Water Quality in Seneca Lake Tributary Streams

Stephen Penningroth, Director
Community Science Institute

Hobart and William Smith Colleges

March 24, 2018

Community Science Institute

Independent, nonprofit, tax-exempt environmental organization founded in 2000, website: **communityscience.org**

Budget and Staff: Four (4) full-time, four (4) part-time; $268,000 in 2017, ~37 % from local governments and other stakeholders in Tompkins County

Certified water quality testing lab: NY State and EPA certified for both non-potable water and drinking water since 2003.

QAPP-based, affordable monitoring partnerships between certified lab and volunteer groups: We recruit, train and partner with community-based volunteer groups to build scientifically credible, long-term data sets -- at less than half the cost of environmental consulting firms -- with the goal of understanding and protecting water resources locally and regionally

Free online access to raw data and interpretive maps and graphs: Public can view raw data with maps and graphs, also search and download results, at **database.communityscience.org**

Biological stream monitoring: CSI staff also partner with volunteer groups to monitor the health of streams as aquatic ecosystems by collecting and identifying small bottom-dwelling organisms called benthic macroinvertebrates (BMI), on a par with NYSDEC's stream monitoring program

Maintaining a Certified Lab – Benefits and Challenges

Maintaining a certified lab is a lot of work!

- The quality assurance and quality control measures are extensive.
- The amount of paperwork involved is sizable.
- Inspections are rigorous.

So why make the effort?

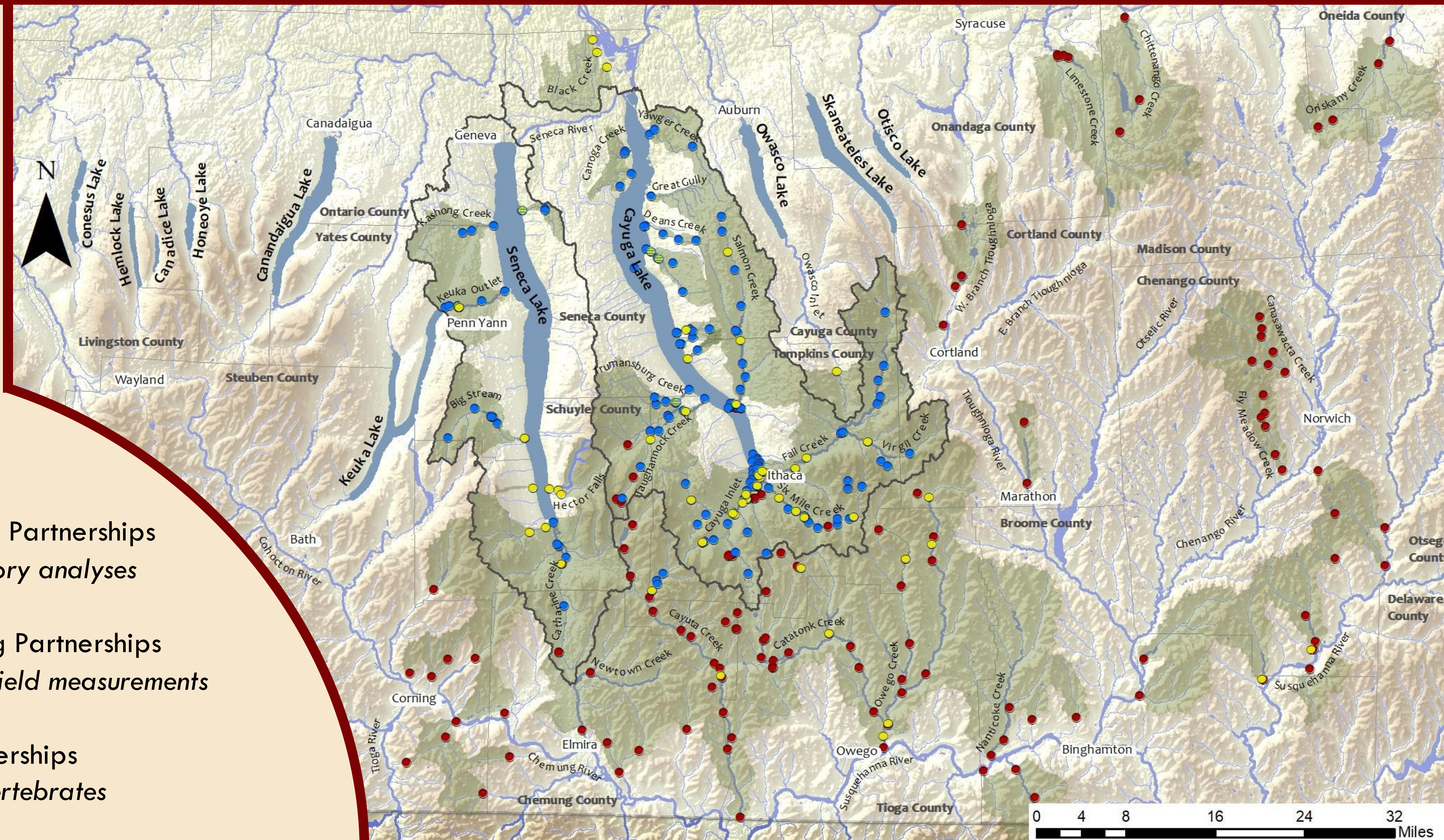
- **Certified data can be used for regulatory purposes.**
  - It is difficult for citizen science groups to ensure that their data is taken seriously. Certification is one way.
- Maintaining certification also allows CSI to address the community's potable water testing needs.

"Do I detect sarcasm?"

Volunteer Water Monitoring Partnerships

Three Volunteer Water Monitoring Programs

- Synoptic Sampling
- Red Flag Monitoring
- Biomonitoring



- Synoptic Monitoring Partnerships
  - *Certified laboratory analyses*
- Red Flag Monitoring Partnerships
  - *Quality-assured field measurements*
- Biomonitoring Partnerships
  - *Benthic macroinvertebrates*

CSI Monitoring Programs – Synoptic Sampling

Three Volunteer Water Monitoring Programs

- **Synoptic Sampling**
  - Certified Lab Analyses
  - Analytes include:
    - E. coli
    - Total Phosphorus
    - Soluble Reactive Phosphorus
    - Nitrate -+ Nitrite Nitrogen
    - Total Kjeldahl Nitrogen
    - Ammonia Nitrogen
    - Turbidity
    - Total Suspended Solids
    - Chloride
    - Chlorophyll a
    - And others
  - Primary focus of program is monitoring nutrients, sediment, and pathogenic bacteria

Synoptic Sampling Process

Sample
- Water samples are collected by teams of volunteers three to four times a year including once under storm water conditions. Sampling of a single stream, from headwaters to mouth, occurs within a few hours to get a "snap-shot" of water quality.

Drop off
- Volunteers bring samples to CSI's certified lab and complete a chain of custody.

Analyze
- Samples are analyzed by CSI staff using certified methods.

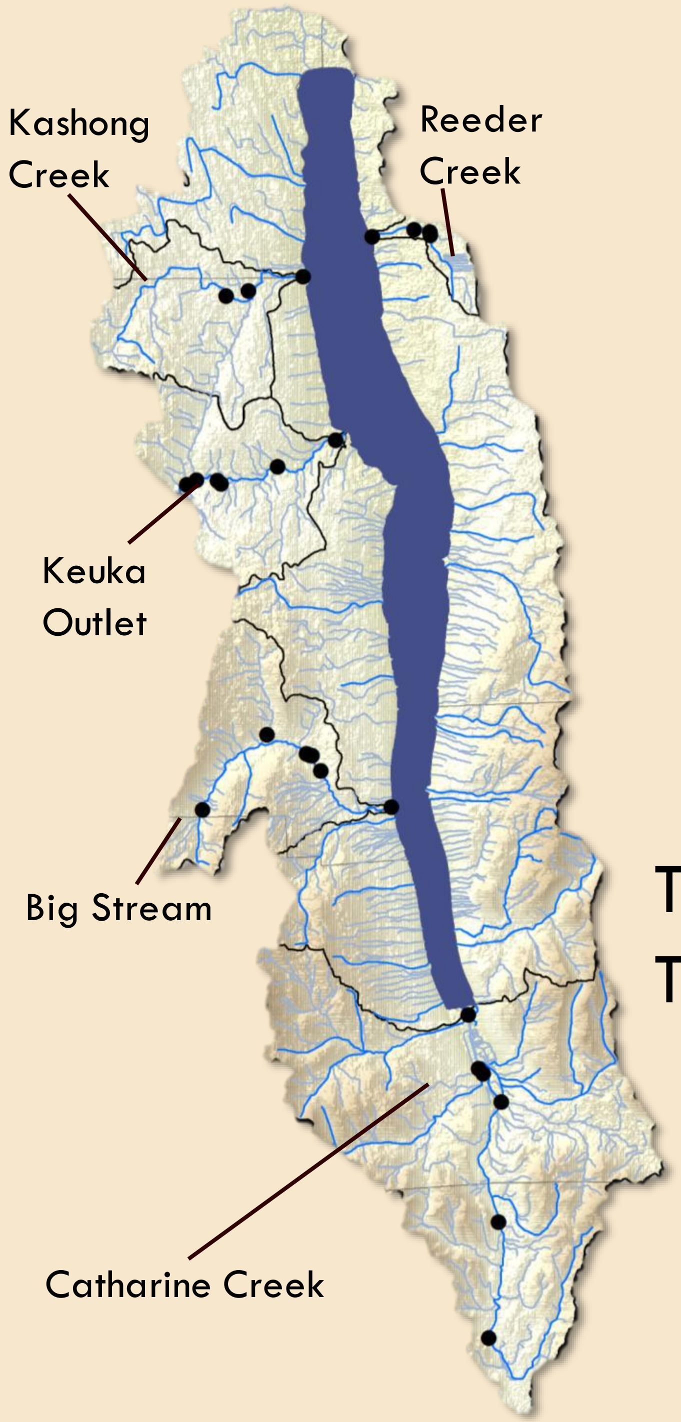
Database
- Test results are entered into CSI's online public database:

