partners on this particular project include: New York State Department of Environmental Conservation, Honeoye Lake Watershed Task Force, Ontario County Soil and Water Conservation District, The Honeoye Valley Association, and Finger Lakes Community College.

Over the next two years, The Nature Conservancy will monitor the inlet for improvements to both water quality and habitat. By collecting and analyzing water samples and studying macroinvertebrates, over time we will be able to describe how the project is influencing sediment and nutrient loads. Additional tree planting has begun and drones will be employed to monitor landscape-scale conditions, especially after flood events, to get a picture of how fish and other aquatic species benefit from these newly inundated areas. Conducting bird and amphibian surveys will help us understand how quickly life regenerates in and around the channel.

"We can't re-engineer a healthy lake in a day," says Adams, "But if we think like nature, we are more likely to devise cheaper and longer-lasting solutions to environmental problems."

This article first appeared in The Nature Conservancy's Central & Western New York Chapter Spring/Summer 2017 Newsletter. This year marks the 60th anniversary of The Nature Conservancy in Central & Western New York. The mission of The Nature Conservancy is to conserve the lands and waters on which all life depends. Our vision is a world where the diversity of life thrives, and people act to conserve nature for its own sake and its ability to fulfill our needs and enrich our lives. Learn more at nature.org/cwny.

Honeoye Inlet and floodplain. This aerial view of the stream course, taken in October 2016, shows how it was restored into a winding channel that reconnects the Honeoye Inlet with its floodplain. *©TNC/Mat Levine*

Enhancing Canandaigua Lake's Natural Capital to Improve Flood Resiliency and Protect Water Quality

by Kevin Olvany and Kimberly McGarry

Canandaigua Lake is one of New York's 11 renowned Finger Lakes, which are nestled between the glacially-carved rolling hills iconic to this part of the state. State and local research efforts have shown that Canandaigua Lake continues to be a high-quality water resource. However, in August and September of 2015, Canandaigua Lake experienced its first harmful algal bloom of *Microcystis*, resulting in closed beaches and increased concern regarding the future quality of the lake. An already pro-active watershed community has called on our local and state government officials to increase resources to protect the lake's water quality.

Our most recent update of the Canandaigua Lake Watershed Management Plan was completed in late 2014. The plan built on the knowledge gained from field research and projects completed over the last fifteen years to develop a more comprehensive strategy to protect Canandaigua Lake and its surrounding watershed from existing and emerging threats. National, state and local research efforts have found that the watershed area surrounding the lake plays a critical role in the overall water quality of the lake. Therefore, protection at the watershed level is vital in maintaining and enhancing all that a healthy Canandaigua Lake ecosystem provides to the region.

Extreme Storm Events

Numerous researchers at the federal, state and academic levels have documented that more extreme rain events are occurring on a more frequent basis in the Northeast region of the United States. A study led by Dartmouth College, for example, found a 53 percent increase in precipitation events of 2 inches or greater for the 19-year period of 1996 to 2014, as compared to the 95-year period from 1901 to 1995 *(Dartmouth College Office of Communications 2017)*. The Third National Climate Assessment report has estimated a 71 percent increase from 1958 to 2012 in the amount of precipitation that falls in the heaviest one percent of daily precipitation events *(Melillo, Richmond and Yohe, 2014)*.

Our local experiences correlate very well with these scientific assessments. We have faced two Federal Emergency Management Agency (FEMA) disaster-level flooding events in the last six years. In addition, we have had several localized events that caused substantial flooding impacts. These increased rain intensities on a more frequent basis have devastating impacts on farm fields in our watershed. Farmers lose their top soil and crops, and the severity of loss is based on the seasonal timing of these storms. Canandaigua Lake receives the increased volume of runoff, which also transports to the lake elevated levels of sediment, nutrients, bacteria, pesticides and other pollutants from a wide array of land uses.

Our Natural Capital

Research and case studies have documented that a highly effective and cost-efficient way to maintain and enhance a high-quality lake is to protect and restore the critical land areas in the surrounding watershed, particularly those that provide the greatest water quality and habitat benefits. The Canandaigua Lake Watershed Management Plan defines a wide array of strategies to prioritize the protection and restoration of critical areas. Some examples of these critical areas include: wetlands; shorelines; streamside and roadbank buffer areas; floodplains; forested areas; and other areas that filter and reduce stormwater runoff. Protecting and restoring these critical areas provides substantial benefits to individuals and the overall community, both within and beyond the watershed boundaries.

