

GUIDE TO SURFACE WATER QUALITY MONITORING
IN THE CAYUGA LAKE WATERSHED

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Guide to Surface Water Quality Monitoring for the Cayuga Lake Watershed

INTRODUCTION

The Cayuga Lake Watershed (CLW) is home to many municipal agencies, educational institutions, non-governmental environmental organizations and citizens' groups with significant interests in the quality of the lake and its tributaries. As a result, numerous studies and monitoring programs have been, and will continue to be, conducted throughout the watershed. Management of water quality benefits from the assessment of the physical, chemical and biological conditions of the waters and sediments of the lake and its tributaries. Water quality monitoring is a valuable tool for assessing the level of pollutants, identifying emerging problems, documenting changes resulting from water management, and for building understanding of the aquatic ecosystem. Although some information can be obtained from models and expert opinion, water quality sampling or monitoring programs are the primary sources of data.

Water quality monitoring studies have differed widely in purpose and scope, corresponding to the interests and funding of scientific investigators, the information needs of specific agencies and the enthusiasm of volunteers. Such diversity has sometimes been seen as a hindrance to effective, or at least efficient, water quality assessment. Without common goals and sampling protocols, as well as uniform data reporting, it can be difficult to obtain the coherent picture of lake and watershed quality needed for management.

The CLW management process, begun in the late 1990's, collected existing data and information, identified the greatest threats to water quality and outlined strategies to address those threats. The process resulted in two documents. The *Cayuga Lake Watershed Preliminary Watershed Characterization* (Cayuga Lake Watershed Intermunicipal Organization, 2000) detailed the baseline conditions of water resources and identified phosphorus and sediment as the primary threats. Pesticides, volatile organic compounds, heavy metals, pathogens and invasive species were other identified threats. The *Cayuga Lake Watershed Restoration and Protection Plan* (Cayuga Lake Watershed Intermunicipal Organization, 2001) outlined the strategies for water management and argued for a comprehensive monitoring plan. Appendix M of that document, "A Framework for a Cayuga Watershed Monitoring Plan" by Callihan and Kappel, summarized the essential characteristics of a coordinated monitoring plan.

Relatively little progress has been made in formulating a plan since publication of the "Framework", but major monitoring efforts have continued in CLW, including monitoring of sediment and nutrient loads in southern tributaries, lake-wide water column sampling, and heightened interest in water monitoring by citizens. The sampling efforts to date are largely uncoordinated, and as a result, may not inform the management of the CLW as much as they could. A notable exception is the joint Tompkins County Water Resources Council -- Cornell University Partnership that has developed the "Monitoring Plan Southern Basin of Cayuga Lake" (2008).

It is hard to argue against the need for a comprehensive monitoring plan, but given the immense diversity of interests and study questions that drive water quality monitoring in the CLW, it is even harder to see how such a plan for the entire watershed could be developed and implemented. We settled on a simpler step, in the form of this “*Guide to Surface Water Quality Monitoring in the Cayuga Lake Watershed*”, to achieve some of the goals of a comprehensive plan while still accommodating the needs and scopes of current and future monitoring activities. The Guide provides an introduction to study design, five objectives for CLW monitoring and the types of sampling programs that could meet the objectives, and an overview of a data clearinghouse begun as part of this project. Appendices provide supporting information such as questions to inform study design, sample field data sheets and explanations of key parameters suggested in the Guide.

We realize that not all water quality sampling in the CLW will be consistent with the goals of this Guide. Programs will often address needs that are broader or more specific than those described here. We recommend that investigators incorporate the suggestions in the Guide wherever possible into their monitoring programs and projects. Regardless of the extent to which that is done, data, reports and publications are sought for the data clearinghouse.

WATER QUALITY MONITORING PROGRAMS

STUDY DESIGN

“There is a whole lot of monitoring being done that is of diminished value because it was not designed to fulfill any specific objectives.”

US EPA Nonpoint Source Information Exchange

Taken together defining the why, how, where, when and who forms a study design. Study design is important for building in objectivity and scientific rigor. Even when the purpose of monitoring is to discern the source of a problem, monitoring must be designed to collect unbiased information. To skew data collection or interpretation to prove what one already believes can lead to faulty management decisions and can create unnecessary community conflict.

Defining the purpose of water quality monitoring is a critical first step. Having a question or an objective in mind—the why—will guide the determination of what, where, when and how to monitor. “Why” includes articulating why water quality monitoring is needed.

“What” is the selection of what will be monitored in order to meet the objectives. Since it includes what information will be collected in the field, it informs the creation of field data sheets (see Appendix B for sample data sheets). If the data collected are to be considered credible, “how” includes using protocols and quality assurance/quality control (QA/QC) established by US Environmental Protection Agency (Barbour et al. 1999), NYS Department of Environmental Conservation (Bode et al. 2002) or the industry reference *Standard Methods for the Examination of Water and Wastewater* (Clesceri et al 1998) Water samples should be sent to a certified laboratory for chemical analysis, with the exception of analysis done by experienced researchers at an academic institution. In this case, internal lab QA/QC should be provided along with the study results.

The monitoring objectives direct where and when samples should be taken. “Where” includes the site locations and the number of sampling sites. “When” includes how often data would be collected and the conditions that should be met.

There is much interest in sampling during high flow (storm and snow meltwater) events. The study design should define the conditions that qualify as a storm event. The size of the tributary and its watershed, the specific land use and land cover, and the time of year should be taken into consideration. For example, a study of storm events in Sixmile Creek used the criterion of one standard deviation above the monthly mean discharge as the definition of high flow. This criterion set for each month a unique discharge threshold, measured in cubic feet per second (cfs) (Table 1).

Table 1
Definition of High Flow Events
(Moran, 2005)

Month	Monthly Mean Discharge (cfs)	Standard Deviation (cfs)	Threshold for High Flow Event (cfs)
January	82.9	61.45	144.35
February	90.9	26.98	117.88
March	105	41.02	146.02
April	110	55.14	165.14
May	77.1	57.61	134.71
June	49.9	29.82	79.72
July	20.1	13.2	33.3
August	12.9	14.28	27.18
September	14	7.5	21.5
October	21.8	15.58	37.38
November	44.3	38.58	82.88
December	61.8	55.73	117.53

Appendix A contains two sample sets of questions to consider in the study design process and a completed sample for each. The planning shown in the first example will be required by water monitoring projects that seek Finger Lakes-Lake Ontario Watershed Protection Alliance funds beginning in 2009. It is a good example of information that data users may want to know and that should be documented as part of the metadata (data about data).

Hudson Basin River Watch (River Network, 2000) gives a good summary of the importance of good study design in its list of common problems that result from a poor-quality or the lack of a study design:

- Spending time and money on equipment and procedures that are inappropriate for your purposes
- Looking for the wrong things at the right places or the right things at the wrong places
- Not answering the question you asked, answering a question you did not ask, or, worst of all, not answering a question at all
- Not knowing how to interpret your data, because you didn’t have a question or focus when you started your study

- Finding that others are reluctant to use your data, since they do not know how good the data are or how they can be used.

OBJECTIVES

The following five objectives can be used to guide study designs that will contribute to a larger, comprehensive understanding of the water quality with the Cayuga Lake basin.