www. database.communityscience.org

Seneca Lake Tributary Stream Volunteer Monitoring

A Volunteer-CSI Synoptic Monitoring Program

- Water quality in Seneca Lake is determined largely by water quality in its many tributary streams
- Water quality in streams is, in turn, determined largely by land use in their watersheds, for example, forest, agriculture, waste water treatment plants, natural areas, and diverse types of businesses
- SLPWA volunteers collect samples several times a year at ~25 fixed locations on 5 tributary streams draining 48% of the Seneca Lake watershed
- Locations have been chosen to maximize the likelihood of documenting potential impacts

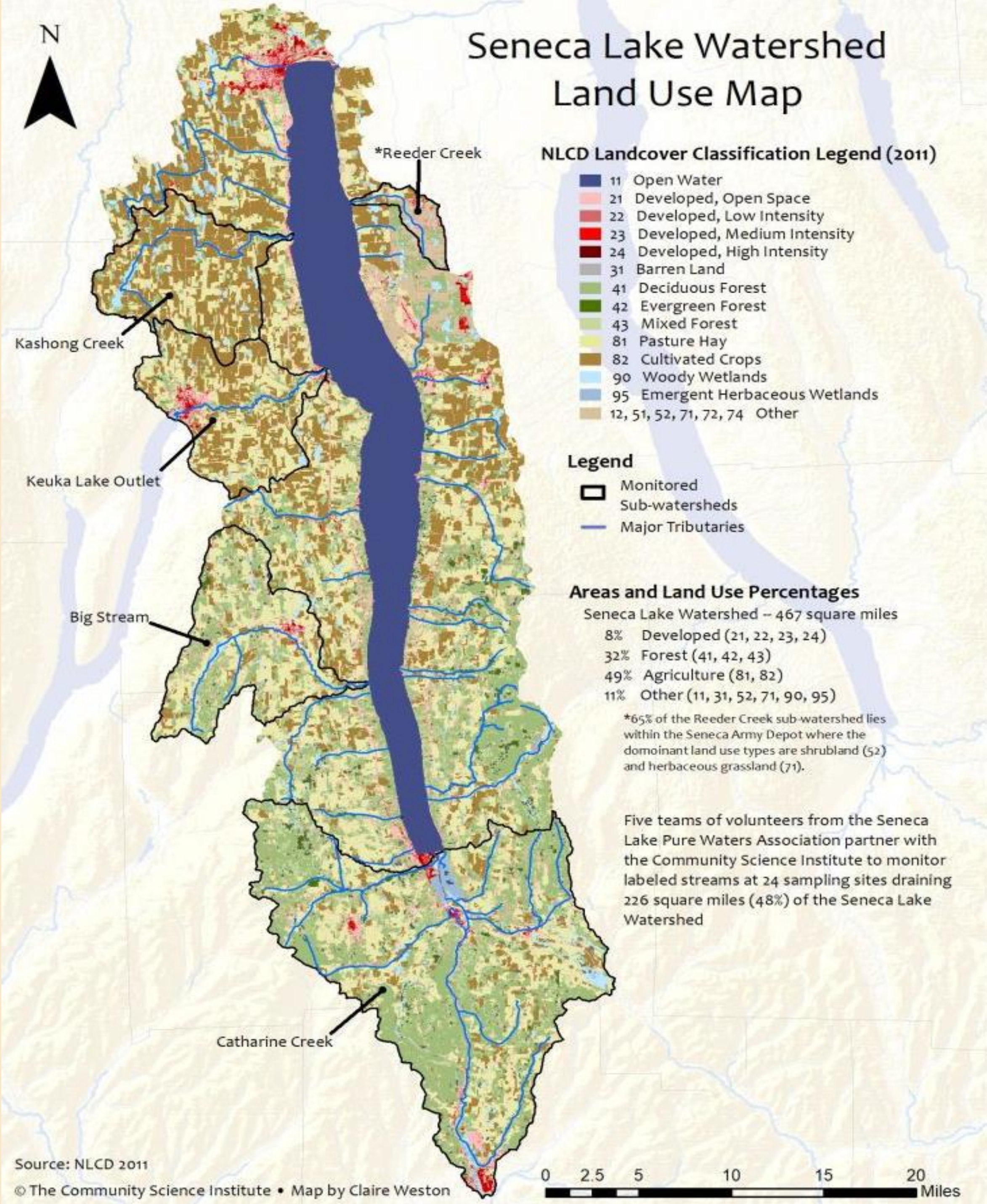


Fixed Locations Monitored Regularly by SLPWA Volunteers on Seneca Lake Tributary Streams

Total drainage area monitored: ~226 mi^2

Total number of monitoring sites: ~25

View, search and download raw data free at database.communityscience.org


Seneca Lake Watershed Land Use Map
N
*Reeder Creek
Kashong Creek
Keuka Lake Outlet
Big Stream
Catharine Creek
NLCD Landcover Classification Legend (2011)
11 Open Water
21 Developed, Open Space
22 Developed, Low Intensity
23 Developed, Medium Intensity
24 Developed, High Intensity
31 Barren Land
41 Deciduous Forest
42 Evergreen Forest
43 Mixed Forest
81 Pasture Hay
82 Cultivated Crops
90 Woody Wetlands
95 Emergent Herbaceous Wetlands
12, 51, 52, 71, 72, 74 Other
Legend
Monitored Sub-watersheds
Major Tributaries
Areas and Land Use Percentages
Seneca Lake Watershed -- 467 square miles
8% Developed (21, 22, 23, 24)
32% Forest (41, 42, 43)
49% Agriculture (81, 82)
11% Other (11, 31, 52, 71, 90, 95)
*65% of the Reeder Creek sub-watershed lies within the Seneca Army Depot where the domoinant land use types are shrubland (52) and herbaceous grassland (71).
Five teams of volunteers from the Seneca Lake Pure Waters Association partner with the Community Science Institute to monitor labeled streams at 24 sampling sites draining 226 square miles (48%) of the Seneca Lake Watershed
Source: NLCD 2011
© The Community Science Institute • Map by Claire Weston
0 2.5 5 10 15 20 Miles

Program Focus is on Nutrients, Bacteria, Sediment and Hazardous Chemicals

- Monitoring partnership between SLPWA and CSI produces reliable measurements of water quality indicator concentrations under base flow and high flow conditions
- Concentrations at stream mouths reflect total watershed contributions to water quality, including groundwater (base flow) plus surface and sub-surface runoff (at high flows)
- Concentrations at stream mouths are also general indicators of nearby nutrient concentrations in the lake
- Note: Concentrations are not the same as the amounts or loads (mass) of nutrients entering Seneca Lake