With the increasing frequency of extreme storm events, these critical land areas become even more important to protecting Canandaigua Lake. They are our natural assets, and therefore we considered them our natural capital. Natural capital is defined as consisting "… of those components of the natural environment that provide a long-term stream of benefits and services to individual people and to society as a whole…." *(Liu et. al, 2010)*. Natural capital areas can range in size from a single, one-thousand square foot rain garden or stream buffer to a forest covering hundreds of acres. The five main management approaches used to preserve and enhance the functional value of these natural capital areas include research, education, open space protection, restoration and regulation.

An Economic Force

Canandaigua Lake is the life blood of our region, serving as a major economic engine. Our communities rely on the ecosystem services that result from our natural capital, including:

- *High quality drinking water supply.* The raw water from the lake is of high quality and clarity, so costs for water filtration are low. This results in low water supply rates for over 70,000 consumers.
- *Major recreation and tourism destination.* Recreational activities such as boating, sailing, kayaking, canoeing, sightseeing, fishing and swimming generate millions of dollars for the region each year. The latest estimates from the New York State Department of Environmental Conservation (NYSDEC) show that Canandaigua Lake is the 23rd most fished waterbody in New York, contributing an estimated $2.3 million boost to the local economy.
- *Higher market value for lake shore properties benefits the community tax base.* Numerous studies have linked the market value of shoreline properties to the quality of the lake that those properties adjoin. The market-based assessed value for shoreline property on Canandaigua Lake is over $11,000 per foot of shoreline in some areas. The value of the lake-influenced tax base is over $1 billion, which helps to reduce the overall local, school and county tax rates for everyone.
- *More people come to live in or visit the communities around a high-quality lake.* Canandaigua Lake is not only a financial driver for communities within the watershed, but also improves the quality of life for residents through its beauty and intrinsic value. Numerous municipal surveys have documented that the beauty of Canandaigua Lake is, without question, one of the main reasons most people live in or visit the region. In addition, the residents surveyed placed a high value on protecting the water quality of Canandaigua Lake. These survey results are borne out by the measurable population increases occurring around Canandaigua Lake, which are counter to the overall declining population trend in the Genesee/Finger Lakes region.

Based on these factors, it is obvious that the natural capital of the watershed contributes greatly to both the economy and the overall quality of life. If the watershed ecosystem remains in good health, then the communities in the region can expect a high rate of return from investing in our natural capital. There will continue to be a high demand for the ecosystem services of our unique area as long as our natural capital is protected and enhanced.

Enhancing Our Natural Capital

As identified in the Canandaigua Lake Watershed Management Plan, the major thrust of the watershed restoration and protection approach is the enhancement of our natural capital. More specifically, our goals are to provide increased flood resiliency and improved water quality protection that will better withstand more frequent and powerful storm events. Listed below are just a few of the current projects that span the geographic area of the watershed:

Sucker Brook Wetland Creation and Restoration Initiative

Extensive water quality monitoring of more than 50 storm events over the last 15 years has documented that Sucker Brook contributes the highest concentrations of phosphorus and fecal coliform bacteria entering Canandaigua Lake. In comparison with the other 16 streams sampled, Sucker Brook has the highest overall pollution index. In addition, this subwatershed has had substantial flooding issues in recent years, which flooded city streets and homes along Sucker Brook and damaged 17 classrooms at the Canandaigua Primary School.

To address water quality and flooding issues, we sought to increase the natural capital of this subwatershed. To help solve flooding at the Primary School, a two-acre stormwater wetland was created on school district property with NYSDEC and New York State Department of State funds in 2007. While this was a great start, this project alone cannot solve the problem; these stormwater wetlands reached capacity during one intense rain event in the summer of 2017.

To build even more resiliency and water quality protection into this system, we have obtained additional state funding to construct/enhance two to three additional wetland areas that will enhance the natural capital potential of 40 acres of land. These projects are possible due to the commitments of both the Town and City of Canandaigua, who have contributed $150,000 and $175,000, respectively. Private individuals have also donated land for the projects. To keep costs down, municipal labor and equipment are used and we also work in partnership with the Canandaigua Lake Watershed Association. The cost savings allow us to restore and enhance more acreage. The benefits in water quality, flood resiliency, and habitat value will benefit the lake and our local communities for years to come.

