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EPA Tools and Resources Webinar: Advances in Environmental Monitoring–Water Sensors

WATER SENSORS TOOLBOX

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US EPA Office of Research and Development (ORD)

March 16, 2022

CYAN
CYANOBACTERIA
ASSESSMENT
NETWORK

Presentation Outline

- Introducing [EPA's Water Sensor Toolbox]
- Remote Sensing: EPA's Participation in the Cyanobacteria Assessment Network
- Case Studies to evaluate the potential for using sensors to monitor source water quality with regard to nutrients, algae, and disinfectant byproducts

Background

- The demand for more frequent, lower cost monitoring approaches for water is increasing and will be important as EPA works to respond to existing and new challenges in managing water quality
- Sensors are playing an increasing important role in the monitoring of water quality. EPA ORD has several efforts aimed at the development and use of sensors
- These efforts are all aimed at providing data and tools to support utilities and water quality managers

United States Environmental Protection Agency

EPA’s New Water Sensors Toolbox

https://www.epa.gov/water-research/water-sensors-toolbox

WATER SENSORS TOOLBOX

What is in the Water Sensors Toolbox?

- Uses and Applications
  - Uses for Water Sensors
  - Applications of Water Sensors
- Development to Evaluation
  - Water Sensor Development
  - Interpreting and Evaluating Water Sensor Data
  - Supporting Technology and Data Management of Water Sensors
  - Water Sensors Performance Evaluations

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Water Sensors Toolbox

This toolkit is a collection of resources and information related to EPA research that uses, evaluates, and/or develops water sensors—including remote sensors and related data management technology. These resources may be useful to students, researchers, citizen scientists, water quality decision makers, or others interested in collecting data on water quality with the use of water sensors.

Water sensors can be used both for drinking water and environmental applications. Because those applications often overlap, they are presented together in this toolkit. Where the distinction is important, it has been noted.

On this Page
- Uses and Applications
- Development to Evaluation
- How EPA is Using Water Sensors
- Publications and Presentations
- Additional Resources

Uses and Applications

Uses for Water Sensors:
- Monitoring water quality
- Detecting contaminants
- Monitoring septic systems for discharges
- Measuring levels of nutrients in surface waters
- Detecting chlorophyll *a*, which can in turn be used for predictions (e.g., harmful algal blooms and/or cyanotoxins in watersheds)
- Measuring the use and effectiveness of wastewater and drinking water treatment
- Monitoring distribution systems

Applications of Water Sensors:
- Measuring water quality parameters, such as pH, water temperature, conductivity, dissolved oxygen, and turbidity.
- Monitoring for contaminants, such as cyanobacteria and cyanotoxins, chlorophyll and algae, nutrients (i.e., nitrogen and phosphorus) and nutrient species (e.g., ammonia, nitrite, nitrate, orthophosphate, total nitrogen, total phosphorous), arsenic, bromine, calcium, magnesium, and chloride.
- Help describe physical characteristics of water, such as water presence/absence, water level, and discharge.

WATER SENSORS TOOLBOX

Development to Evaluation

Water Sensor Development:
- While EPA's focus is on using available sensors, there is some work aimed at developing sensors for specific contaminants, such as for arsenic detection. (Report: A disposable acetylcholine esterase sensor for As(iii) determination in groundwater matrix based on 4-acetoxyphenol hydrolysis. Analytical Methods.)
- EPA encourages inventors and entrepreneurs to develop needed sensors through Challenges. A recent example includes the development of nutrient sensors. View a complete list of EPA Challenges.

Invites and Updates

Research Webinar Series Invites
Receive emails for upcoming webinars

Science Matters Newsletter
Stay current with EPA research

Interpreting and Evaluating Water Sensor Data:

As the number of water sensors increase, EPA is working to better understand the capabilities and limitations of water sensors. Below are documents and information on water sensors and their use:
- Online Water Quality Monitoring Resources. Online instruments for real-time water quality measurement in source waters and/or distribution systems. These

WATER SENSORS TOOLBOX

What is in the Water Sensors Toolbox?