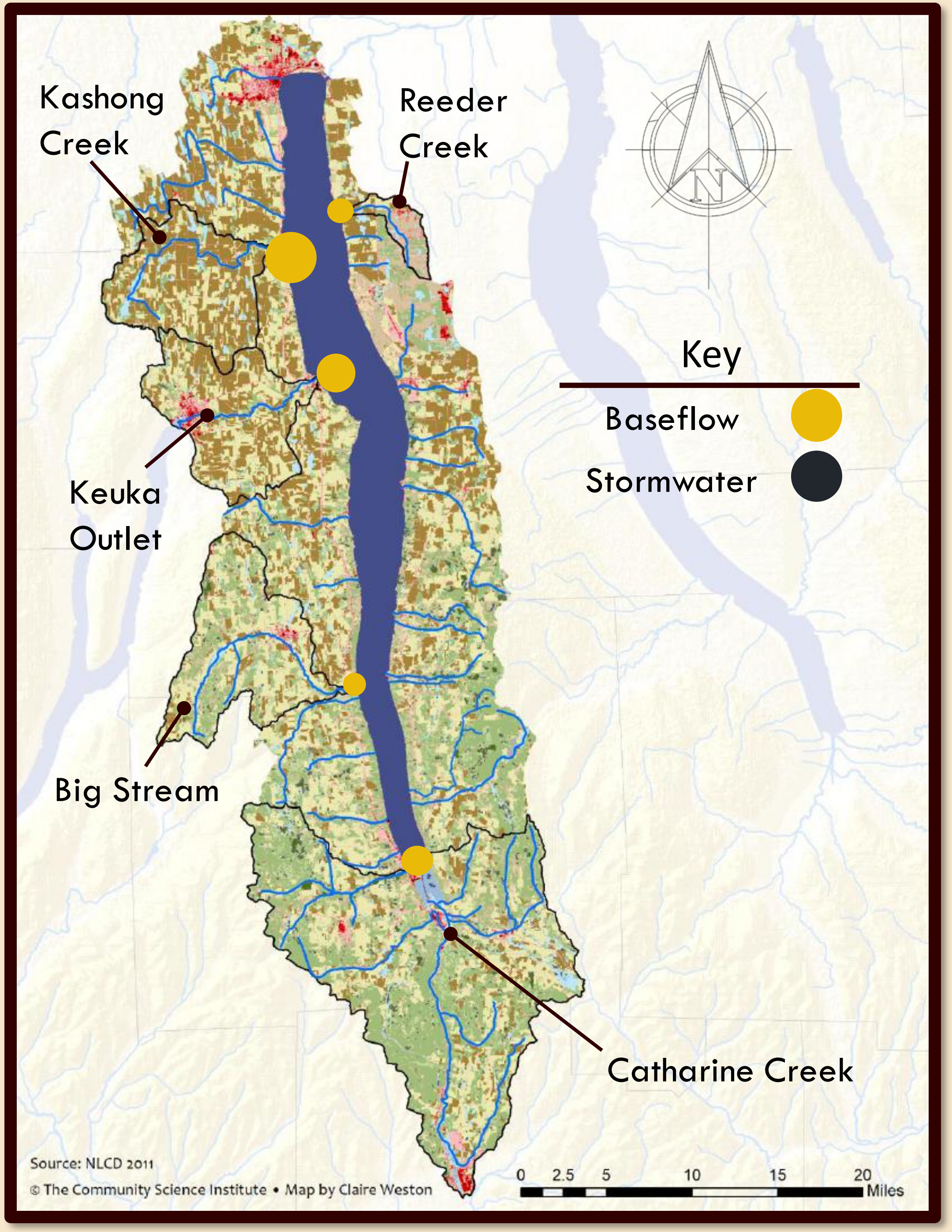
No Evidence of Hazardous Substances in Reeder Creek Downstream from Seneca Army Depot

	N. Patrol Rd.	Access Rd.	Rte 96A	Mouth	Drinking Water Standard
Gross Alpha Radioactivity (pCi/L)	0.31	0.39	- 0.37	0.64	15 pCi/L
Gross Beta Radioactivity (pCi/L)	2.4	2.66	1.28	2.31	15-50 pCi/L
Arsenic (mg/L)	<0.01	<0.01	<0.01	<0.01	0.01
Beryllium (mg/L)	<0.001	<0.001	<0.001	<0.001	0.004
Copper (mg/L)	<0.002	0.004	0.002	0.003	1.3
Lead (mg/L)	<0.01	<0.01	<0.01	<0.01	0.015
VOCs (58 total) (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	0.005

Average E. coli Counts

Contact Recreation Limit = 235 colonies/100 mL

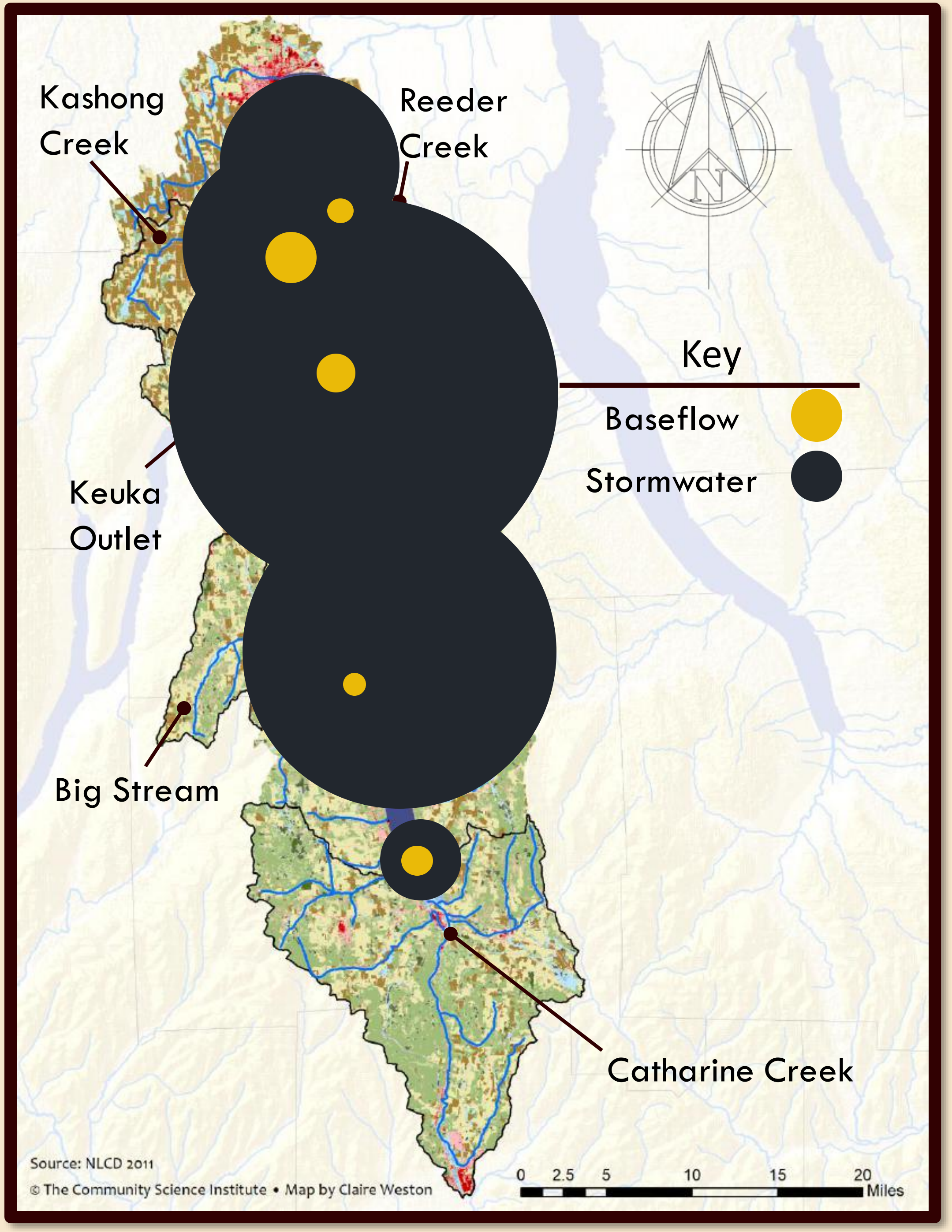
Stream (North to South)	Average E. coli at stream mouth, base flow (colonies/ 100 ml)	Average E. coli at stream mouth, stormwater (colonies/ 100 ml)
Reeder Creek	264	12,500
Kashong Creek	996	15,000
Keuka Outlet	582	59,250
Big Stream	202	38,175
Catharine Creek	349	2,615