Creative Partnerships for Floodplain and Wetland Restoration and Enhancement

Like many streams throughout the Finger Lakes, many of our streams are no longer connected to their floodplain due to stream incisement (downcutting) and berming (to prevent flood waters from overtopping stream banks). One of our strategies to improve water quality and flood resiliency is to reconnect streams to their floodplains. These projects are larger in scale and therefore require creative partnerships.

We are in the planning phase for two floodplain projects. We have partnered with the Nature Conservancy, the Town of Naples, and NYSDEC to restore 200 acres of floodplain in Naples, along

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Beautiful Canandaigua Lake

Naples Creek and Parish Gully. The Nature Conservancy purchased 80 acres that are integral to the project. We are now securing grant funding to implement the plan. We have also partnered with Ontario County and Finger Lakes Community College (FLCC) to develop a water quality improvement project in a 17-acre area along Fall Brook on the FLCC campus. We are also in the process of securing funding to implement this project.

Upland Solutions to Downslope/Shoreline Problems

Like other Finger Lakes, Canandaigua Lake has hundreds of small drainage features that discharge directly into the lake. These drainage features are typically less than 1,000 acres in drainage area, which dry up during a good portion of the year but can be raging rivers during extreme storm events.

Residential development hugs the shoreline of Canandaigua Lake. In many areas, the houses were built close together on small parcels. The recent high intensity storm events have shown the challenges of managing stormwater in the densely developed shoreline areas. Numerous homes have been flooded and roads have been closed, but very few options are possible for stormwater improvements where the problems are occurring. We have seen this problem grow over recent years with the increasing number of high intensity storm events, so we have been looking for solutions upstream.

In each case, we first need to understand where the water is coming from. Our subwatersheds have been highly manipulated through diversion swales on residential lots, drainage along roads, and agricultural ditching. Understanding and mapping these complex drainage areas can take many hours in the field, walking and driving the area to fully understand flow routing. Once we understand the drainage area, we then look for areas with the topographic potential to temporarily store stormwater. We have done this in countless locations across our watershed. Each drainage area is unique in terms of its issues and the potential for solutions.

Government will play a role in solving or mitigating these issues, but we are also trying to encourage downstream property owners to collaborate with their upstream neighbors to complete projects together. We have also applied for state funding to implement projects along the edge of farm fields to capture pollutants and slow water movement through the watershed. In addition, our Soil and Water Conservation Districts play a key role in working with farmers to improve their practices.

Intermunicipal Leadership: The Watershed Council

The Canandaigua Lake Watershed Council, now in its 17th year of existence, coordinates the implementation of the comprehensive watershed protection program. The Watershed Council consists of the 14 watershed and water purveying municipalities: towns of Canandaigua, Bristol, South Bristol, Potter, Naples, Gorham, Italy, Middlesex and Hopewell; villages of Newark, Palmyra, Naples and Rushville; and the City of Canandaigua. Each municipality sends their chief elected official, or other elected municipal board member, to the Watershed Council meetings. The Watershed Program Manager, who is overseen by the Council, is responsible for recommending and implementing management decisions approved by the Watershed Council, along with coordinating all the various partners.

The Watershed Council provides a base level of funding to support the watershed program through a fair share formula that equitably divides the costs of the program among the 14 municipalities. The Watershed Council and its member municipalities have been successful in obtaining close to $2 million in grant funding through various agencies. Based on the intermunicipal leadership and success of the program, the Watershed Council has received both the prestigious NYSDEC Environmental Excellence Award and the USEPA Clean Water Partner for the 21st Century Award.

Although the Watershed Council was established to lead the watershed protection effort, no single entity can provide comprehensive protection of the lake. Continuing and enhancing the partnerships with the wide range of organizations at the local, regional, state and federal levels are integral to the comprehensive watershed effort and will be what ultimately makes this effort successful.

Conclusion

The increased intensity and frequency of precipitation events, combined with a long history of manipulation of our drainage systems, have combined to dramatically increase flooding and water quality issues throughout the Finger Lakes region. The associated increase in harmful algal blooms and the negative consequences that have occurred require that we substantially increase our efforts to restore and enhance the natural capital areas throughout each of our watersheds to build in the necessary resiliency and provide for the long-term protection of our critical water resource areas.