- Development to Evaluation
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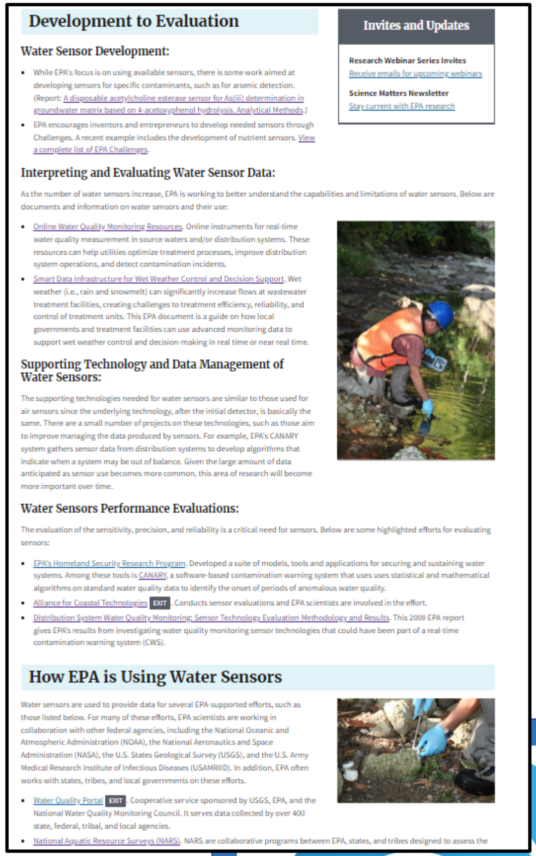
  - Supporting Technology and Data Management of Water Sensors
  - Water Sensors Performance Evaluations
- How EPA is Using Water Sensors
- Research Publications and Presentations
  - Publication Highlights
- Additional Resources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As the number of water sensors increase, EPA is working to better understand the capabilities and limitations of water sensors. Below are documents and information on water sensors and their use:

- Online Water Quality Monitoring Resources. Online instruments for real-time water quality measurement in source waters and/or distribution systems. These resources can help utilities optimize treatment processes, improve distribution system operations, and detect contamination incidents.
- Smart Data Infrastructure for Wet Weather Control and Decision Support. Wet weather (i.e., rain and snowmelt) can significantly increase flows at wastewater treatment facilities, creating challenges to treatment efficiency, reliability, and control of treatment units. This EPA document is a guide on how local governments and treatment facilities can use advanced monitoring data to support wet weather control and decision-making in real time or near real time.

Supporting Technology and Data Management of Water Sensors:

The supporting technologies needed for water sensors are similar to those used for air sensors since the underlying technology, after the initial detector, is basically the same. There are a small number of projects on these technologies, such as those aim to improve managing the data produced by sensors. For example, EPA's CANARY system gathers sensor data from distribution systems to develop algorithms that indicate when a system may be out of balance. Given the large amount of data anticipated as sensor use becomes more common, this area of research will become more important over time.

Water Sensors Performance Evaluations:

The evaluation of the sensitivity, precision, and reliability is a critical need for sensors. Below are some highlighted efforts for evaluating sensors:

- EPA's Homeland Security Research Program. Developed a suite of models, tools and applications for securing and sustaining water systems. Among these tools is CANARY, a software-based contamination warning system that uses uses statistical and mathematical algorithms on standard water quality data to identify the onset of periods of anomalous water quality.
- Alliance for Coastal Technologies EXIT. Conducts sensor evaluations and EPA scientists are involved in the effort.
- Distribution System Water Quality Monitoring: Sensor Technology Evaluation Methodology and Results. This 2009 EPA report gives EPA's results from investigating water quality monitoring sensor technologies that could have been part of a real-time contamination warning system (CWS).

How EPA is Using Water Sensors

Water sensors are used to provide data for several EPA-supported efforts, such as those listed below. For many of these efforts, EPA scientists are working in collaboration with other federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the U.S. States Geological Survey (USGS), and the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID). In addition, EPA often works with states, tribes, and local governments on these efforts.

- Water Quality Portal EXIT. Cooperative service sponsored by USGS, EPA, and the National Water Quality Monitoring Council. It serves data collected by over 400 state, federal, tribal, and local agencies.
- National Aquatic Resource Surveys (NARS). NARS are collaborative programs between EPA, states, and tribes designed to assess the

WATER SENSORS TOOLBOX

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CYAN CYANOBACTERIA ASSESSMENT NETWORK

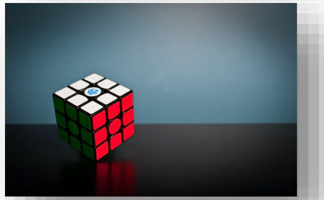
Cyanobacteria Assessment Network (CyAN)