1. Characterize the water quality of Cayuga Lake to identify status and trends (Lake Sampling).

The *CLW Preliminary Characterization* and the *CLW Restoration and Protection Plan* identified sediment, phosphorus, and pesticides, volatile organic compounds (VOCs), heavy metals, pathogens and exotic or invasive species as water-quality issues that “pose the greatest long-term challenge to the ecosystem of Cayuga Lake and its watershed.” (Cayuga Lake Watershed Intermunicipal Organization, 2001). In a comparison of pesticide levels in several Finger Lakes and Great Lakes, US Geological Survey found pesticide levels to be highest in Cayuga Lake, though they remained below federal and state thresholds (Philips, et al., 1999). It is important to document the current levels and trends of these contaminants within the water column and shallow area sediments.

2. Determine the tributary mass loads of water contaminants entering the lake (Tributary Mass Load Sampling).

Much, but not all, of the lake’s water pollution is brought by the tributaries flowing into it. Determination of tributary mass loads is particularly important for management of the lake’s phosphorus and sediment problems. There has been relatively little mass load sampling in the CLW, due to the large expense of the necessary continuous monitoring of quality and discharge. Data may be augmented by modeling studies. For this purpose the data collected are used to calibrate and test models that subsequently can estimate mass loads for other time periods and for evolving land uses and management practices.

3. Characterize the water quality of tributaries to identify status and trends (Tributary Water-quality Sampling)

Tributaries may be threatened by contaminants or stresses that affect the stream health but are not significantly detrimental to the lake. The tributaries are valued for recreation and aesthetics, drinking water, irrigation and wildlife habitat and deserve protection.

4. Characterize the long-term ecological health of the lake and tributaries (Biological Integrity Sampling).

Sampling for chemical and physical parameters frequently provides only a snapshot of conditions when and where the samples are taken. Ecological sampling is useful for detecting the effects of impairments that are not present at the time of sampling, for evaluating habitat

health and for determining the biological integrity of surface waters. Ecological sampling may include bioassessments of fish and benthic macroinvertebrate communities, periphyton, and single species monitoring (trout, salmon, and freshwater mussels are often used). Biological indices, a composite of different indicators, can be developed.

5. Encourage citizen participation in the measurement of watershed quality (Citizen Monitoring)

The future of the CLW is in the hands of the thousands of people who live in and visit the region. To the extent that people care about the watershed's lands and waters, the watershed will be protected and enhanced for generations to come. One way to encourage such stewardship is through involvement of students and other citizens in water-quality monitoring. Monitoring conducted by citizen volunteers increases public awareness and knowledge about water quality and its protection. Citizen monitors are encouraged follow the guidelines in this document and provide data that supports monitoring objectives 1 through 4.

MONITORING GUIDELINES

Monitoring guidelines are provided for each of the first four objectives listed above. Under each objective the parameters are clustered into primary and secondary tiers. The primary parameters provide the most valuable information for assessing surface water health across studies and over time. Secondary parameters provide very useful additional information and are included for consideration when resources allow. It is not necessary to measure every parameter included in either tier. Some study questions of specific and limited intent may be best served by measuring selected parameters from each tier, for example a study focused on invasive species might consist of monitoring few chemical parameters and focus on the populations of invasive and disrupted-native species. A table listing the primary and secondary parameters for each objective appears in Appendix C. An introduction to key primary parameters appears in Appendix D.

1. Lake Sampling

Two major types of lake monitoring are water-column sampling and near-shore (shallow water) sampling. Water-column sampling attempts to measure an integrated, or overall, response of the lake to contamination. Of particular concern is the lake's trophic status, as indicated by phosphorus, turbidity, chlorophyll-*a* and dissolved oxygen. Some invasive species, such as spiny water flea, can also be detected by water-column sampling. During seasons when the lake is stratified, the water column sample should be sampled in both the epilimnion (the warm upper layer) and hypolimnion (lower layer of cold water).

“Near-shore” refers to the depth at which rooted plants can grow. Sampling can be adequately done at the end of a dock. Sampling for pathogens and pathogen indicators is important because of contact recreation such as swimming. Concern about pathogens in the south end of the lake is growing as evidenced by a 2008 New York State section 303(d) list of impaired water bodies showing pathogens added to the 2002 listing for phosphorus and silt/sediment (NYSDEC, 2008). Near-shore monitoring allows study of the lake bottom including sediment sampling for heavy metals, macroinvertebrates, as well as attached or rooted invasives such as zebra mussels and Eurasian watermilfoil.

In summary, we suggest the following primary and secondary parameters for lake sampling:

- | | | |
|-------------------------|------------------|---|
| <u>a. Water Column:</u> | <u>Primary</u> | 1. Total phosphorus
2. Soluble reactive phosphorus
3. Dissolved oxygen
4. Temperature
5. Turbidity (Secchi disk)
6. Chlorophyll- <i>a</i>
7. Atrazine |
| | <u>Secondary</u> | 8. Invasive organisms
9. pH |
| <u>b. Near-shore</u> | <u>Primary</u> | 1. <i>E. coli</i>
2. Invasive plants
3. Invasive animals |
| | <u>Secondary</u> | 4. Fecal coliforms
5. Pesticides (particularly atrazine)
6. Benthic macroinvertebrates
7. Heavy metals (Pb, Cr, Cu, Zn, Cd, Hg) |

2. Mass Load Sampling

The primary purpose of mass load sampling is to determine the contributions of phosphorus, sediment, and perhaps pesticides into the lake. (See Appendix D for a discussion of concentrations versus mass load.) This type of monitoring is time-consuming and expensive. Little can be learned from intermittent or short-term sampling since concentrations of these contaminants in stream flow are highly variable. Sampling needs to capture the high loads carried by snowmelt during late winter and early spring. During storms, hourly, or more frequent, sampling is often required because concentrations change so rapidly. During low-flow periods weekly, or less frequent, sampling may be adequate since concentrations are relatively stable.

The most accurate way to measure loading is with long-term, continuous, concurrent measurements of discharge and concentrations. This is especially true of small tributaries, where a rapid response to wet weather earns the descriptor “flashy”. Larger, less flashy systems do not need to be sampled quite as time intensively though at a minimum 5 recommended (Figure 1).

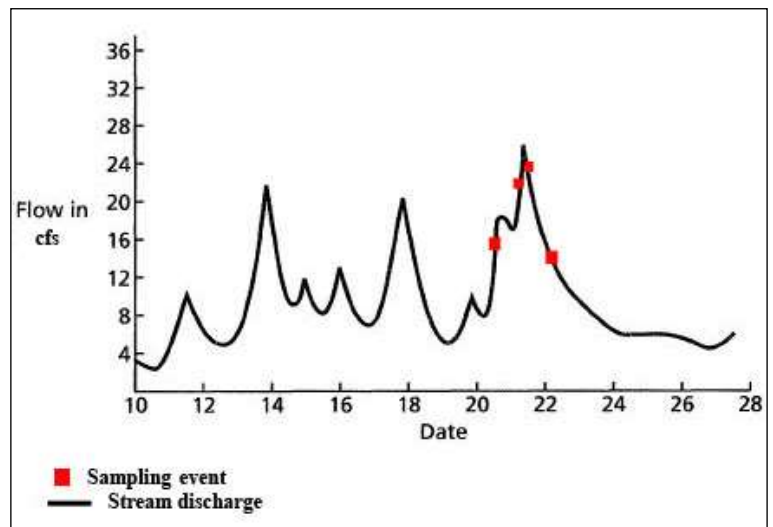


Figure 1
Hydrograph Showing Sampling During Rising and Falling Limbs

The time of sampling should be noted in “watch time” (the actual time on a watch, which might be in standard or daylight savings time).