Average E. coli Counts

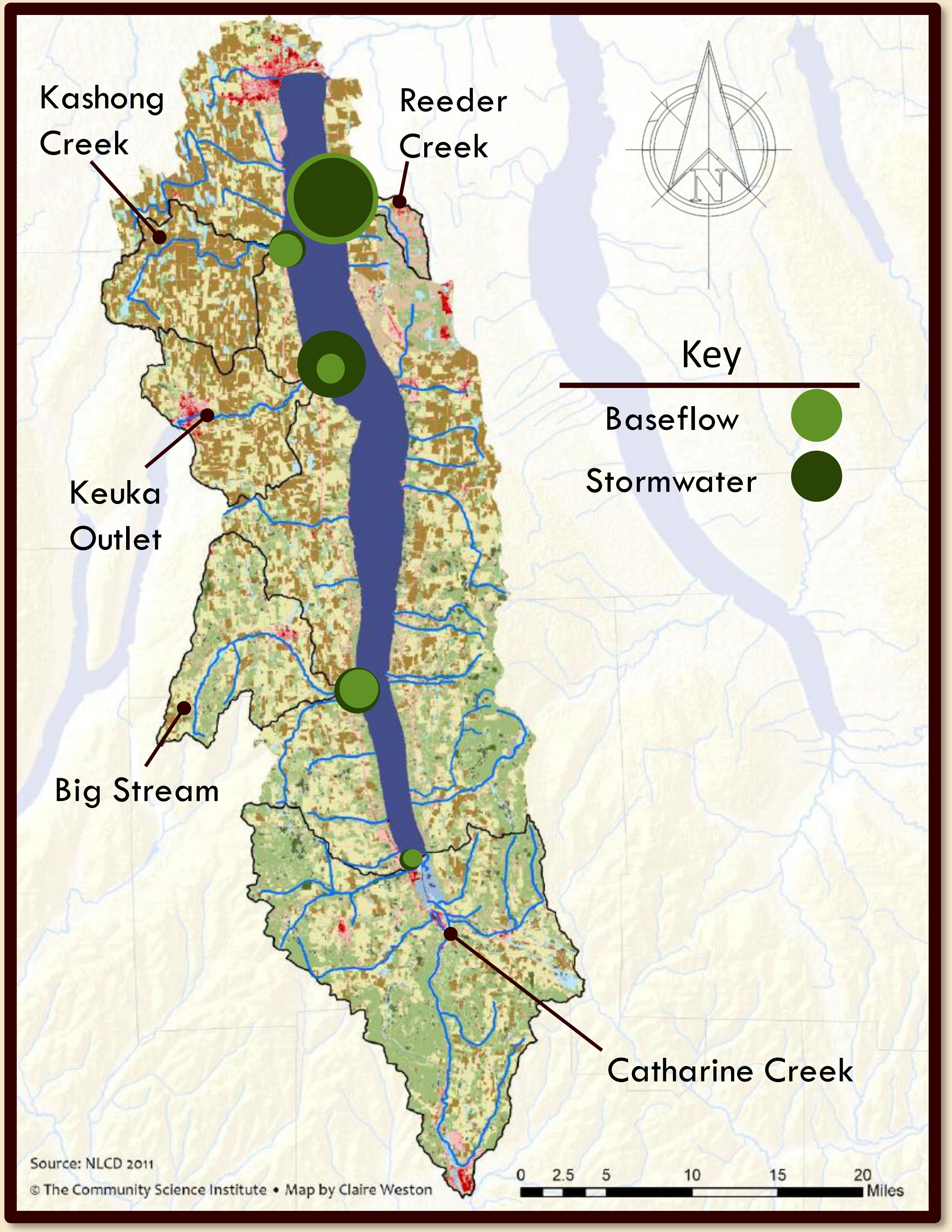
Contact Recreation Limit = 235 colonies/100 mL

Stream (North to South)	Average E. coli at stream mouth, base flow (colonies/ 100 ml)	Average E. coli at stream mouth, stormwater (colonies/ 100 ml)
Reeder Creek	264	12,500
Kashong Creek	996	15,000
Keuka Outlet	582	59,250
Big Stream	202	38,175
Catharine Creek	349	2,615



Average Dissolved (~Bioavailable) Phosphorus Concentrations Measured at Stream Mouths

Stream (North to South)	Average Dissolved Phosphorus, Base Flow (µg P/L)	Average Dissolved Phosphorus, Stormwater (µg P/L)
Reeder Creek	326.21	255.33
Kashong Creek	43.38	52.20
Keuka Outlet	32.51	176.50
Big Stream	59.18	81.62
Catharine Creek	12.76	14.95

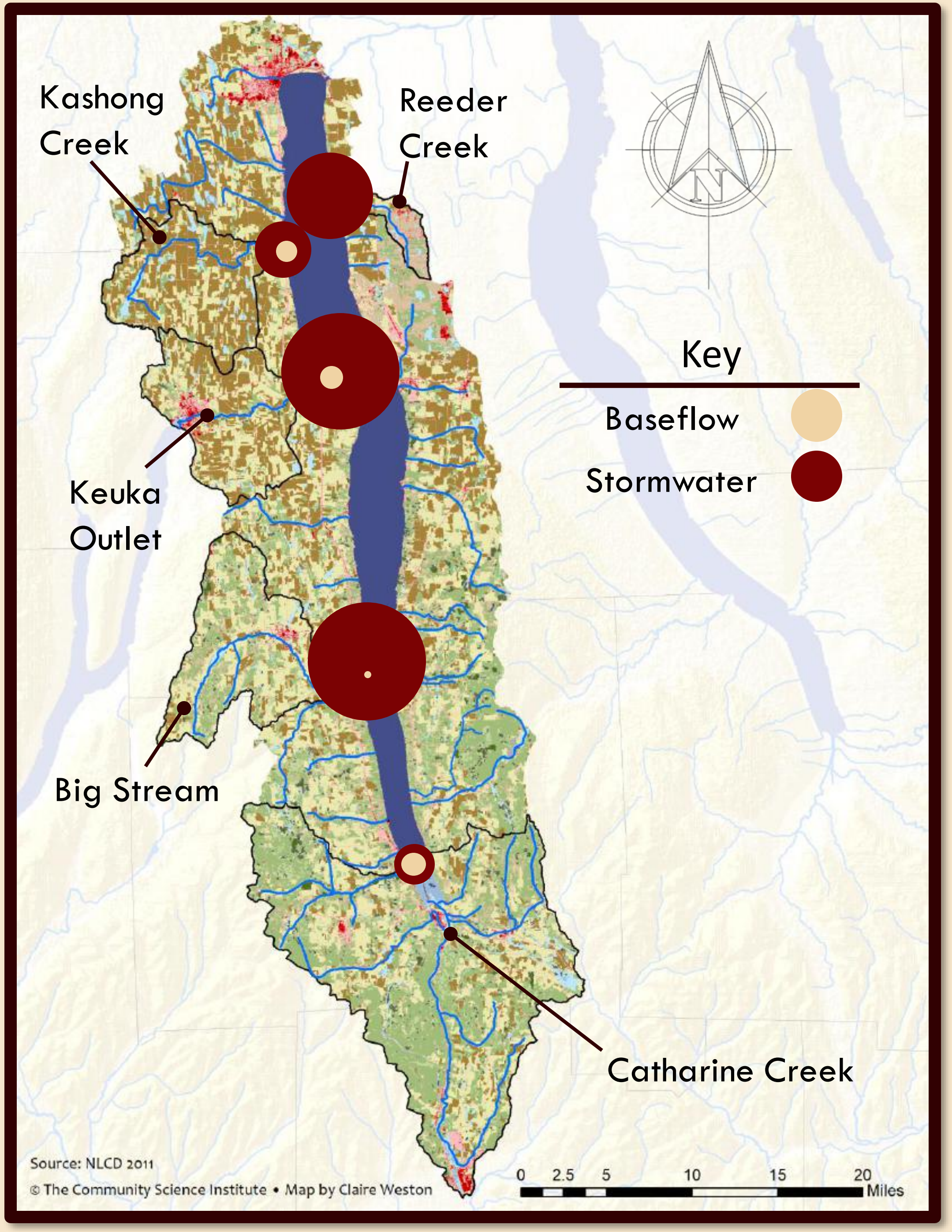


General Comparison Between Dissolved P in Seneca Lake Streams and Cayuga Lake Streams

- Reeder Creek: Dissolved P is extremely high in groundwater feeding Reeder Creek, possibly due to legacy contamination from munitions disposal at the Seneca Army Depot
- Base flow dissolved P concentrations average ~3x higher in the other four monitored Seneca Lake streams, ~37 ug/L, compared to ~13.4 ug/L in five Cayuga Lake streams
- Stormwater dissolved P concentrations average ~2x higher in Seneca Lake streams, ~81 ug/L, compared to ~45 ug/L in five Cayuga Lake streams

Average Particulate Phosphorus Concentrations at Stream Mouths = Total P – Dissolved P (Not Readily Bioavailable)

Stream (North to South)	Average Particulate Phosphorus, Base Flow (μg P/L)	Average Particulate Phosphorus, Stormwater (μg P/L)
Reeder Creek	(-22.9)	283.0
Kashong Creek	17.7	118.8
Keuka Outlet	20.4	535.0
Big Stream	2.19	548.2
Catharine Creek	22.8	62.3