Context

- ***Problem:*** Limited resources with broad spatial and temporal scales

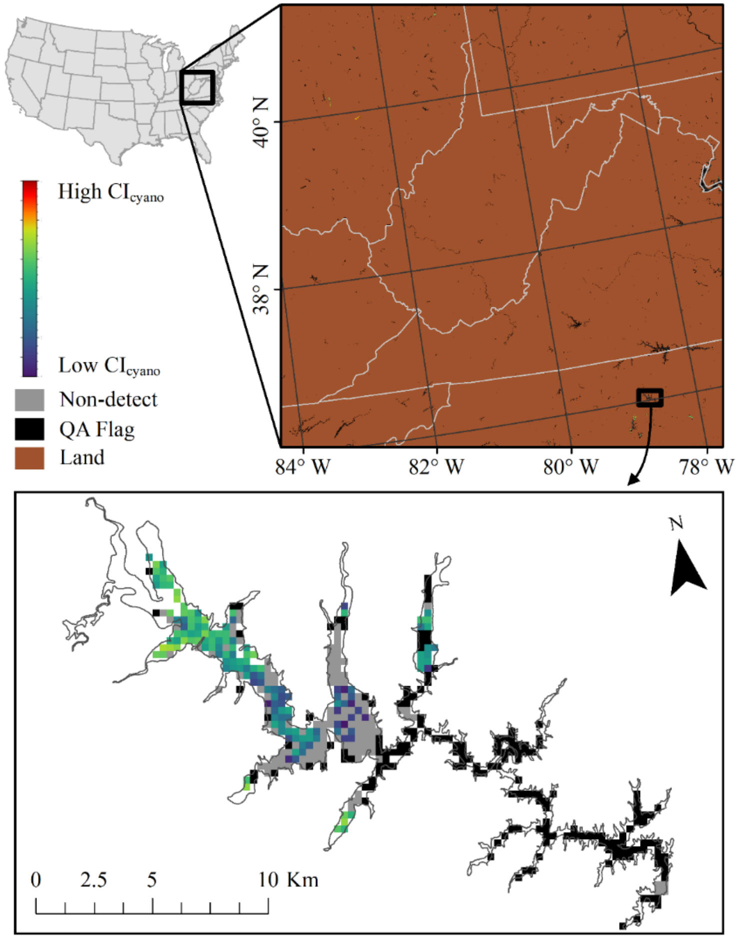
- ***Action***: Satellite technologies complement traditional field measures

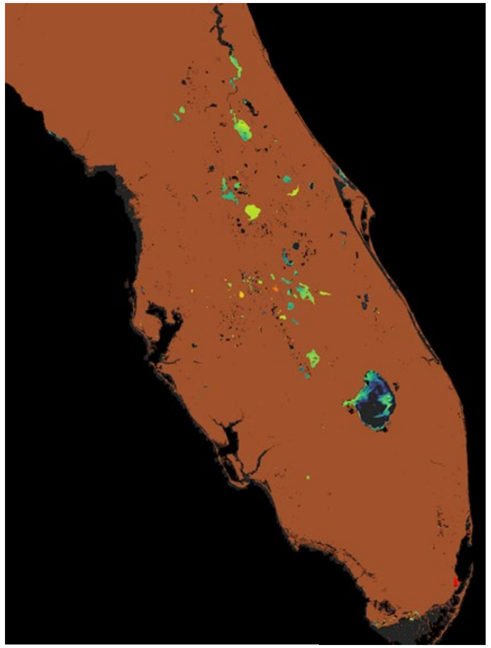
- ***Results***: Earlier response and informed decision making



- ***Impact***: Save money and protect humans, animals and the environment

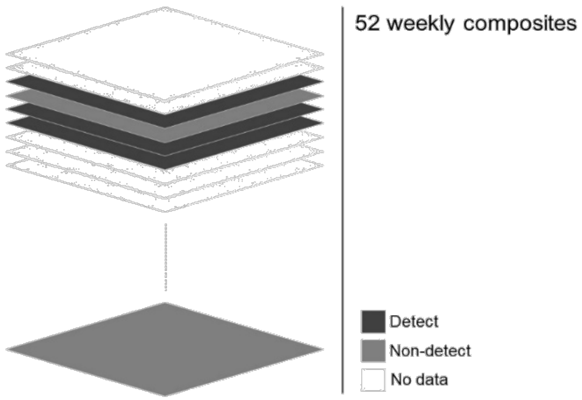
Near real-time detection of cyanobacteria





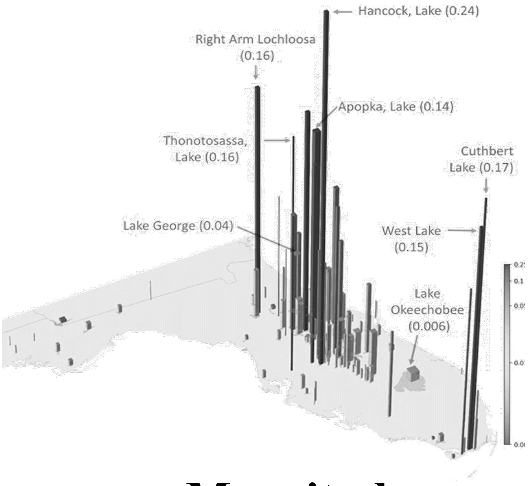
CyAN produces daily true color images and algorithm detections of cyanobacteria biomass