Mass load sampling information can be used to improve the results obtained from water-quality models that simulate the movement of precipitation and pollutants. Although each water-quality model has its own unique purpose and built-in assumptions, field data can greatly improve the results obtained from modeling. As long as limitations are taken into account, modeling can reduce the amount of sampling needed to predict water quality. For example, the NYS DEC has been encouraging the use of modeling to understand stormwater runoff and to comply with “Phase II” stormwater regulations.

Primary Parameters

1. Total phosphorus
2. Soluble reactive phosphorus
3. Sediment as Total Suspended Solids (TSS)
4. Discharge

Secondary Parameters

5. Pesticides (particularly atrazine)

3. Tributary Water-quality Sampling

This sampling is meant to monitor the health of the tributaries or sub-watersheds and to identify potential or actual sources of pollution. An initial watershed inventory that evaluates current land and water uses, threats and community values can help identify key issues to inform study questions.

Where possible, a recent map should be obtained, delineating the stream’s watershed and indicating patterns of land use/land cover. Locations along the stream should be identified where sampling may take place at least annually and preferably on or about the same date each year, between July and September. Sampling during storm flow events is more informative of loads and major pollutants, sampling during baseflow periods is more indicative of typical water quality in the tributary.

Primary Locations for Sampling: For major lake tributaries, such as Yawger Creek or Salmon Creek, at least 3 locations should be sampled: in the headwaters, at mid-river and near the entry to the lake but not under the influence of the lake. It is important, especially for sampling of macroinvertebrates, that the location not be influenced by the lake: for some minor tributaries the location may be well above the lake level. Monitoring in the headwaters will not give information about specific pollution sources but can be used for comparison with the parameters downstream. Additional sampling locations may be selected to be representative of stream reaches using information such as soil types, slope, land use, etc.

For minor or short tributaries, such as the many minor tributaries that are often unnamed on the east and west lakeshores, one location near the entry to the lake is sufficient. Monitoring at the mouths of a number of tributaries should be accomplished rather than enhanced monitoring of any one tributary.

If the water quality does not meet expectations (based on soil types, land uses, regulatory standards, etc.), more detailed sampling should be pursued to determine cause/source. One way to accomplish this is to sample at bridge crossings moving from the mouth of the stream to the headwaters. Targeted sampling can be located where changes in water quality are found. See the Hudson Basin River Watch (River Network, 2000) for more detailed information on the chemical, physical and biological sampling of streams.

Secondary Locations for Sampling: For major lake tributaries additional locations should be selected to help define the contributions of the feeder streams. Samples can be collected in the feeder stream or near its junction with the main stream depending on access. For larger feeder streams, monitoring should be prioritized – the mouth of each, then the headwaters and finally the mid-point of the streams.

Sampling Parameters: Minimally, total phosphorus, nitrate nitrogen, and sediments should be evaluated. For the latter, total suspended solids is the recommend common measure, except if the study calls for comparing data with USGS data collected at gaging station; then suspended sediment should be sampled for instead. If suitable instruments are available (e.g., Hydrolab and flow meter), on-site measurements of physical and chemical characteristics should be made: temperature, pH, conductivity, and dissolved oxygen, and water velocity and stream cross-section area.

Primary Parameters

- | | |
|------------------|---|
| Water Chemistry | 1. Total phosphorus
2. Nitrate nitrogen (NO ₃ -)
3. Sediment as Total Suspended Solids (TSS) |
| Pathological | 4. <i>E. coli</i>
5. Total coliforms |
| Physico-chemical | 6. Temperature
7. Dissolved Oxygen (DO)
8. pH
9. Conductivity/specific conductance |

Secondary Parameters

- | | |
|-----------------|--|
| Water Chemistry | 10. Chloride
11. Alkalinity |
| Physical | 12. Discharge |
| Pathological | 13. <i>Cryptosporidium</i> |
| Ecological | 14. Invasive organisms
15. Percent canopy cover
16. Periphyton (attached algae)
17. Width of forested riparian zone |

Biological Integrity Sampling

Ecological sampling, also known as bioassessment, offers information on biological integrity that is not provided by periodic chemical assessment. A grab sample may miss a contaminant that has passed through the sampling site before or after a water sample has been collected. Since the organisms live in the water over time, the structure of the biological community reflects the long-term status of water quality, not just its status at a particular point in time. Further, ecological sampling is the best method for assessing for concerns that are not dependent on physio-chemical factors. Examples include the effects of invasive species and disruptions to the food chain due to over fishing.

Data collected from bioassessment and monitoring activities can be evaluated and integrated into one biological indicator or index that incorporates the taxonomic and functional characteristics of the biological community. Such a biotic indices or an index of biotic integrity (IBI) is a measure of the overall ecosystem health. The development of a single, simplified parameter that reflects the health of the waterbody can assist in summarizing the consequences of human activities on a watershed. To be of value IBIs are usually developed for a given region or area and must take into account normal variations in communities and populations. Developing an IBI that gives accurate assessment requires experienced professionals. A number of authors have described protocols for bioassessment of surface waters using various groups of organism (e.g., fish, mussels, and periphyton, as attached algae is known).

Use of IBIs can indicate thresholds below which communities are deemed unsustainable and unhealthy. This is particularly useful in determining water quality policy guidelines and in communicating the health of surface waters to the general public. The numeric values of IBIs provide a straightforward method of classifying a community and/or habitat in various categories of quality, especially those in need of attention and/or restoration. IBIs have been used elsewhere to confirm the recover of a waterbody placed on the 303(d) list of impaired waters. Development of an IBI or similar metric is desirable, however it is not a short-term objective.

Without the construction of an IBI, bioassessment based on the community structure of benthic macroinvertebrates (mostly immature stages of insects) is probably most appropriate for this watershed. The sensitivity and reliability of such assessment depends on the taxonomic level to which the species found can be identified. Study of these small, bottom dwelling organisms often interests citizen volunteers and can improve their commitment to monitoring projects. Citizen volunteers can be trained to identify these organisms to the taxonomic level of the family. Analysis to this level has been found to produce reliable estimates of water quality (O' Leary et al. 2004). Identification to species or even genus usually requires assistance from an entomological expert.

Benthic macroinvertebrate sampling should follow protocols for rapid bioassessment like those described for the NYS DEC in Bode et al. (2002). This should begin with a visual-based habitat assessment of the physical qualities of the stream channel, the stream bank and the riparian vegetation so that changes can be monitored through time (see Appendix B for a sample field data sheet).

a. <u>Lake:</u>	<u>Primary</u>	1. Zooplankton composition 2. Phytoplankton composition
	<u>Secondary</u>	3. Fish
a. <u>Tributary:</u>	<u>Primary</u>	4. Macroinvertebrates
	<u>Secondary</u>	5. Fish

DATA CLEARINGHOUSE

Water-quality monitoring data are potentially useful beyond the group or organization that collects the data. To this end the Cayuga Lake Watershed Network is working to collect and make publicly available on the World Wide Web data, reports and publications about water quality in the CLW. These are being posted at <http://ecommons.library.cornell.edu>; search for Cayuga Lake Watershed. According to the website “The eCommons Digital Repository ... is open to anyone affiliated with Cornell University (faculty, staff, students, or groups/organizations) as a place to capture, store, index, preserve and redistribute materials in digital formats that may be useful for educational, scholarly, research or historical purposes.” Previously established partnerships with Cornell to study and protect Cayuga Lake make this collaboration possible.