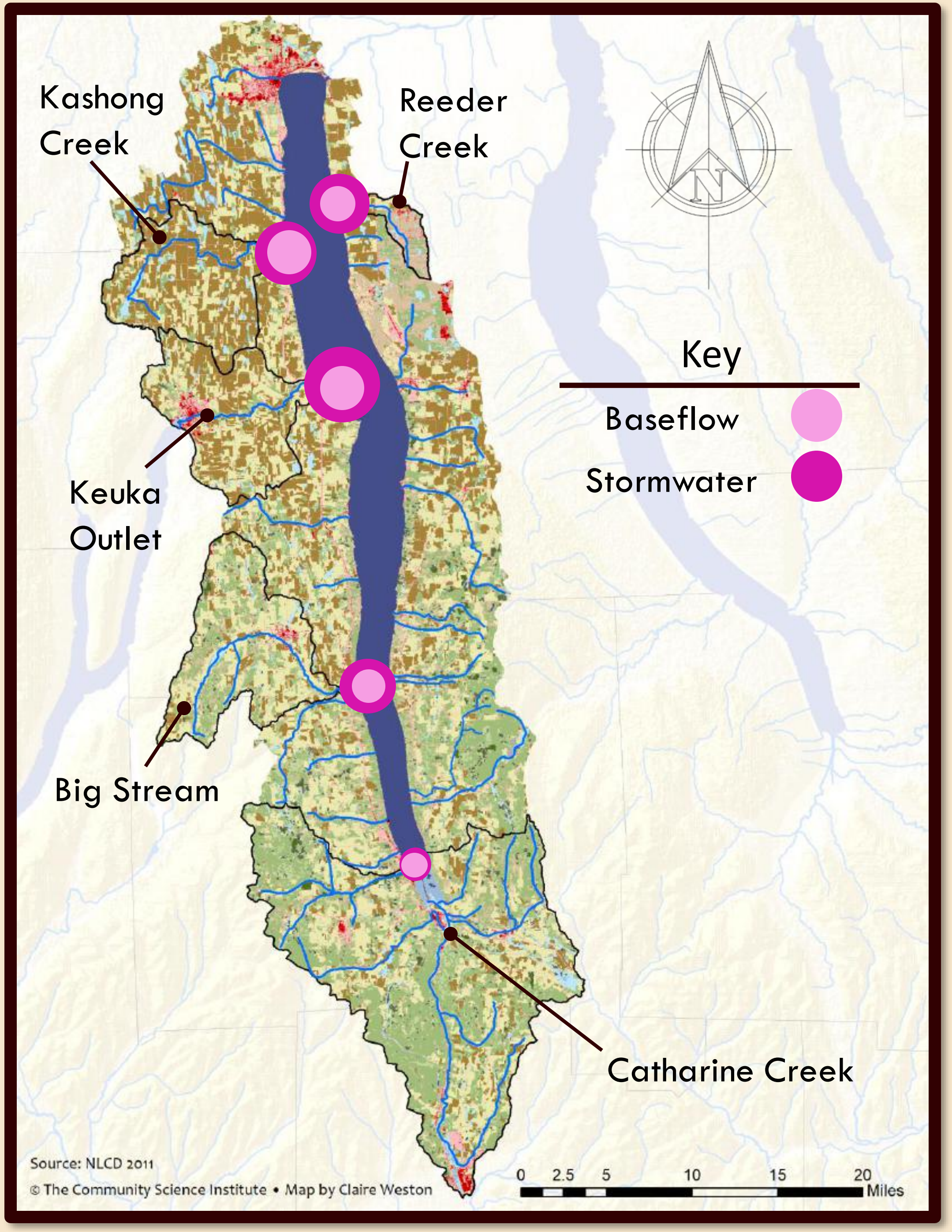


What is "Particulate Phosphorus?"

- "Particulate phosphorus" is the phosphorus associated with particles that do not pass through a fine (0.45 micron) filter
- Particulate phosphorus is calculated as the difference between two measured quantities: Total phosphorus, which includes dissolved and particulate phosphorus, and dissolved phosphorus:
  - Particulate P = Total P – Dissolved P
- High particulate phosphorus is generally correlated with high concentrations of suspended soil and sediment at high flows, e.g., in Big Stream and Keuka Outlet
- Particulate P is mostly stored in lake sediments and is believed to have only a small degree of bioavailability compared to dissolved P

Average Total Nitrogen Concentrations Measured at Stream Mouths (NOx + Total Kjeldahl Nitrogen)

Stream (North to South)	Average Total Nitrogen, Base Flow (mg/L)	Average Total Nitrogen, Stormwater (mg/L)
Reeder Creek	1.73	4.74
Kashong Creek	2.47	5.11
Keuka Outlet	2.47	7.39
Big Stream	1.55	4.09
Catharine Creek	0.84	1.40



General Comparison Between Total Nitrogen in Seneca Lake Streams and Cayuga Lake Streams

- Total nitrogen is the sum of inorganic nitrogen including nitrate (NO_3) and nitrite (NO_2); ammonia (NH_4); and organic nitrogen, mainly protein (N_{org})
- Main source of inorganic nitrogen is fertilizer; main sources of organic nitrogen and ammonia are animal waste and decaying plant matter
- Base flow: Total N concentrations are similar, 1.8 mg/L in five monitored Seneca Lake streams and 2.0 mg/L in five Cayuga Lake streams
- Stormwater: Average total N concentration increases to 4.5 mg/L in monitored Seneca Lake streams, somewhat more than the increase to 3.5 mg/L in five Cayuga Lake streams

Nutrient concentrations are great to know. So are loads. Why?

- A load is the actual amount, or mass, of a pollutant that enters a waterbody such as Seneca Lake
- For non-point source pollutants, the load depends on pollutant concentration and the size of the stream
- Having the data that's needed to estimate loads makes it possible to prioritize streams, and catchment areas within a stream's watershed, for pollutant reduction efforts
- A load reduction strategy called "Total Maximum Daily Load" (TMDL) is incorporated into the Clean Water Act

To Calculate Load: Combine Nutrient Concentrations with USGS Flow Measurements

Nutrient Load = Nutrient Concentration x Stream Flow

= [Nutrient] (ug/L or mg/L) x [Flow] (cfs)

Transform units and calculate load in tons/year

- **Concentrations** are measured in CSI's certified lab (ELAP# 11790) on samples collected by trained volunteers
- **Flows** are measured by USGS gauging station, if there is one
- **Flows are estimated** using drainage area ratio, if there isn't
  - Estimate assumes flow is proportional to drainage area
- **Concentrations and flows are needed to calibrate Loadest software**

Calculating Loads When Flows Are Measured or Can Be Reasonably Extrapolated From USGS Gauging Station Measurements

Simple step-by-step description of LOADEST Load Estimation Methodology

Step	Description	More Info
1	Download Phosphorus concentration data from CSI Website	Website
2	Download daily average and instantaneous flow data from USGS website	Website
3	Download Latest LOADEST version (2013) and documentation	Website
4	Calculate watershed area at CSI monitoring location - StreamStats	Website
5	Estimate flows at CSI monitoring site using watershed are ratio method	
6	Create Calib file for each analyte (SRP and TP) including instantaneaous flow estimations and CSI concentration data	TP_Calib!A1
7	Create Est file using daily average flow data	
8	Run LOADEST for Model 1 and using model auto-select option	
9	Select model with best model fit stats for a given analyte and watershed	Model Fit'!A1
10	Obtain load results from LOADEST for each parameter for selected model	Load_Results!A1
11	Sum loads over water years to get final yearly load numbers	Yearly Totals'!A1
12	Optional step: determine days with significant stormwater flow in order to estimate loads occurning during stormwater events versus days with base flow.	Online baseflow separation tool

LOADEST Documentation

Runkel, R.L., Crawford, C.G., and Cohn, T.A., 2004, Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p.

Predicting Nutrient Loading When Flows Cannot Be Reasonably Extrapolated From Gauged Streams

- There are no USGS gauging stations providing continuous flow measurements on any Seneca Lake tributary stream
- Nevertheless, nutrient loading from monitored streams to Seneca Lake can be predicted to a reasonable degree of approximation if it is assumed that:
  1. Load is proportional to a stream's drainage area
  2. Load is proportional to stormwater nutrient concentrations
  3. Load can be indexed to loading from a reference stream