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References

Liu, S., R. Costanza, A. Tory, J. D'Agostino, and W. Mates. 2010. "Valuing New Jersey's Ecosystem Services and Natural Capital: A Spatially Explicit Benefit Transfer Approach." *Environmental Management* 45:1271-1285.

Dartmouth College Office of Communications. 2017. "Dartmouth-Led Study Finds Heavier Precipitation in the Northeast Began in 1996." Dartmouth College. May 23. Accessed August 18, 2017. *http://www.dartmouth.edu/pressreleases/heavier_precipitation_northeast.html.*

Melillo, J.M., T.C. Richmond, and G.W. Yohe, eds. 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment.* Washington D.C.: U.S. Global Change Research Program. *doi:10.7930/J0Z31WJ2.*

My Water Legacy – NYWEA Connects with the Saikkonen Family from Central New York

by Al Saikkonen and Kelly Saikkonen

Editor's Note: In October 2016, the Water Environment Federation (WEF) launched the #MyWaterLegacy social media campaign to bring attention to the value of mentorship and membership, the tradition of working in the water sector, and the important contributions that water professionals make every day to build a legacy of clean water for future generations.

In the spirit of the WEF's #MyWaterLegacy social media campaign, Clear Waters *is featuring members of our own NYWEA family of water professionals. For this issue, we spoke with two natives of the Central New York/ Finger Lakes region: engineers Al and Kelly Saikkonen.*

Al and Kelly Saikkonen, father and daughter, are both engineers in the water and wastewater field.

Al is a Senior Environmental Engineer with CDM Smith, working from Syracuse, New York, during the summer and from Orlando, Florida, during the winter. Al takes on the role of technical leader for wastewater process mechanical designs, and acts as the self-described "project-designated clear-thinker."

Kelly is a Managing Engineer with Natural Systems Utilities in Hillsborough, New Jersey. She serves as the engineer on a variety of water and wastewater projects with a focus on Design-Build-Operate, managing the projects and a design team of five engineers.

Kelly and Al Saikkonen: A Water Family Legacy *Dimitrios Zervas*

It was an easy career choice for both Al and Kelly to become engineers in the water and wastewater field.

"Engineering was a clear choice for someone who likes to solve technical problems and see things being built," said Al. "Engineering would be a field that I knew I would always enjoy. It was an easy choice as neither the liberal arts nor pure science interested me."

Kelly credits her parents' influence when she decided to get a technical degree in college. "I did well in math and science in high school, and they encouraged me to pursue a degree in science or engineering," she said.

> *"In my mind, the optimal job for a new grad would be one that combines 'hard' design experience with spending time in the field to see how things are built and how they operate. I spent three years in the field as a resident engineer, and learned a wealth of information."*
>
> *–Kelly Saikkonen*

She also saw the future career potential in the field. "The world will always have technical challenges that need solutions, so I knew there would be great career prospects after graduation," she said.

However, the engineering field has its challenges.

"I struggled early in my career to find the 'niche' that interested me," said Kelly. "I was lucky to have mentors and managers that recognized my interests and talents, and tried to align them with the business needs of various clients."

Kelly believes it is important to think outside the box when it comes to choosing an engineering path. "If you are not feeling satisfied or fulfilled with the work you are doing, there are so many different types of opportunities in this industry," she said. "One engineer I worked with, after several years in consulting, went to work as a technical director for Engineers Without Borders. Another is a P.E. but enjoys managing construction projects and spends every day the field."

Al agrees. "Like what you do and do what you like is the best advice," he said.

Kelly recommends that college students do an internship. "See what setting they enjoy being in," she said. "Do they want to do design engineering and sit in an office for eight or more hours a day? Or do they like being in the field, engaged in construction and operations projects?"

While there are challenges in the water and wastewater engineering field, there are also rewards.

"A significant challenge is pursuing projects in a highly competitive environment," said Al. "Hurdles are always related to dealing with unforeseen (changed) conditions and managing change during design and construction." The greatest reward, said Al, is seeing a completed project functioning flawlessly and knowing it would continue to function for another 20 to 40 years. "Receiving unexpected compliments from operating and maintenance staff on a project is always the icing on the cake," he added.