Cyanobacteria Metrics

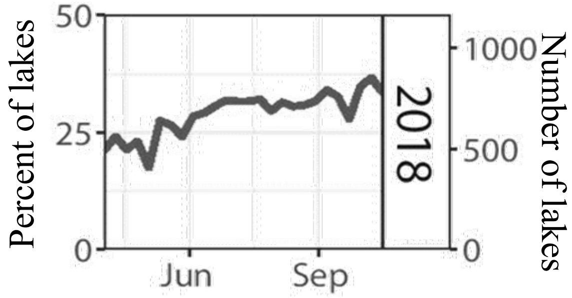


Temporal Frequency

Spatial Extent



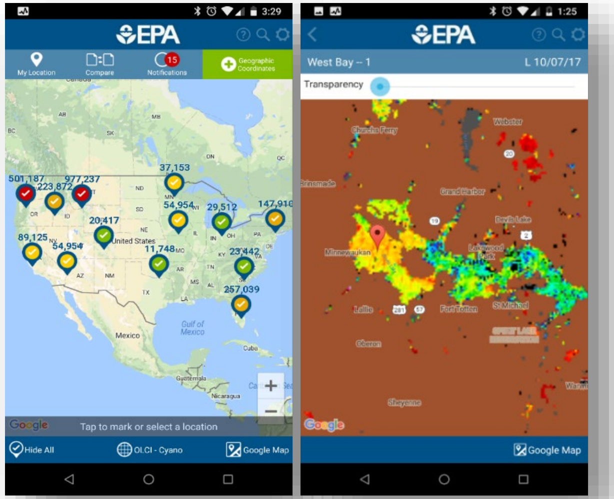
Magnitude

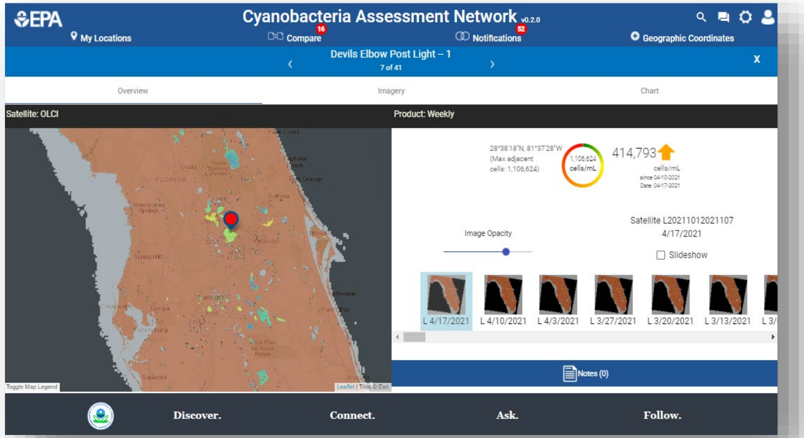


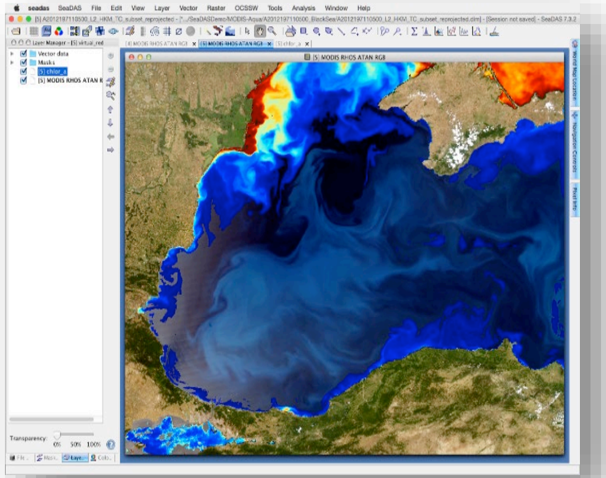
Occurrence

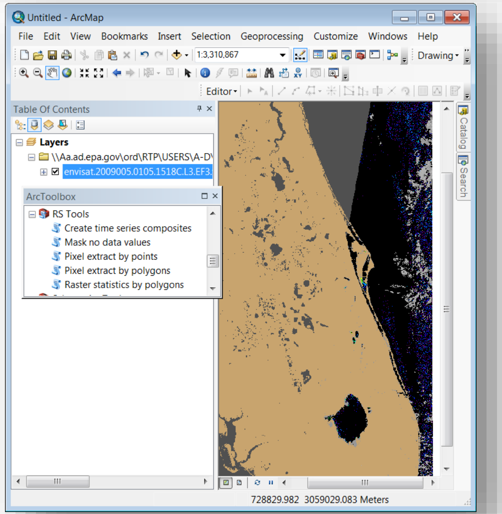
CyAN developed four metrics to quantify cyanobacteria biomass

