2023 Chautauqua Lake Jefferson Project Questions and Answers

In 2023 the Jefferson Project conducted a large research project to assess drivers of water quality trends through high-frequency sensor deployments, manual boat-based surveys and experiments, satellite remote sensing, and computational modeling. This Q&A accompanies a report that was submitted to the County in December, 2023. The questions are based on feedback from community members following a presentation to the County Legislature in January, 2024. Questions are shown in black text, with answers following each question shown in blue.

1. The mean value of soluble reactive phosphorus during 2023 in the North basin was more than twice the South basin. Why then is the North basin less productive?

Soluble reactive phosphorus (SRP) represents the phosphorus that is dissolved in the water and available for uptake by algae. Water samples for SRP are first filtered to remove algae, zooplankton, and other matter. SRP is often a key nutrient supporting algal growth, and hence is commonly measured to characterize water quality. The South Basin tends to have good growing conditions for algae (this includes factors like shallow water, warm temperatures, and frequent, thorough mixing which cycles algae through sunlit conditions). As algae grow they take up SRP. Thus, phosphorus and algae are in a cycle where high SRP increases algae growth, then as algae grow, they deplete the SRP. As a result, low SRP during the growing season in the South Basin is an indicator of high algae growth, and a large amount of phosphorus can instead be found in the algae themselves.

Our data also indicate algal growth is nitrogen limited at times, in both basins, and specifically for many of the sampling sites in the north basin for much of the season. The caption for Figure 34 in our report to the County includes the statement, “The low ratios observed here indicate co-limitation between nitrogen and phosphorus, or nitrogen limitation of algal growth.” If productivity is stifled by insufficient nitrogen, there will not be enough algae to consume the excess SRP.

2. The mean value of Total nitrogen during 2023 in the South basin was nearly twice the North basin, while the Nitrate and Ammonium were the same. Does this indicate the levels of Nitrite and Ammonia are much higher in the South basin? If so, what are the likely sources/causes?

Possible sources of nitrogen (all forms of it) include atmospheric deposition, agriculture, wastewater, septic systems, runoff from developed areas, and natural processes. The higher total nitrogen in the South Basin despite having the same nitrate and ammonium likely indicates that there is more nitrogen sequestered in algae and other organisms in the

South Basin. Total nitrogen includes all algae, zooplankton, etc., whereas nitrate and ammonium are certain chemical species that are dissolved in the water.

3. The results of the in-lake sampling at the locations in the North basin are relatively uniform for each parameter, whereas there is substantial variation between the locations in the South basin. To what do you attribute this?

We would argue that both basins show a great deal of variability, which is common in natural systems due to site-specific factors, such as site depth, proximity to tributaries, and underlying sediment conditions at each location. The higher volume of water in the North Basin (because it is deeper) allows it to be less "flashy," whereas the South Basin responds to changes more rapidly due to its lower water volume. Additionally, the North Basin is stably stratified throughout the summer until the water layers mix during the fall. In contrast, the South Basin is shallower, and as such, experiences transient stratification when we have a few days of warm, calm weather. The processes that sometimes accompany stratification such as oxygen depletion and consequent internal loading of phosphorus, therefore, occur on a less predictable timescale and spatial scale in the South Basin.

Our findings also indicate that stream inflow dynamics vary widely around the lake, and especially between the two basins. As the season progresses, the thermal stratification in the north basin dictates that much of the stream inflow either concentrates around the thermocline or sinks into the hypolimnion, becoming sequestered (i.e., its constituent nutrients unavailable for algal consumption) until fall turnover. Streams flowing into the South Basin may sink towards the lakebed at first, but the very shallow morphology of the South Basin and it's frequent full-column mixing result in stream inflow being fully mixed vertically into South Basin water much more quickly than in the North Basin. Heterogeneity of samples in the South Basin likely result, at least in part, from stream inflow vertically mixing in the region of the inflow before lateral mixing within the basin further distributes/mixes it around the basin.

4. The results of the in-lake sampling indicate there is a dramatic spike in ammonium at four sampling locations in the South basin in September. What is the probable cause?

One potential cause of increased ammonium is transient low oxygen at those stations because low oxygen inhibits the bacteria that process ammonia into other forms of nitrogen. However, we cannot rule out the possibility that there was external loading of ammonium at that time from tributaries because the three highest values were from stations close to Bemus Creek and Ball Creek. The tributary stations that we are in the process of building will help us better understand tributary loading of all forms of nitrogen and phosphorus.

5. The results of the in-lake sampling indicate there is a dramatic spike in nitrate in the South basin in October, and a dramatic spike in nitrate in the North basin in October and November. What are the probable causes?

The spikes in nitrate were detected in surface waters. We limited this figure to only surface samples in order to make all sites comparable for visualization purposes. However, when we look at bottom water in deep spots in the North Basin, nitrate is higher throughout the season. Nitrate tends to accumulate near the bottom of the lake during summer in deep lakes, where it is inaccessible to algae, which is what we see in deep parts of Chautauqua. Increased surface nitrate in the late fall occurs as the lakes cools down and deep waters are mixed toward the surface. This process is called fall turnover and results in the loss of thermal stratification in the North Basin. Once the lake fully mixes in the fall, the nitrate near the bottom is redistributed into the rest of the water column, resulting in the late fall spikes in surface waters. The nitrate released makes its way throughout the lake and often into the South Basin. Notably, this nutrient release following fall turnover is a potential mechanism that drives blooms in the late fall.

6. I agree 100% with the last bullet on the chart, "You can't manage it if you don't measure it". Unfortunately, there has been none of this associated with the millions of dollars spent on Chautauqua Lake watershed projects. They "feel good" but there's no proof of commensurate benefits.