Overtime, data will also be posted at The Knowledge Network of Biocomplexity, <http://knb.ecoinformatics.org>. According to the website “The Knowledge Network for Biocomplexity (KNB) is a national network intended to facilitate ecological and environmental research on biocomplexity. For scientists, the KNB is an efficient way to discover, access, interpret, integrate and analyze complex ecological data from a highly-distributed set of field stations, laboratories, research sites, and individual researchers.”

Geospatial data will also be posted in repositories that specialize in Geographic Information System (GIS) data such as the New York State GIS Clearinghouse, <http://www.nysgis.state.ny.us> and the Cornell University Geospatial Information Repository (CUGIR), <http://cugir.mannlib.cornell.edu>.

Data will not be analyzed or evaluated for accuracy. In an ideal world, data from different sources would be collected and analyzed according to common protocols and published in standard formats to facilitate comparisons, aggregation and interpretation. This uniformity is difficult to achieve given the different study questions and entities undertaking sampling. The focus will be to collect and post data and adequate metadata to allow the end user to evaluate the quality and usefulness of the data sets. Data sets and metadata will be formatted according to standard criteria. Cayuga Lake Watershed Network staff and a Cornell University librarian have customized the “Best Practices for Preparing Environmental Data Sets to Share and Archive” available at <http://daac.ornl.gov/PI/bestprac.html>.

A system for posting only metadata or links to data sets and information that is already available via the World Wide Web is being developed. Real-time data, such as from US Geological Survey gaging stations, is an example of information already electronically available on the Web. Some

creators of data and information may not want primary data publicly available to all. These types of situations are most efficiently handled by posting metadata and contact information in the central CLW repository.

Water management professionals and researchers have expressed interest in a data clearinghouse for years. We realize that some issues concerning data quality and comparability will not be solved by these repositories of data and information. However, it should make data from various efforts more accessible and useful to others. The beginning of a data clearinghouse is a significant outcome of this monitoring guidance project.

APPENDIX A

Two Sample Study Design/Project Plan Formats

I. Excerpted from Finger Lakes-Lake Ontario Watershed Protection Alliance Quality Assurance Project Plan

Beginning in 2009, water monitoring projects that seek Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA) funds will be required to submit a quality assurance project plan. Details are available in the *Guidance for FL-LOWPA Supported Water Quality Monitoring Programs*. The select information from the associated planning worksheets is provided below reformatted to save space.

Quality Assurance Project Plan (QAPP)

The pages listed under the various topics below refer to the *Guidance for FL-LOWPA supported Water Quality Monitoring Programs*. Additional detail can be found in Chapter 4 of the USEPA document, *The Volunteer Monitor's Guide to Quality Assurance Project Plans....*

1. Project Planning (p.2-3)

- a) What are the objectives of the monitoring program?
- b) How will the data be used?
- c) How will you evaluate your results? i.e., compare to State WQ standards, State established- reference conditions, historical data?

2. Project Design (p.3)

- a) Include the following information in **Table 1**:
 - Sample ID
 - Description of sampling location
 - Location (i.e, latitude/longitude, UTM, permanent landmark , etc.)
 - Rationale for selecting sampling site
 - Flow and/or other important site characteristics
 - Parameters/constituents to be measured/analyzed
 - Sampling frequency (note special sampling conditions such as storm-events, high flow, etc).
 - Type of sampling (grab, depth or width integrated, profile, etc.)
- b) How will the data be processed, analyzed and reported?

3. Data Quality (p.4)

Enter values for parts a, b, c, and d in accompanying Table 2

- a) **Measurement Range (MR)**- Range of measurement possible with equipment and/or analytical procedures used. For laboratory analysis the minimum reporting limit (detection limit) is critical. *Place values in Table 2 _____.*
- b) **Accuracy**- Means the measure of confidence that describes how close a measurement is to its "true" value. If contracting for lab services, communicate with lab as to internal quality controls. See manual(s) for field instrument accuracy. *Place values in Table 2.*

- c) **Precision**- Commonly done by comparing the difference between values of duplicate samples and comparing this difference to a pre-determined allowable difference. (You will need to determine how many duplicate samples you will run- See Section 8.) For water quality constituents, USEPA guidance for precision is $\pm 20\%$. *Place value in Table 2.*
- d) **Completeness**- The number of samples that need to be collected to meet the "completeness" objective. (Note- typical number is 90% of proposed samples collected.) *Place value in Table 2.*
- e) **Representativeness**- How will the locations, number and time of sampling ensure the data collected is truly representative of the condition of the waterbody?
- f) **Comparability**- To ensure comparability with any future project phase, will you use standardized or identical:
 - sampling methods? _____
 - analytical methods? _____
 - units of reporting? _____
 - sample site selection? _____
 - other? _____

4. Personnel Training (p.5)

- a) Identify person familiar with FL-LOWPA supported monitoring activities, plans and related procedures (relevant SOPs, safety protocols, etc.) that will provide guidance to county and related personnel on an as needed basis.
- b) Describe any specialized training or other procedures:

5. Data Collection and Documentation (p. 5-6)

- a) Sampling methods used - Enter the sampling equipment, container, preservative and maximum holding times for each parameter in **Table 2.**
- b) How will the locations of sampling sites be recorded (GPS, permanent landmarks etc.)?
- c) How will the sampling area site conditions be described?
- d) Are there any procedures for decontamination or equipment cleaning?

6. Sampling Labeling, Handling, Chain-of Custody (p.6).

- a) What information is included on the sampling labels?
- b) What are the procedures for tracking the collection, delivery, and/or shipping of samples to the laboratory for analysis?
- c) Where will the data results and records be kept? (Optional: Attach copies of field and laboratory data records kept for the project.)

7. Analytical Methods (p. 6)

- a) **In Table 2**, list the analytical methods being used along with the field or lab equipment used for analyzing each parameter. If a contract lab is being used, list the analytical procedure.
- b) If methods and/or equipment differ from standard procedures, describe the analytical methods and equipment being used or attach your Standard Operation Procedures (SOP). Note in **Table 2.**

8. Quality Control-QC (p.7)

- a) Sampling: How many and what type of quality control samples such as duplicates/triplicates, field blanks, replicates, maintaining voucher specimens (biological) etc. will be taken? Your duplicates / triplicates will be used to see if you meet your precision objectives. For water quality analyses, it is suggested that one duplicate sample be run for every twenty samples or one per sampling event.
- b) Laboratory QA/QC: If you are you using a contract laboratory for chemical analyses, reference your lab's QA/QC plan here:

- c) What action will you take if the QC samples reveal an analytical or sampling problem?
- d) Instrument Calibration/ Frequency
 - How is sampling and analytical equipment calibrated and how often?
 - What types of standards and/or certified equipment is used to calibrate sampling instruments?
 - How are maintenance and calibration records maintained for each instrument?
 - For biological sampling equipment, what are the routine procedures ensuring equipment is clean and working properly?
- e) Quality of other data sources: List any other data or informational sources that you will use such as historical information, topographic maps, aerial maps, or reports from other monitoring groups. Discuss any limitations on the use of this data resulting from concern over its quality.