Visualization and Analysis Software









CyAN developed four software options to analyze the satellite data

Impacts of CyAN

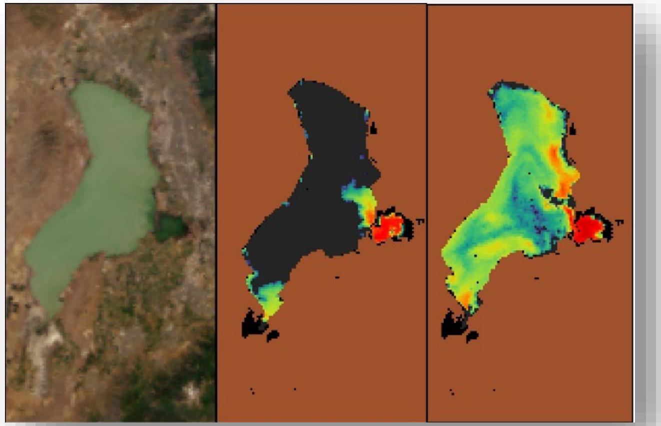
WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY

Wyoming Department of Environmental Quality | view as a webpage

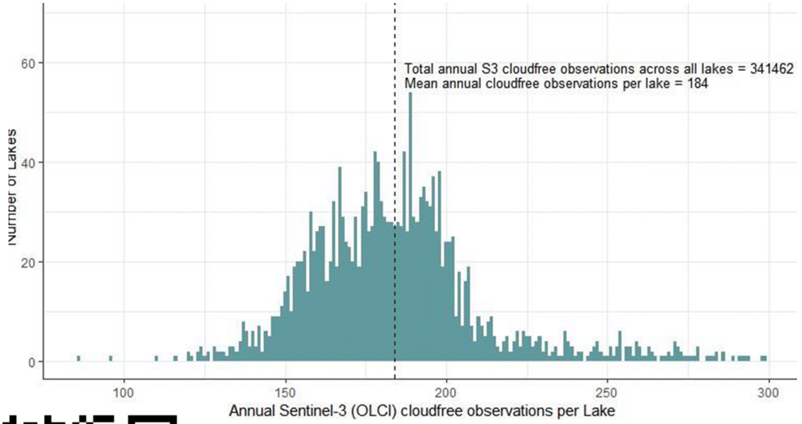
Harmful Cyanobacterial Bloom (HCB) Recreational Use Advisories: Big Sandy, Eden, Lower North Crow, Pathfinder, and Woodruff Narrows Reservoirs

The Wyoming Department of Health has issued recreational use advisories…

Potential blooms were identified by satellite imagery from the Cyanobacteria Assessment Network (CyAN) or reported to the Wyoming Department of Environmental Quality.



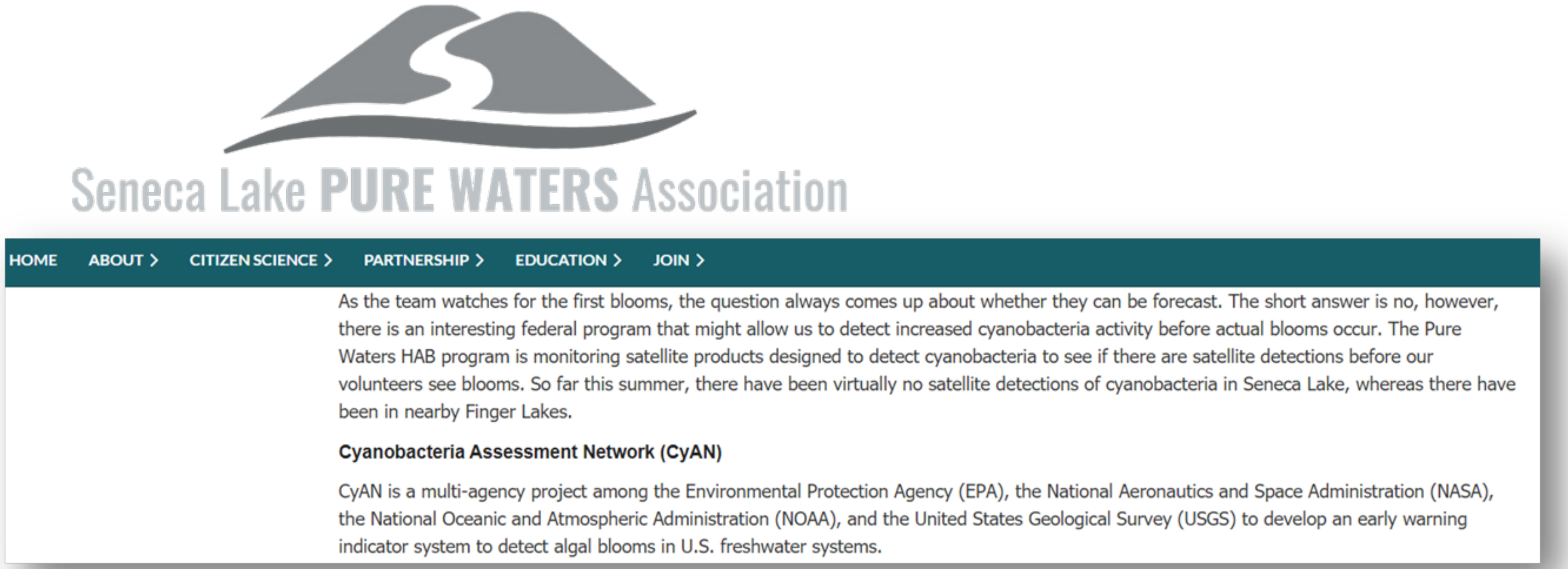
Improving human health outcomes ~$370,000