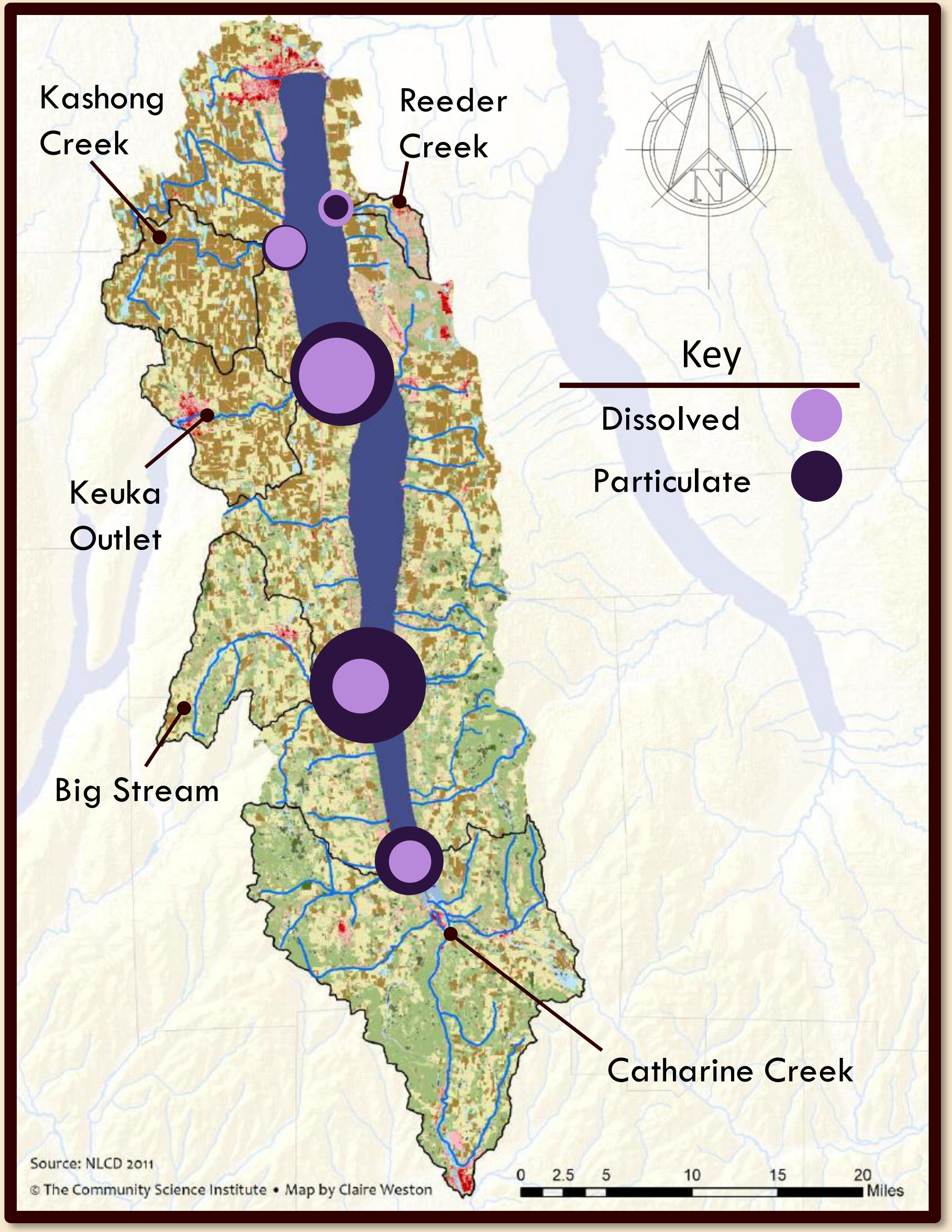
Reference stream: Fall Creek in Cayuga Lake watershed, which has USGS gauging station. Drainage area is 129 mi^2, average stormwater dissolved P at mouth = 25 ug/L, and dissolved P loading to Cayuga Lake = 4.34 tons/year (3-year average)

Test of prediction approach to estimating loads: Predicted P loads averaged 95 % +/- 18% of calculated P loads for five (5) Cayuga Lake streams

Example prediction for a Seneca Lake stream: Dissolved P loading from the Keuka Outlet = 4.34 tons/year x (31.7 mi^2/129 mi^2) x (176.5 ug/L/25.06 ug/L) = 7.51 tons/year

Prediction of Dissolved and Particulate Phosphorus Loading to Seneca Lake (tons/year)

Monitored Sub-watersheds ($226\ mi^2$)	Drainage Area (mi^2)	~ Dissolved Phosphorus (tons/year)	~ Particulate Phosphorus (tons/year))
Reeder Creek	4.9	1.68	0.78
Kashong Creek	30.7	2.15	2.75
Keuka Outlet	31.7	7.51	13.59
Big Stream	37.1	4.10	17.70
Catharine Creek	121.6	2.40	6.36
Seneca Lake Watershed	**470.8**	**37.1**	**85.7**
Cayuga Lake Watershed	***794.0***	***41.0***	***76.6***



Seneca Lake Tributary Streams: Conclusions

- Total nitrogen concentrations are elevated in predominantly agricultural areas, similar to Cayuga Lake streams
- E. coli counts are above the recreational limit at base flow, similar to many Cayuga Lake streams. But there are extraordinary rises in E. coli counts at high flows, by a factor of as much as 100
- Dissolved (mostly bioavailable) phosphorus concentrations average roughly 2x to 3x higher in Seneca Lake streams than in Cayuga Lake streams
- The Seneca Lake watershed loads (exports) a ~50% greater mass of dissolved phosphorus per square mile to Seneca Lake than the Cayuga Lake watershed loads to Cayuga Lake

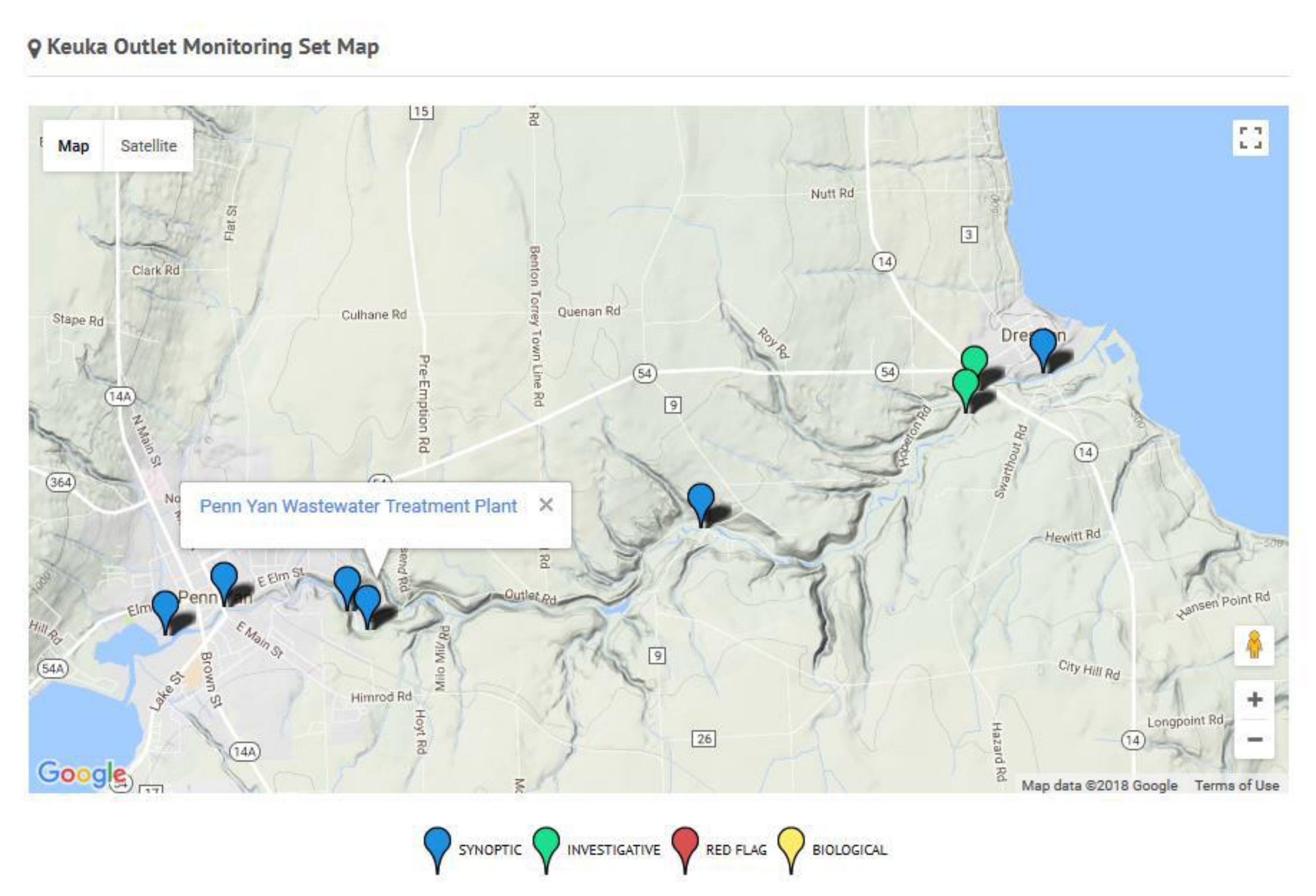
Implications for Risks from Pathogenic Bacteria and HABs in Seneca Lake