9. Data Storage, Management, Validation and Verification (p.7)

- a) How will you check for accuracy and completeness of field/lab forms?
- b) How will you minimize and correct errors in calculations, data entry to forms or databases and included in reports?
- c) How will you validate and verify data? (see examples p.7)
- d) Who reviews data in order to accept, reject, or qualify the data?
- e) If errors are found, how are they corrected or accounted for?
- f) Does your laboratory have a protocol for data review?

10. Overall Program Assessment and Oversight (p.8)

- a) How are your overall field, lab and data management activities overseen and evaluated?
- b) How are problems identified and corrected?

Sample of Completed FL-LOWPA QAPP

Table 1 Generic QAPP-Sample Locations, Site Descriptions, Sampling Procedures (Example Only)

Sample ID	Sample Location	Lat/Long.	Rationale for Site Selection	Flow/Site Description	Parameters	Sampling Frequency	Sampling Procedure
A	Babbling Brook @North Rd.	40.xxxx/76.xxxx	Upstream of suspected pollutant source	Relatively shallow and wide.	TSS, Total Nitrogen Total and o-Phosphate	Monthly Storm-event 1per spring, summer, fall season	Composite/width integrated
B	Babbling Brook @North Rd.	40.xxxx/76.xxxx	Downstream from suspected pollutant source	Relatively deep, well mixed..	TSS, Total Nitrogen Total and o-Phosphate	Monthly Storm-event 1per spring, summer, fall season	Composite/vertically integrated.
Blue Lake Inlet	Friendly Rd. crossing; 500 ft upstream from lake	40.xxxx/76.xxxx	Main inlet to lake to evaluate preliminary mass loading.	Relatively shallow, moderate flow/well mixed	TSS, Total Nitrogen Total and o-Phosphate	Every two weeks and storm-events	Grab, collect sample from middle of stream
Blue Lake Outlet	At outlet dam	40.xxxx/76.xxxx	Mass export from lake during base flow conditions.	Flow over broad-crested dam	TSS, Total Nitrogen Total and o-Phosphate	Every two weeks	Collect sample form weir overflow
Igmire Reservoir	mid-lake(@ max. lake depth	40.xxxx/76.xxxx	To understand extent of lake stratification	N/A	Temperature, dissolved oxygen	Monthly in July, August, September	Profile surface to bottom @ one meter interval.
Landre Lake	South basin North basin	40.xxxx/76.xxxx	To understand extent of vertical water quality variability and lake stratification	N/A	Temperature, dissolved oxygen , Total Nitrogen Total /o-Phosphate, secchi disc, chlorophyll a,	Monthly in July, August, September	Profile- surface to bottom @ one meter interval. Collect samples below surface (1ft.); use Kemmerer or similar sampler collect in metalimnion and just above bottom w/o disturbing sediments.

Table 2 Generic QAPP Data Entry (Example Only)*

Parameter	EPA Approved Method	Method Detection Limit	Minimum Reporting Limit (mg/l)	Accuracy (%Rec.)	Precision	Completeness	Preservative	Volume	Container	Holding Time
Bacteria (total fecal coliform)	SM9221 Or 9222	1 FC/100ml	1 FC/100ml	NA	NA	85-100%	Na ₂ S ₂ O ₃ ^A 4° C	100ml	Sterile Plastic	6 hrs.
Dissolved Oxygen	EPA 360.2 or SM4500	0.05 mg/l	0.05 mg/l	85-115	<30	85-100%	NA	300ml	Plastic	Do in field
Total Nitrogen (ammonia, nitrate, nitrite, TKN)	SM 4500 Or EPA 350 series	0.06 mg/l	0.06 mg/l	70-130	<30%	85-100%	Analyze immediately or add H ₂ SO ₄ to ph<2, Cool to 4°	500 ml	Plastic or Glass	28 days
Total Phosphate or o-Phosphate	EPA 365 series or SM4500	0.01 mg/l	0.01 mg/l	70-130	<30%	85-100%	Analyze immediately or add H ₂ SO ₄ to ph<2, Cool to 4°	100ml	Plastic or Glass	48 hours
Total Suspended Solids	EPA 160 series or SM2540	.2 mg/l	4 mg/l	85-115	<20%	85-100%	Cool to 4°	1 liter	Plastic or Glass	7 days

A= should only be used in the presence of residual chlorine

*Table taken from a "Generic Quality Assurance Project Plan for Water Quality Program Staff Sampling and Analysis Activities" Alaska Department of Environmental Conservation Division of Air and Water- Water Program. May 2003.

Study Design Worksheet

II. Adapted from: Hudson Basin River Watch ©June 2000 by River Network, used with permission.

Observation and/or Problem (discovered during the watershed inventory)

Study Question (What questions(s) do you want to answer with your monitoring?)

Hypotheses (A testable explanation)

Predicting (If the hypothesis were true, then you would predict that...)

Experimental Design

1. Describe how you will test your hypothesis.
2. Define the data users.
3. Indicate what will be measured and how the analysis will be done, including QA/QC protocols you will follow.
4. Where and when will the necessary tasks be carried out?
5. Who will do what tasks?

Design a Field Data Sheet

Sample of a Completed Hudson Basin Worksheet

Below is a sample of a completed Study Design Worksheet taken directly from the Hudson Basin document (used with permission). Question 3 refers to their tiered system, which is different than the objectives and primary/secondary levels of parameters suggested in this Cayuga Lake Watershed Monitoring Guidance Document. However, the thought process necessary to complete that portion of the worksheet is germane.

Study Design Worksheet - Example

Observation and/or Problem

Wappinger Lake is eutrophic

Study Question

Where are the high nutrient levels coming from?

Hypothesis

Route 9 storm drains contribute more to the problem than the watershed upstream of the lake.

Prediction

Nutrient loading from Route 9 storm drains is greater than nutrient loading in the creek just upstream from the lake.

Experimental Design

1. Describe how you will test your hypothesis.

Measure phosphate & nitrate concentrations and flow of water coming from Route 9 storm drains and in creek just above lake. Calculate loading values (loading = concentration x flow) and compare.

2. Define your data uses and users – which tier do they fit into?

Dutchess County Environmental Management Council and Wappinger Creek Watershed Planning Committee. They will accept either Tier 2 or Tier 3 data.

3. For each indicator that you will need to measure, describe methods, including QAQC.

Indicator	Monitoring Methods (Tier 1, 2, or 3?)	QAQC Procedures (Level A, B, or C?)
NO_3-N	<i>Zinc reduction color comparator (Tier 2)</i>	<i>Level C: Calibrate Nitrate test kit with blank and standard before testing sample.</i>
PO_4 flow	<i>DR890 colorimeter (Tier 3) Extrapolate flow of creek from USGS data. Measure flow from pipes with a known volume container and a stop watch.</i>	<i>Analyze one duplicate for each indicator each day. Split one sample for each day of sampling and send to an ELAP-certified lab for analysis. (Skip the split for a sampling day if it is within 30 days of a previous one). Thoroughly wash all sampling bottles and glassware. Make sure all reagents are current. Collect a grab sample from main current or a composite sample from cross section of the stream. Because analysis will not be done right away in the field, follow procedure for preserving the sample for later analysis. Use known PO_4 standards to develop calibration curve for DR890 colorimeter.</i>

4. Where and when will you carry out the necessary tasks?

The day after a rainstorm of at least 1 inch. Sample at storm drain pipes and from creek at road crossing upstream from lake. Sample 5 rainstorms over the course of a season.