Annual potential avoided costs ~$5.7 million/year

CyAN tracked impacts through recreational advisories and quantifying economic value

Impacts of CyAN

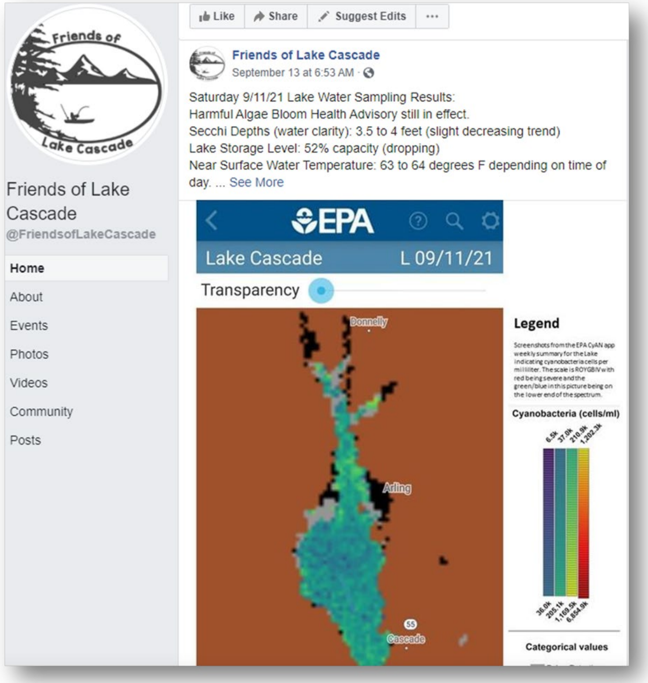

Seneca Lake PURE WATERS Association

HOME ABOUT › CITIZEN SCIENCE › PARTNERSHIP › EDUCATION › JOIN ›

As the team watches for the first blooms, the question always comes up about whether they can be forecast. The short answer is no, however, there is an interesting federal program that might allow us to detect increased cyanobacteria activity before actual blooms occur. The Pure Waters HAB program is monitoring satellite products designed to detect cyanobacteria to see if there are satellite detections before our volunteers see blooms. So far this summer, there have been virtually no satellite detections of cyanobacteria in Seneca Lake, whereas there have been in nearby Finger Lakes.

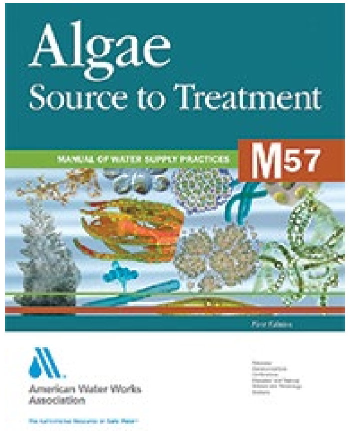
Cyanobacteria Assessment Network (CyAN)

CyAN is a multi-agency project among the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS) to develop an early warning indicator system to detect algal blooms in U.S. freshwater systems.

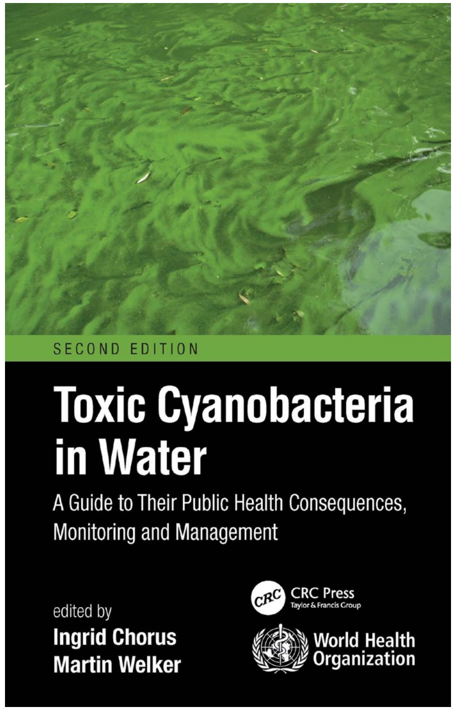


CyAN puts the power of satellite data in the hands of local lake associations

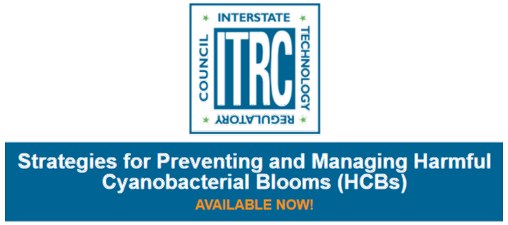
Impacts of CyAN



In Review:
Quantification
through Remote
Sensing



Chapter 11



Monitoring
Section

CyAN demonstration of satellite data has been incorporated into national and international recommendations