- High E. coli counts point to the presence of significant sources of untreated animal and/or human waste that is readily mobilized in runoff
  - High counts indicate health risks from swimming in streams
  - Recommend checking E. coli counts in Seneca Lake
- High phosphorus levels are broadly correlated with increased HABs in freshwater lakes
  - Shoreline concentrations of dissolved P are likely to be elevated near the mouths of many streams
- Average Nitrogen : Phosphorus > 26:1at stream mouths except:
  a) Reeder Creek at base flow (high dissolved P)
  b) Keuka Outlet and Big Stream at high flow (high particulate P)
- Near shore HABs are probably phosphorus-limited except possibly near Reeder, where HABs may be nitrogen-limited

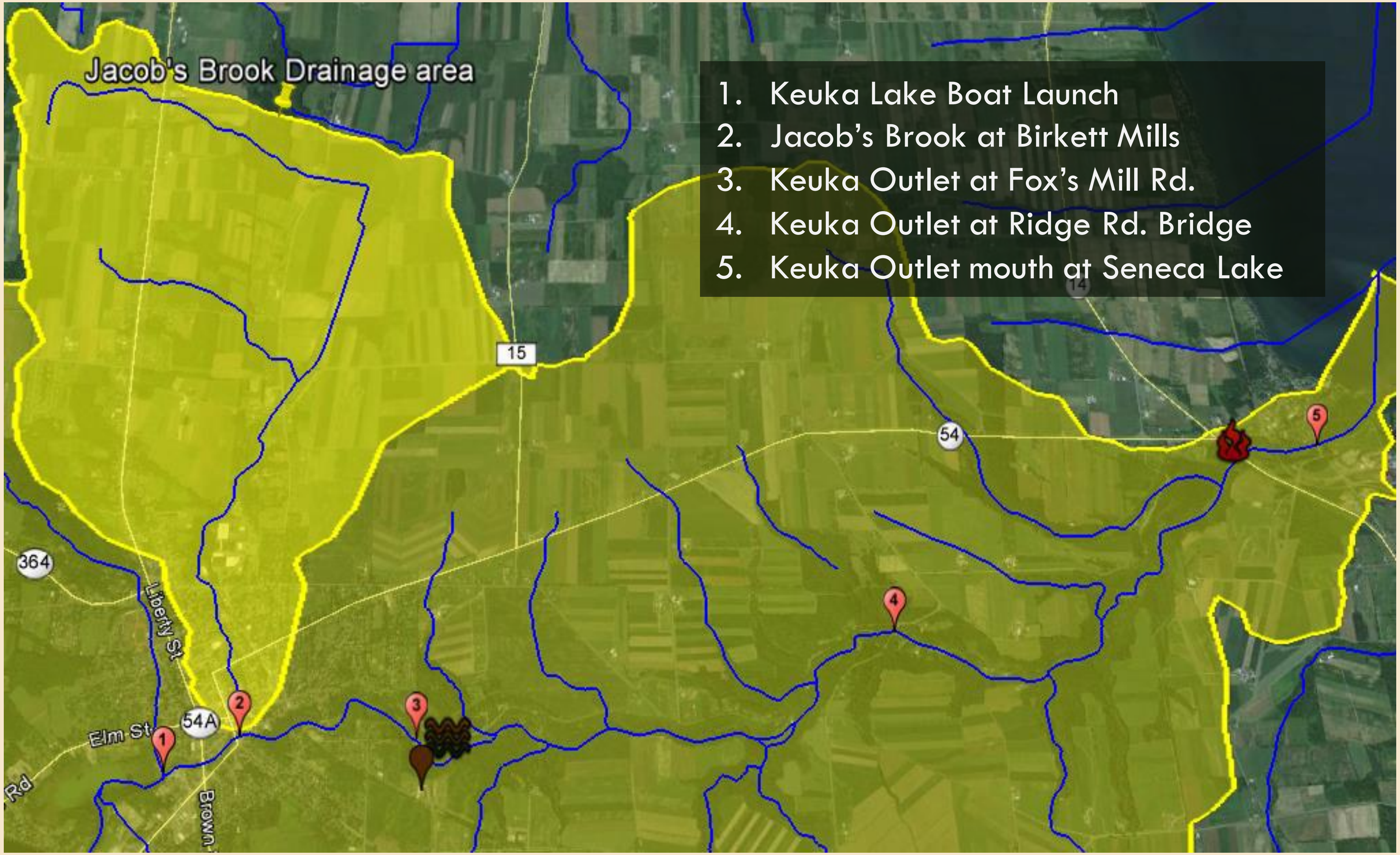
Bonus Slides: Investigating Agriculture and Penn Yan WWTP as Pollutant Sources in the Keuka Outlet Watershed

- E. coli and dissolved P exhibit similar concentration profiles upstream to downstream across the Keuka Outlet watershed
  - There is a spike at the mouth of Jakob's Brook; a decrease at Fox's Mills due to dilution; then a steady rise beginning downstream of the WWTP and continuing for the remaining ~3/4 of the length of the Outlet
- The Penn Yan WWTP may explain some of the small downstream increases in E. coli and dissolved P at base flow
- Agricultural land use is the logical explanation for high stormwater E. coli and phosphorus, both upstream of the WWTP at Jakob's Brook and downstream all the way to Seneca Lake
  - If downstream E. coli and phosphorus were from WWTP, dilution should cause them to decrease