5. Who will do what tasks?

Because storm sampling is important for this study, students will not be able to do the sampling unless they can walk there from the school (need prior notice to arrange a field trip). However, teachers can still carry out this study with students. Take them on a field trip of the watershed, the creek, and the lake to learn about and observe the situation. If possible, recruit and train a parent and student willing to take samples the day after the next rainstorm. Otherwise, a teacher or community volunteer can do the sampling. Students can analyze the samples in the classroom.

II. **Hudson Basin River Watch Field Data Sheet** (June 2000 by River Network, used with permission).

Monitoring Program Cover Sheet

Name of Group/Program _____ River/Stream _____
 Location (county, USGS Quadrangle(s)) _____ Date _____

Type of study: Water Quality Standards Survey River Characterization
 (check all that apply) Trend Analysis Impact or Improvement Assessment
 Ecological Study Other _____

What is the purpose of your study?

Describe sampling sites and other study details below (attach another sheet if needed):

Site name	Site description/location	Dates sampled	Indicators analyzed	HBRW Tier	QAQC level

Describe your group, ages and experience of those carrying out tasks:

Indicate total number of each:
 sampling sites sampling days
 BMI samples collected chemical samples collected

Indicate total number of each that are attached:
 Physical/Habitat Survey Sheets (one per site per season)
 Stream Bottom Survey Sheets (Tier 3: one per BMI site sampled; Tiers 1-2: optional)
 Flow Data Sheets (one for each chemical sample collected, if possible)
 BMI Sample Sheets (one for each BMI sample)
 BMI Data Reporting Sheets (one for each BMI sample & replicate)
 Chemical Sample Sheets (one for each chemical sample)
 Chemical Data Reporting Sheets (one for up to chemical samples, including duplicates)

Remarks:

Name, phone & email of contact person: _____

©Hudson Basin River Watch Guidance Document 28 DESIGNING YOUR RIVER STUDY

APPENDIX C

Primary and Secondary Sampling Parameters Listed by Monitoring Objective

OBJECTIVE	PRIMARY	SECONDARY
Lake Sampling: Water Column	Total phosphorus	Invasive organisms
	Soluble reactive phosphorus	pH
	Dissolved oxygen	
	Temperature	
	Turbidity (Secchi disk)	
	Chlorophyll <i>a</i>	
	Atrazine	
Lake Sampling: Near shore	<i>E. coli</i>	Fecal coliforms
	Invasive plants	Pesticides (especially atrazine)
	Invasive animals	Benthic macroinvertebrates
		Heavy metals (Pb, Cr, Cu, Zn, Cd, Hg)
Mass Load Sampling	Total Phosphorus	Pesticides (particularly atrazine)
	Soluble reactive phosphorus	
	Sediment (TSS)	
	Discharge	
Tributary Water-quality Sampling	Total Phosphorus	Chloride
	Nitrate nitrogen	Alkalinity
	Sediment (TSS)	Discharge
	<i>E. coli</i>	<i>Cryptosporidium</i>
	Total coliforms	Invasive organisms
	Temperature	Percent canopy cover
	Dissolved Oxygen	Periphyton
	pH	Width of forested riparian zone
Biological Integrity Sampling: Lake	Zooplankton composition	Fish
	Phytoplankton composition	
Biological Integrity Sampling: Tributary	Macroinvertebrates	Fish

APPENDIX D

Overview of Key Sampling Parameters

Concentration Versus Mass Load

Understanding the difference between concentration and mass load is important for understanding the amount of a contaminant being introduced by a stream into the lake. The initial laboratory analysis of a water sample gives the quantity, or concentration, of a certain contaminant in a given amount of water. Using phosphorus as an example, the result of the test may show the phosphorus concentration to be 0.02 micrograms per liter of water. While concentrations provide useful information about exposure to a pollutant, such a number does not provide information on how much phosphorus the stream is transporting to the lake, which is referred to as mass load.

In order to determine the quantity of a pollutant a stream is contributing, an additional piece of information is needed – discharge, or water flow. Once the stream discharge at the time of sampling is known, we have a much better grasp on the amount of phosphorus that is moving via the stream to the lake at that time. A calculation using the concentration and the flow gives the phosphorus load for a given sampling incidence. For example, suppose we know that, during a storm event, the discharge rate for our stream was 5 million liters per second and that the storm event lasted 20 thousand seconds (between 5 and 5 ½ hours). Therefore, during the storm, 100 billion liters of water ran into the lake. We'll use 0.02 micrograms of phosphorus per liter as the concentration the laboratory analysis reported. Multiplying the number of liters of water that entered the lake by the amount of phosphorus per liter we calculate that 2 billion micrograms or 2 thousand grams of phosphorus entered the lake during the storm.

Chlorophyll *a*

The most practical way to measure algae is to approximate the amount of algae by measuring chlorophyll *a*, the primary photosynthetic pigment found in all algae and most photosynthetic organisms. It constitutes approximately 1.5 percent by dry weight of the algal biomass. Lakes with excessive algae are often characterized by chlorophyll *a* levels greater than 10 µg/l. Chlorophyll can be measured directly by filtering water onto a glass-fiber filter, extracting the filter with acetone or methanol, and measuring chlorophyll on a spectrophotometer (if levels are sufficiently high) or with a fluorometer (if levels are low). Generally, the filters are frozen after filtration and before analysis. However, it is important to freeze the filters very soon after filtration, and storage time is limited, so the samples should generally be run within a few days to a few weeks at most.

Alternatively, chlorophyll levels in water can be estimated directly by fluorometry. This can be done by bringing water samples back to a lab and placing in a fluorometer, or *in situ* in the lake. If bringing water samples back to the lab, it is very important that they be analyzed within a few hours of sampling, as chlorophyll can degrade quickly. Using either fluorometric approach, it is necessary to calibrate periodically against a direct measure of chlorophyll on filtered samples.

Conductivity

Conductivity measures the electrical current that passes through a solution. Since electrical current is carried by charged particles (ions such as Ca⁺, Mg⁺⁺, Na⁻ and K⁺), this is an indirect measure of the number of ions in solution, mostly as inorganic substances. Conductivity is affected primarily by the geology of the area through which the water flows and the presence of naturally occurring electrolytes, or salts. The conductivity should remain fairly constant for a given water body throughout the year.

Any significant changes over a short period of time may indicate a significant amount of precipitation or water-quality problem. The addition of suspended soil particles from storm runoff and watershed erosion can temporarily increase conductivity. A failing septic system, heavy metals, chloride, phosphates and nitrates can also raise the conductivity while an oil spill would lower it. Internal waves, or seiches, can re-suspend bottom sediments and locally increase conductivity readings.