Case Studies and Applications

Problem

- The quality of source water is a significant parameter to consider in determining drinking water treatment and for spill detection

Sensors

- Water sensors provide real-time data to capture short term source water quality changes that compliment water treatment plant laboratory grab sample analyses

- Sensors can be used to provide real-time data on spills, allowing plant operators to make decisions on water sources and informing communities

- Sensor and grab sample data provide information to make and adjust treatment operations to provide safe drinking water to communities

Applications of Water Sensor Measurements

- Upstream discharge surveys
- **Upstream of intake – spill detection**
- **Intake or raw water – spill detection, algae, and water quality changes that impact treatment**
- Monitoring in plant treatment processes
- **Finished water – disinfection byproducts, turbidity**
- Distribution system - Online Water Quality Monitoring in
- Distribution Systems
- Case studies
  - Ohio treatment plant Intake in an impoundment reservoir
  - North Carolina treatment plant intake on a river
  - New sensor techniques and data analysis methods

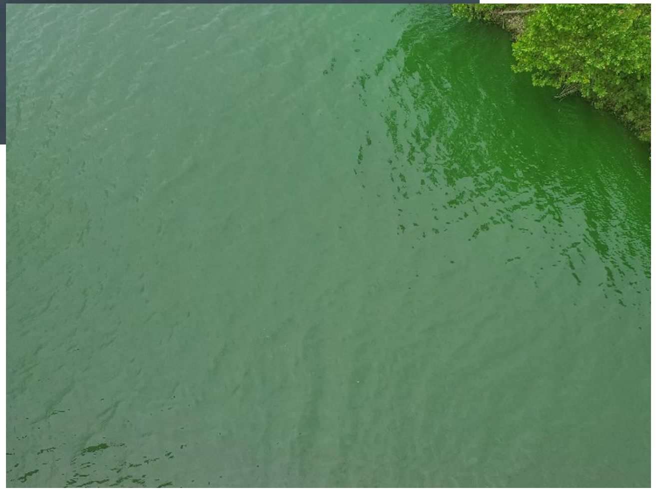
Ohio Drinking Water Treatment Plant on reservoir

Problem:

- Drinking water (DW) intake structure, located in southwestern Ohio, constructed for flood control, recreation and DW
- Elevated levels of algae due to nutrients

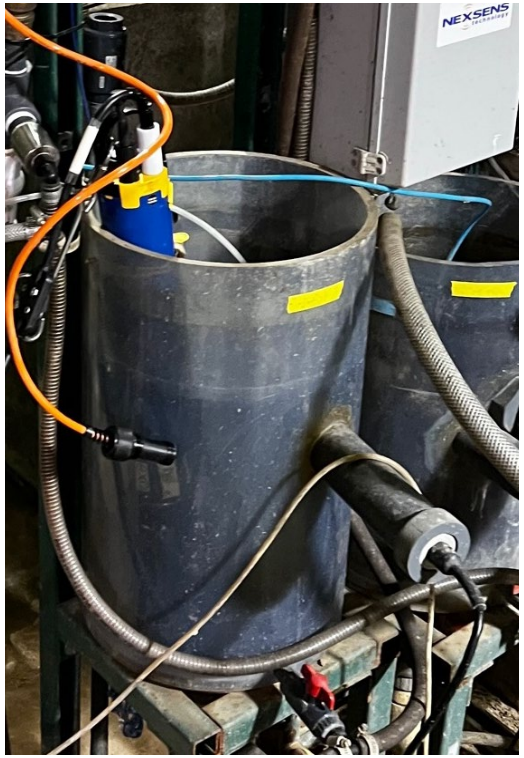
Approach:

- Implement water sensors at DW intake, in conjunction with a wider watershed project



Approach: Suite of Sensors deployed inside Ohio DW intake structure

- Pictured are:
  - Systea WIZ Nitrate, Nitrite, Phosphate
  - YSI EXO2 with CDT, ODO, chlorophyl, phycocyanin, and NitraLED probes
  - s::can
  - Sea-Bird SUNA V2 Nitrate/Nitrogen
  - Trios Nico Nitrate/Nitrogen
- Deployment
  - The WIZ draws from the chamber using internal pumps
  - The EXO2 and s::can are in a chamber
  - The SUNA and Nico are using flow cells
  - All use the same, 8 meter deep intake