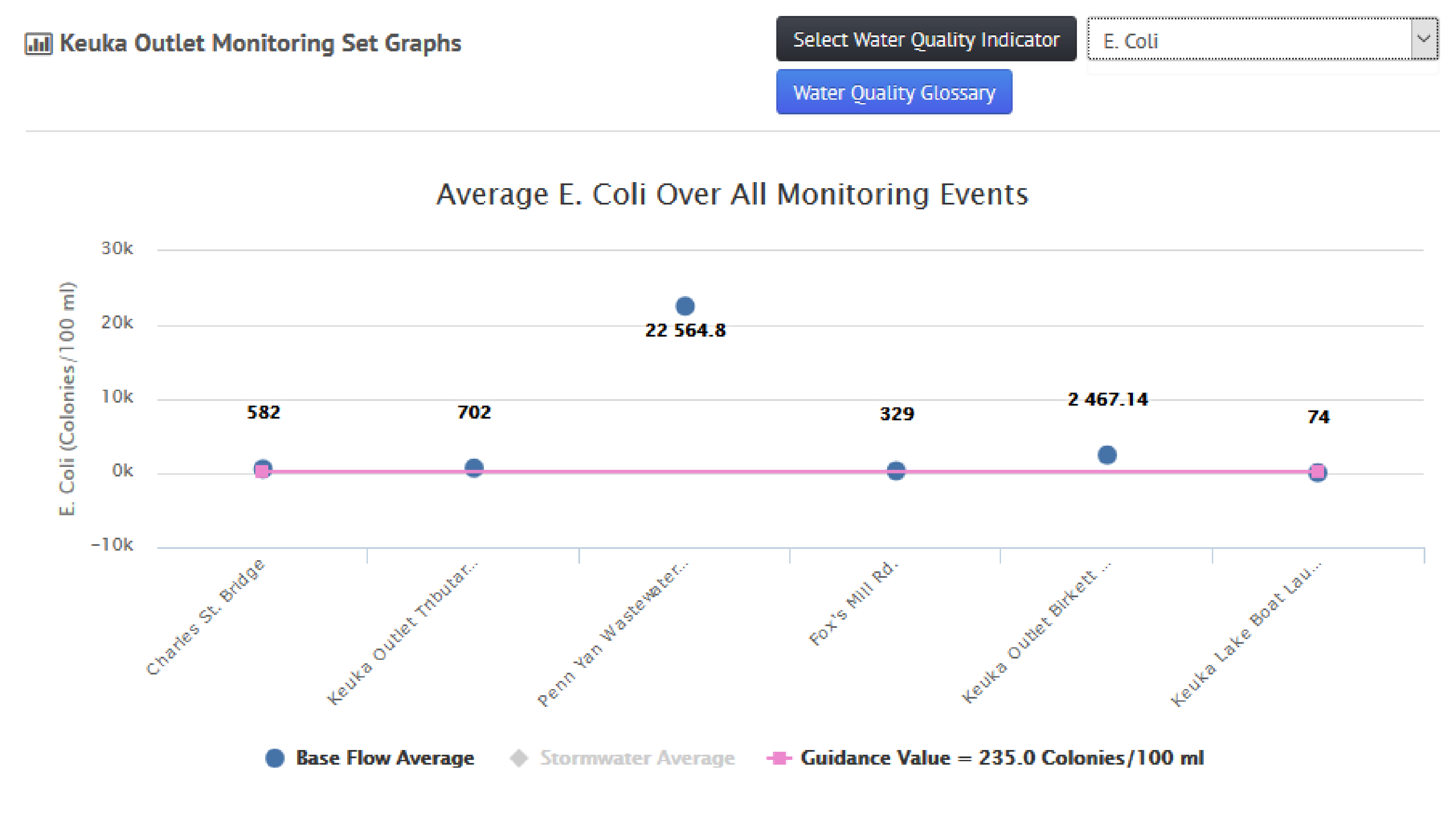
Monitoring Locations on Keuka Outlet



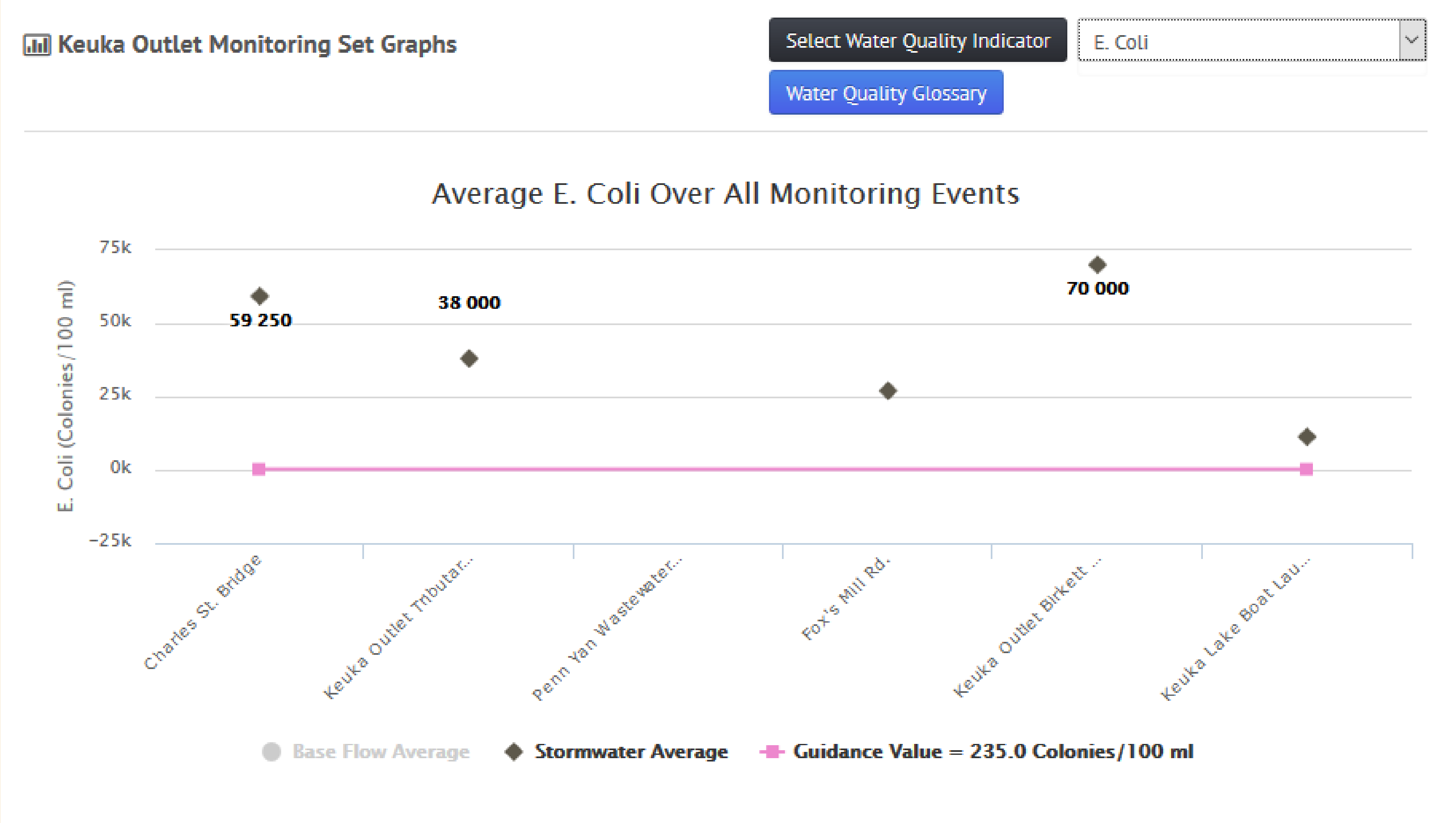
Keuka Outlet and Jacob's Brook Drainage Areas



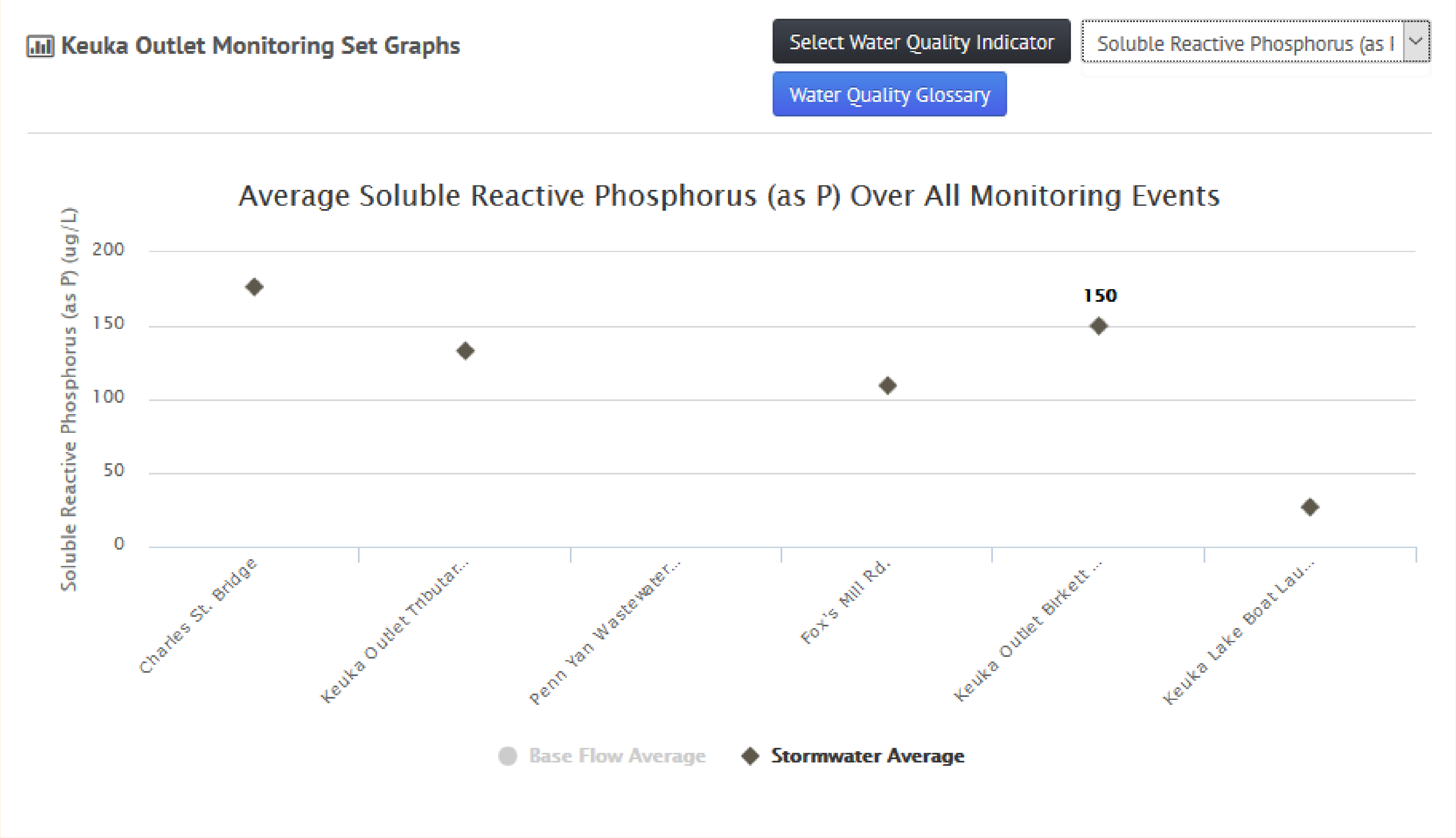
Base flow E. Coli is highest at Jakob's Brook and in WWTP effluent (note reverse order of locations on graphs compared to maps)



Stormwater E. Coli peaks at Jakob's Brook, falls due to dilution, then rises post-WWTP and downstream agricultural areas



Stormwater phosphorus peaks at Jakob's Brook, falls due to dilution, then rises post-WWTP and downstream agricultural areas



Acknowledgements

- Sample collection in fair weather and foul: *Seneca Lake Pure Waters Association*
- Accurate laboratory analyses: *Michi Schulenberg, Noah Mark, Laura Dwyer*
- Graphs and slides: *Claire Weston*
- Database: Abner Figueroa