Conductivity is measured as micromhos/centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Hard water lakes, such as Cayuga, often have a conductivity exceeding 300 µmho/cm. The conductivity of freshwater rivers ranges greatly from 50-1,500 µS/cm. Conductivity may be reported by laboratories as “specific conductance” and referenced to a specific temperature, usually 25°C (centigrade).

E. Coli, Coliforms and Cryptosporidium

Coliform bacteria serve as indicator organisms, meaning they may not pose a health danger themselves. Their presence indicates the possible presence of more dangerous and more difficult to detect disease-causing organisms, or pathogens. Coliforms are naturally occurring bacteria that can originate from decaying matter in the surface water as well as from feces. Total coliform bacteria are quite diverse and ubiquitous in surface waters. They commonly exist in many places at all times. High total coliform bacteria counts are not necessarily indicative of contaminated waters.

Fecal coliform and *E.coli*, are the two indicator that are commonly looked for when contamination by human or animal waste is suspected. Some fecal coliform bacteria grow in the intestinal tracts of warm-blooded animals, including humans, and are present in feces. Other fecal coliform are commonly found in waters near pulp industries and do not reflect an animal source. A high count indicates the possibility that other organisms that are harmful to humans may also be present.

E.coli (*Escherichia coli*) is a single species within the fecal coliform group, as shown in Fig. 1. As with the larger fecal coliform group, *E.coli* are indicators of contamination and generally not pathogenic. The strain *E. coli* 0157:H7, which has been in the news as causing severe illness, is not a water-quality concern since it is primarily transmitted through food. In some monitoring programs, *E. coli* is the organism of choice because of its association with intestinal illnesses. The US EPA recommends using *E. coli* over fecal coliform as a bacterial indicator, though at the time of writing New York State is still using fecal coliform. New York State is expected to adopt the federal *E.coli* standards for freshwater systems.

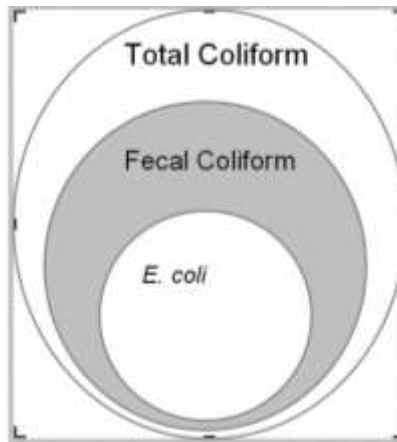


Fig. 1

E. coli is a type of fecal coliform, which in turn is a type of total coliform.
 (Adapted from the Tompkins Co., NY, Department of health)

Cryptosporidium is a parasitic protozoa, a type of one-celled animal, that lives in the intestines of people and other animals. The infective form of the organism, called the oocyst, is a dormant stage that is excreted in the feces. There are different species of this microscopic pathogen and not all species infect humans.

The methodology for cryptosporidium analysis is expensive and imprecise. Interpretation of results is complicated since most analyses do not give species specific results. Therefore, positive results can not be correlated to a human health risk. Also, cryptosporidium have been detected in pristine streams, implying that a positive result does not correlate closely to pollution. Finally, false negative results are common.

Local water utilities perform source water monitoring for cryptosporidium. We are not recommending that other entities prioritize monitoring for cryptosporidium given the hurdles of expense, lack of specificity of current methods and our inability to tie results to disease potential,. This recommendation may change in the future.

Dissolved Oxygen and Temperature

Dissolved oxygen (DO) consists of molecules of oxygen (O₂) dissolved in the water. Oxygen is much less abundant in water than in the atmosphere. It enters the water primarily through plant photosynthesis and to some extent by absorption from the atmosphere, especially in moving water. Dissolved oxygen is affected by temperature, time of day, and pollution. As water temperature decreases, increasing amounts of oxygen can dissolve in water. During the day photosynthetic plants release oxygen. At night or at depths below those reached by light, plants, animals, aerobic bacteria and other oxygen-respiring organisms deplete it. Fish and many other aquatic organisms require a minimum of four to five mg/l (milligrams-per-liter) of oxygen.

Since cold water holds more oxygen than warm water, dissolved oxygen is frequently expressed as the percent saturation, which is the DO content relative to what the water *could hold* at the measured temperature. It is desirable to be at or near 100 percent saturation. Water can become supersaturated, above 100 percent.

Nutrients: Phosphorus and Nitrogen

Phosphorus more than any other chemical element regulates rates of phytoplankton (*e.g.*, algal) production and biomass in most moderately to highly productive freshwaters in the US. This is certainly the case in Cayuga Lake, where several studies over the last half century have demonstrated that phosphorus is the so-called “limiting nutrient.” When phosphorus enters the lake, algal growth and water turbidity increase during summer in the upper levels of the lake. This is of great concern, since the southern end of the lake is already classified as impaired due to excess phosphorus inputs. The increase phosphorus leads to eutrophication (or excess production), and a host of related problems, including reduced biodiversity, degradation of habitat quality in the lake, and the threat of reduced concentrations of dissolved oxygen., The sources of phosphorus to Cayuga Lake remain poorly known. Some comes from wastewater treatment plants, although this input has decreased recently due to improved sewage treatment by the City of Ithaca. Other sources include phosphorus bound to sediment that is eroded from the watershed and delivered to the lake, and inputs from fertilizer and animal wastes. The major source of phosphorus inputs is probably the eroded soil and sediment in the watershed, but it is unknown how much of this becomes bio-available within the lake. Some of this particle-found phosphorus is adsorbed to the surfaces of particles, and probably de-sorbs and helps fuel eutrophication in the lake. Some of it is also chemically bound within the sediment matrix; this is less available, and some of it is permanently buried in the lake sediments. However, some of the chemically bound phosphorus may be released within the sediments, due to chemical changes that occur there, and this also may help fuel eutrophication in the lake.

The concentrations of soluble reaction phosphorus have been increasing in recent years in the bottom waters of the lake. The reason or reasons for this are not known. One possibility is that phosphorus bound in the sediments has become more available due to actions of invasive mussels in changing sediment chemistry. Another possibility is that the total inputs of highly available phosphorus into the lake may have increased due to the greatly increased spreading of manure in the watersheds associated with a large increase in the abundance of confined animal feedlot operations (CAFOs), particularly in the Salmon River watershed. There is a potential for a further huge increase in such activities in the watersheds of the lake, should a new ethanol-producing plant be built in Seneca County. As proposed, the plant would take its phosphorus-rich waste (“distillers grain”) and sell it for feed for cows and cattle. The supply would be sufficient to support 40,000 cows and cattle, and most would likely be located within 20 miles of the plant, due to the high cost of transporting the distillers grain.

Phosphorus can be either organic or inorganic and can be either particulate or dissolved. Organic phosphorus is bound in the microscopic algae that comprise the phytoplankton but also occurs in dissolved form and in organic matter associated with inputs of material from land. Inorganic phosphorus, also known as orthophosphate, is the form required by the algae. This is most commonly measured as “soluble reactive phosphorus (or SRP), a measure that also includes some relatively labile forms of organic phosphorus. While it is possible to measure only the inorganic phosphorus, this is difficult, and almost never done. The SRP measurement is therefore a convenient approach, but it tends to overestimate actual dissolved inorganic phosphorus. The inorganic phosphorus can be rapidly taken up by algae, and is often very rapidly cycled, with typical turnover times for SRP of minutes to hours.,

Phosphorus is analyzed in most surface waters as total phosphorus and soluble reactive phosphorus. Total phosphorus is all the phosphorus present including that which is extracted from the algae in the water and that adsorbed to or chemically bound within suspended sediment particles. Total phosphorus therefore includes both dissolved and particulate forms. Soluble reactive phosphorus is the “free phosphorus” in the water column. In Cayuga Lake, as in most moderately productive lakes, the soluble reactive phosphorus concentrations are quite small compared to the total phosphorus concentration.