Kelly likes the technical challenges of managing innovative water reuse projects, as well as working with engineers with diverse backgrounds, specialties, personalities and experience levels. One of the benefits of her work, she said, is providing solutions to real-world problems that have immediate impact.

"How to deal with the waste that we humans produce has been a challenge for as long as humans have existed," she said. "With the world's population growing, the technology needs to continue to advance. Who would have thought, even a few decades ago, there would be water resource recovery facilities so advanced that a person can take the treated effluent and drink it from a glass? That level of recycling just amazes me."

Al and Kelly each have role models they have looked to for inspiration. Al admires the work of Dr. Wesley Eckenfelder Jr., a renowned engineer in the industrial wastewater management field. Al also respects the work of his local colleagues. "Al Firmin at CDM Smith and Ken Gerbsch at OBG are among the best role models

I have known and worked with," he said.

One of Kelly's heroes is not an engineer, but an esteemed astronomer. "I have always looked up to and admired Carl Sagan," she said. "His books about humanity's unique presence in the universe really captured my heart and imagination. I remember taking walks by his house in Cayuga Heights, during my days as a Cornell student, and being amazed that such an incredible mind lived right down the street from me."

Kelly acknowledges the mentorship of colleagues with whom she has worked directly. "John Donovan, from CDM Smith, had a big impact on my early career. Working with him, I designed an anaerobic digester and cogeneration system from 'scratch'," she said. "I am fortunate to work with Adam Stern at Natural Systems Utilities. He has me involved with and leading many unique and forward-thinking projects, which are the company's specialty. I like working on design-built type projects, and it's a great learning experience to see the projects you work on in operation and to get direct feedback from the operations team on your design."

"It is gratifying to see the new generation of engineers enthusiastically engage and create projects with new concepts and technologies." –Al Saikkonen

It goes without saying that Kelly's father has been a huge influence and role model in her life. "He has a practical approach to problem solving and encouraged me to choose a field that is challenging, innovative and has good job security," she said. "He knows a little bit about everything, so he is the 'go to guy' for a lot of people, and I have definitely talked with him when I am stumped on a challenging problem.

"He has the type of personality that he can get along with anyone and is fun to be around," she continued, "so I enjoy spending time with him and feel that I always learn something new. He loves to mentor the younger generations and is already teaching my 5-year-old son how to change the oil and pump up the air on the car tires!"

Both father and daughter agree that those looking for a technical career would do well to consider water and wastewater engineering fields. "The world needs problem solvers and dedicated engineers to solve the immense problems that result from population expansion, changing environment and a fragile environment," said Al.

"Water quality, access to drinking water and basic sanitation is a fundamental human right," added Kelly. "People die if they go more than a few days without water. Water shortages impact food production. There is so much involved in access to potable water and treating wastewater, it will be a challenge moving forward, as it has been through most of human history. Understandably, most of us take access to safe water and adequate sanitation for granted. Most of us have grown up with these basics."

Having dedicated their careers to the water and wastewater engineering field, Al and Kelly feel strongly about the importance of this work for the communities they serve.

"A lot of times, people are thinking about the future, and it is important," Kelly said. "But working in this field, what we do is important now, and is every day." She also stresses the point that there is a lot of variety and variability in the type of jobs available in the water and wastewater industry.

"Don't like working at a desk? There are lots of jobs in operations, construction that would allow one to work outside or in the field," Kelly said. "Engineers can design the best treatment plant in the world, but skilled and passionate people are needed to operate the facilities."

"Ithaca is Gorges"

Al and Kelly have strong ties to the unique water resources of the Finger Lakes region. Both have spent time at the southern end of Cayuga Lake: Al grew up on a farm in Trumansburg, while Kelly attended Cornell University in Ithaca.

Trumansburg is home to the 215-foot Taughannock Falls, one of the many spectacular waterfalls found in the region. The gorges of the Ithaca area are also a draw for many visitors to the local state parks: Buttermilk Falls, Robert H. Treman, Stony Brook and Fillmore Glen.

Enfield Glen in the Robert H. Treman State Park, Ithaca, New York
Kerry A. Thurston

When it comes right down to it, Al and Kelly are proud to be a part of the Water Legacy as engineers in the water and wastewater industry.