In general, there has been limited monitoring of individual watershed projects (stream stabilizations, etc.). The reality is that doing so for individual projects, most of which are in the $20-$30k range, is cost prohibitive. This is why our approach to monitoring in-lake processes combined with tributary monitoring will be effective – it is not a perfect system for measuring the outcomes of individual projects but is a vast improvement and expansion of monitoring to better understand what needs to be done to improve water quality and also monitor the efficacy of management actions.

7. I also agree that "Individual catchment scale loading should be examined" for the same reasons. How have you justified the expenditures for this sampling and data processing? What is the hypothesis?

We need an accurate nutrient budget to make informed management decisions. Although the cost may seem large, the investment is small compared to the economic value of the lake and surrounding communities. The hypothesis is that loading varies among catchments. Testing this hypothesis will help us to narrow in on potential management strategies specific to catchments. Understanding the catchments that are the largest sources, and when they are large sources, is critical knowledge that must be ascertained to conduct effective management and nutrient reductions. Targeted management actions enable effective and efficient use of funds.

As practitioners of the science, we understand first-hand the large costs involved in undertaking large-scale environmental projects. The instrumentation, personnel, equipment, computing resources, and other expenses are considerable. The heterogeneity shown in our data indicate the complexity of the system over space and time. Our efforts are directed towards prioritizing areas to address (e.g., specific stream catchments) *as well as* understanding the functioning of the entire system.

A good example of the difficulty we face is the following: Consider a high-nutrient stream that flows into the lake, but its inflow sinks (because of its temperature) into the hypolimnion, in the North Basin. There, it mixes with other streams' water and the bulk of the hypolimnion, until it gradually mixes into the epilimnion during the season, or quickly mixes with the epilimnion during turnover, contributing to an algal bloom three months after it flowed into the lake. Here, one needs to 1) know the stream inflow is polluted to begin with, and 2) understand how its inflow interacts with the lake to produce adverse effects months (i.e., as external loading) and even years (i.e., as internal loading) down the road. This is not a trivial task, and because the cause and effect (stream loading and later algal blooms) can be separated in time by many months, it can be challenging to ascribe causality without a sophisticated monitoring and research program.

8. From the statement "Internal loading is important...", it's clear your focus is only on external loading, the history in our lake and where significant funding has gone. However, the 2012 TMDL required a 55% decrease in internal loading (25% agriculture, 20% several others), by far the largest required decrease. Nothing, I repeat nothing, has been done in this regard. How do you justify that?

Internal loading refers to the phosphorus that re-enters the system from lake sediments. The TMDL for Chautauqua Lake is dated, and the nutrient budget within it needs improvement. As noted in the TMDL, several of the parameters in the nutrient budget are modeled and not directly measured. Worse, internal loading was neither modeled nor measured for the 2012 TDML, but rather its contribution was assumed to be the resulting input after everything else was accounted for ("Therefore, once all external sources of phosphorus loading were identified, it was assumed that the remaining load must be originating from internal sources (i.e., lake bottom sediments).", p19). One of our goals is to better measure and predict internal loading as part of an improved phosphorus budget. That being said, we agree that internal loading is a huge problem in Chautauqua Lake, as we addressed in our report.

Unfortunately, internal loading is extremely difficult to mitigate directly via management. The best option is often to decrease external loading, and then reduced internal loading will follow over time. As of now, there are no reliable solutions to internal loading, at the required scale; our findings thus far indicate there are large areas of the lakebed, in both basins, which are contributing to internal loading during different times of the season. Chemical treatments such as alum and lanthanum can be done on a small scale, but the size of Chautauqua Lake makes this type of option cost-prohibitive, especially considering that chemical treatments would have to continue forever if external loading was not addressed. Other options, such as aeration, have been tested in other lakes, but as of now, are not promising. External loading must first be substantially reduced because most of the phosphorus that is released from internal loading came from external loading initially.

The comment and response portion of the 2012 TMDL addressed this issue as well:

> "Significant quantities of phosphorus that were unaccounted for were attributed to internal loading. There does not appear to be any justification for this and it is unclear how reductions of the internal loading can be achieved.
>
> Response: Years of excessive phosphorus loading has resulted in large quantities of phosphorus stored within the Lake. Such internal sources may include higher phosphorus concentrations in the sediments and phosphorus contained within increased biological populations. With the external loads sufficiently quantified the internal loads were estimated as those required to accurately model the observed the phosphorus concentrations in the Lake. The internal load is believed to be responsive to the external loads such that reductions in the latter will result in reductions in the former. Phosphorus is lost from the Lake every year via the Lake outlet. As phosphorus loading from the watershed and point sources decreases more of the annual loss of phosphorus will be from the internal loading, resulting in the projected in-lake reductions."

A critical component of estimating the response of internal loading reduction over time after external loading has been reduced, is an improved understanding of each basin's water retention time. We believe the present estimates are too short, owing in part to the previous misunderstanding of water exchange between the basins (a topic we also touched on in our report). The 2012 TMDL does not include any water flow from the South Basin into the North Basin, something we now understand occurs frequently and substantially. Improving this understanding through modeling and measurements from the new stream and outlet stations should also provide further insight toward expectations for response timing of any external loading mitigation efforts.

9. Will the report supporting the charts be peer reviewed?

The report has been reviewed by experts and key stakeholders at Chautauqua Lake. However, a more formal peer-review process is not planned. A formal peer review process often takes many months and is typically done at a scientific journal that publishes final research. Monitoring reports similar to ours are typically not formally peer reviewed. Various parts of the data included in the report, however, are part of ongoing research projects that will be submitted for peer-review at scientific journals, and these articles will undergo peer review before they are published.