Nitrogen like phosphorus is an essential element for all living organisms. In some natural waters, including many coastal marine ecosystems as well as many low-productivity lakes, nitrogen rather than phosphorus is the limiting nutrient. However, this is clearly not the case with Cayuga Lake, and it is highly unlikely that the lake could ever become limited by nitrogen. Therefore, monitoring nitrogen fluxes here is not a high priority, at least in terms of the lake itself. The waters from Cayuga flow through Lake Ontario to the St. Lawrence Seaway and then to the Gulf of St. Lawrence. In the Gulf of St. Lawrence, nitrogen is the prime nutrient of concern, and it is causing a degradation of water quality there. However, nitrogen is removed from waters over time as it is transported along, and given the long transit time between Cayuga Lake and the Gulf of St. Lawrence, it is doubtful that any significant portion of the nitrogen from our community contributes to problems there.

There is value in measuring nitrate (a dominant, highly biologically available form of nitrogen) in the tributaries of Cayuga Lake as it can shed light on the general state of pollution inputs, particularly from CAFOs and other animal agriculture. Academic researchers are also very interested in the interactions of nitrogen and phosphorus even in lakes where nitrogen is not limiting.

pH

pH is used to categorize solutions as acidic or basic. Truly pure water in the laboratory isolated from air is neutral and consists of an equal number of hydrogen (H^+) and hydroxide (OH^-) ions. Pure water in nature that is exposed to air will have a pH of approximately 5.7 due to carbon dioxide dissolved in it, since carbon dioxide is a weak acid. Other substances will further change the pH, making it lower or higher. pH is a measure of the number of hydrogen ions in solution.

If water is "acidic" it has a pH below 7.0, and the concentration of hydrogen ions exceeds the concentration of hydroxide ions. If water is "basic" or “alkaline” it has a pH above 7.0, and the concentration of hydrogen ions is less than the concentration of hydroxide ions. A pH increase or decrease of 1 corresponds to a ten-fold difference in the number of hydrogen (and hydroxide) ions. The pH range of 6 to 9 is acceptable for most aquatic organisms in lakes. The pH of streams is quite commonly lower, and stream organisms are therefore adapted to the lower values.

Acid rain is a major problem in many areas, including the Adirondack Mountains in New York. However, the bedrock geology of the watersheds of Cayuga Lake is dominated by limestones and other calcareous minerals that tend to keep the pH at acceptably high levels (“buffering”). While acid rain may cause problems with our local environment, lowering the pH is not one of these, and Cayuga Lake is very unlikely to ever suffer problems from excess acidity. No units are specified when noting pH.

Sediment: Total Suspended Solids

Water quality monitoring of sediment may be done as either total suspended solids (TSS) or suspended sediment. TSS is easier to measure, is more common (making data comparison easier) and is recommended in most instances.

Total suspended solids refers to the entire amount of organic and inorganic particles dispersed in water and not in true solution. The origin of suspended matter may be human influenced or natural such as silt and algae. Since the solids are not dissolved, they can be removed using a filter. What remains after filtration is the TSS.

The size of particles that can be suspended varies with hydrologic conditions. Usually particles less than 0.1 mm will remain in suspension in water for a considerable period of time. Particles between 0.1 mm and 1 mm may stay in or drop out of suspension. Suspension can be caused by turbulence and currents and/or by colloidal suspension. Colloidal suspension occurs when particles are so fine, such as fine clays, they do not settle under the action of gravity but will remain diffuse even in quiet water.

Measuring TSS frequently entails drying a known sub-volume from the original sample. This use of a subsample can introduce error if the subsample is not representative of the whole. This can be overcome by using the full sample, which necessitates weighing the full bottle and the empty bottle. Some analysis regimes call for dividing the total suspended solids into smaller categories, but that is not included in the recommendations in this Monitoring Guidance.

U.S. Geological Survey (USGS) is the main proponent of suspended sediment analysis. If your research or study design involves comparisons to USGS published sediment data, such as gage data, or USGS is a targeted data user, analyze for suspended sediment. The sample collection process is rigorous to ensure the collected sample is representative and the processing is slightly different.

TSS and suspended sediment analyses give similar results during base flow conditions. During high flow conditions TSS numbers will be on the low side. For improved accuracy, run whole water samples, and use Whatman GF-F filters instead of GF-C filters. TSS will generally be accurate for low-flow conditions and for overall trends of high versus low flows.

Turbidity

Turbidity is caused by suspended materials that cause light to be scattered and absorbed rather than transmitted in straight lines through water. Suspended materials such as clay, silt, algae, and other materials have a major influence on the clarity of the lake. It is particularly important in drinking water supply sources, since turbidity is can be related to substances that either impart tastes or odors to the water or can clog filters and rapidly increase the cost of water treatment. If the source of turbidity is largely organic, it can also create carcinogenic compounds. Turbidity is most commonly measured using a Secchi disk.

The Secchi disk is a 20cm steel or heavy plastic disk quartered into alternating black and white sections. Using a measured rope or cable it is lowered over the shaded side of the sampling boat to measure the transparency of lakes. The water transparency is calculated by average of the

depth at which the disk first disappears from sight as it is lowered with the depth at which it reappears as it is slowly raised.

There is a strong correlation among measures of total phosphorus, chlorophyll *a*, and Secchi disk transparency. Together these parameters can be used to evaluate the degree of eutrophication using a Trophic State Index. Trophic states range from *oligotrophic* water that has a maximum transparency, minimum chlorophyll-*a*, and minimum phosphorus to *eutrophic* water has minimum transparency, maximum chlorophyll-*a*, maximum phosphorus. Waters that are strongly alkaline and/or have high inputs of inorganic sediment and nutrients, may not exhibit the above correlation. In that case, direct measures of chlorophyll will be the most practical way to evaluate trophic state.

Adapted from *The Expanded Diet for a Small Lake* (New York State Federation of Lake Associations, 2008) with additional information from *Managing Lakes and Reservoirs* (Holdren, et al 2001), *Hudson Basin River Watch* (River Network 2000), the *2005 Water Quality Report* (Gilman and Olvany, 2005) and the principle authors of the *Guide To Surface Water Quality Monitoring In The Cayuga Lake Watershed*.

APPENDIX E

Map of Cayuga Lake Watershed



APPENDIX F

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Add EPA reference in the text

ASTM.org to learn about and purchase, section.

Standardmethods.org – gives basic infor and can buy sections and get updates.

can get from local drinking waters or waste water treatment facility. Might be able to copy.

USEPA – available at www.epa/waterscience/methods/method

USEPA NPS Information Exchange, 2001 posting, npsinfo@valley.rtpnc.epa.gov.

APPENDIX G

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