"There is great satisfaction to know that you have designed something that is built," said Al. "There is satisfaction in knowing that something that you have designed benefits society and the environment. And, there is satisfaction in knowing that you have enjoyed the ride!"

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Operator Quiz Test No. 117 – Mean Cell Residence Time

The following questions are designed for trainees as they prepare to take the ABC wastewater operator test. It is also designed for existing operators to test their knowledge. Each issue of *Clear Waters* will have more questions from a different section of wastewater treatment. Good luck!

1. The Mean Cell Residence time is:
   a. An expression of the average time, in seconds, that a microorganism will spend in the suspended solids process.
   b. An expression of the average time, in hours, that a microorganism will spend in the activated sludge process.
   c. An expression of the average time, in minutes, that a microorganism will spend in the settleable solids process.
   d. An expression of the average time, in days, that a microorganism will spend in the activated sludge process.

2. Calculate the total volume, in cubic feet, of a secondary treatment facility consisting of the following:
   Sixteen (16) rectangular aeration tanks measuring 160 ft x 30 ft x 15 ft.
   Four (4) final clarifier tanks, 15 ft deep with a 130 ft diameter.
   a. 1,947,990 cu. ft. b. 1,152,000 cu. ft.
   c. 270,998 cu. ft. d. 198,997 cu. ft.

3. Using the information from Question Number 2, calculate the Secondary Treatment volume, in gallons:
   a. 8,616,960 gal b. 14,570,965 gal
   c. 2,027,065 gal d. 1,005,000 gal

4. Calculate an aeration system mixed liquor suspended solids, in mg/L, based on the following data:
   Crucible weight with filter: 25.000 grams
   Crucible weight with filter and dry solids 25.085 grams
   Sample Volume: 25 mL
   a. 3,400 mg/L b. 2,500 mg/L
   c. 2,125 mg/L d. 8,500 mg/L

5. Calculate the total suspended solids of an aeration system, in pounds, based on the following information:
   Aeration Basin volume: 14 MG
   Aeration Basin MLSS: 3,500 mg/L
   Aeration System flow: 30 MGD
   a. 408,600 lbs b. 1,400,700 lbs
   c. 366,500 lbs d. 785,400 lbs

6. Calculate the total amount wasted from an aeration system based upon the following information:
   Wasting rate: 0.55 MGD
   Return Activated Sludge concentration: 7,000 mg/L
   Aeration Influent BOD: 65 mg/L
   Aeration Influent flow: 30 MGD
   a. 107,200 lbs b. 115,500 lbs
   c. 32,100 lbs d. 28,800 lbs

7. Calculate the Final Effluent suspended solids, in pounds, from the following information:
   Effluent suspended solids concentration: 5.0 mg/L
   Effluent BOD Concentration: 8.0 mg/L
   Effluent Flow: 30 MGD
   Final Clarifier detention time: 1.5 hours
   a. 1,251 lbs b. 2,002 lbs
   c. 1,122 lbs d. 1,795 lbs

8. Calculate the MCRT from the following data:
   Mixed liquor suspended solids concentration: 3,500 mg/L
   RAS concentration: 5,000 mg/L
   Wasting Rate: 0.25 MGD
   Final Effluent suspended solids: 2.5 mg/L
   Aerator volume: 1.0 MG
   Final Clarifier Volume: 1.0 MG
   Final Effluent Flow: 2.0 MGD
   a. 3.1 days b. 2.8 days
   c. 8.7 days d. 5.6 days

9. A 30-minute test settles out to 250 mL in a 1,000-mL cylinder. This result is indicative of the amount of sludge settling in the final clarifiers. What is the Return Sludge Flow Ratio based on this test?
   a. 0.25 b. 0.33
   c. 0.67 d. 0.75

10. Estimate the Return Sludge Rate using the answer from Question Number 9 and the data below:
    Flow to aeration system from primary clarifiers: 9.0 MGD
    a. 0.99 MGD b. 1.98 MGD
    c. 2.97 MGD d. 3.96 MGD

Answers on page 62.

For those who have questions concerning operator certification requirements and scheduling, please contact Tanya May Jennings at 315-422-7811 ext. 4, tmj@nywea.org, or visit www.nywea.org/OpCert.

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Answers from page 61: 1 D, 2 A, 3 B, 4 A, 5 A, 6 C, 7 A, 8 D, 9 B, 10 C