Approach: Algae grab sample analysis and short-term precipitation in Ohio site

- Handheld Turner Designs- CyanoFluor Handheld HAB Indicator
- NexSens Tipping bucket rain gauge

Results: WIZ Chemistry (Ohio location)

Uses standard wet chemistry colorimetric techniques

Results in reliable data in appropriate data ranges

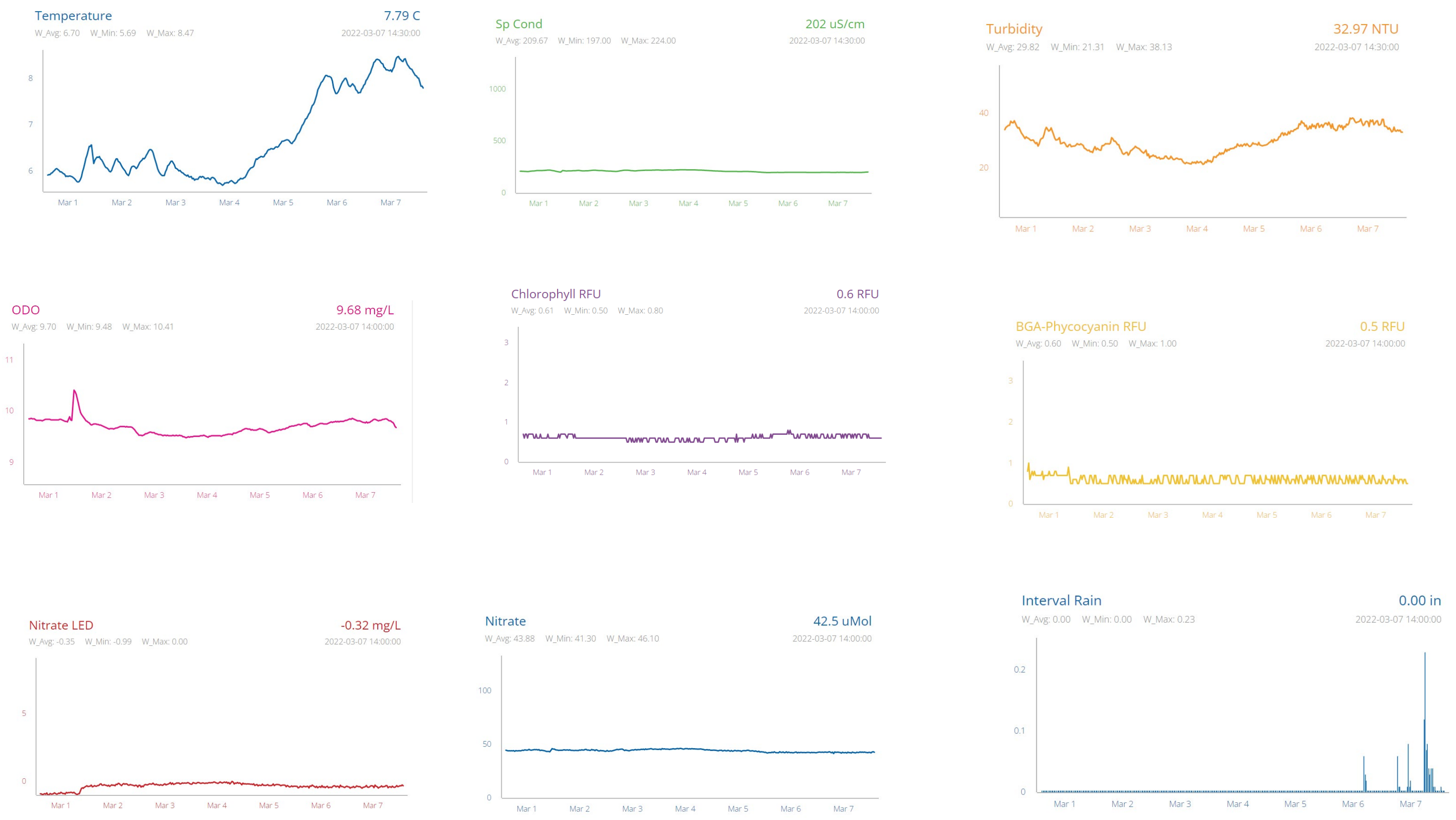
NO_2 as N range 0-250 ug/L
NO_3 as N range 0-50 mg/L
PO_4 as P range 2-2000 ug/L

United States Environmental Protection Agency

Results: Ohio Sensor Data Output

Sensors displaying relatively stable parameters prior to spring turn over

Temperature (top left graph) increased toward the end of the week with a subsequent rain event (bottom right)



Impact

DW utility indicates that this information is useful in maintaining situational awareness of the influent water quality

NC Drinking Water Treatment Plant on river

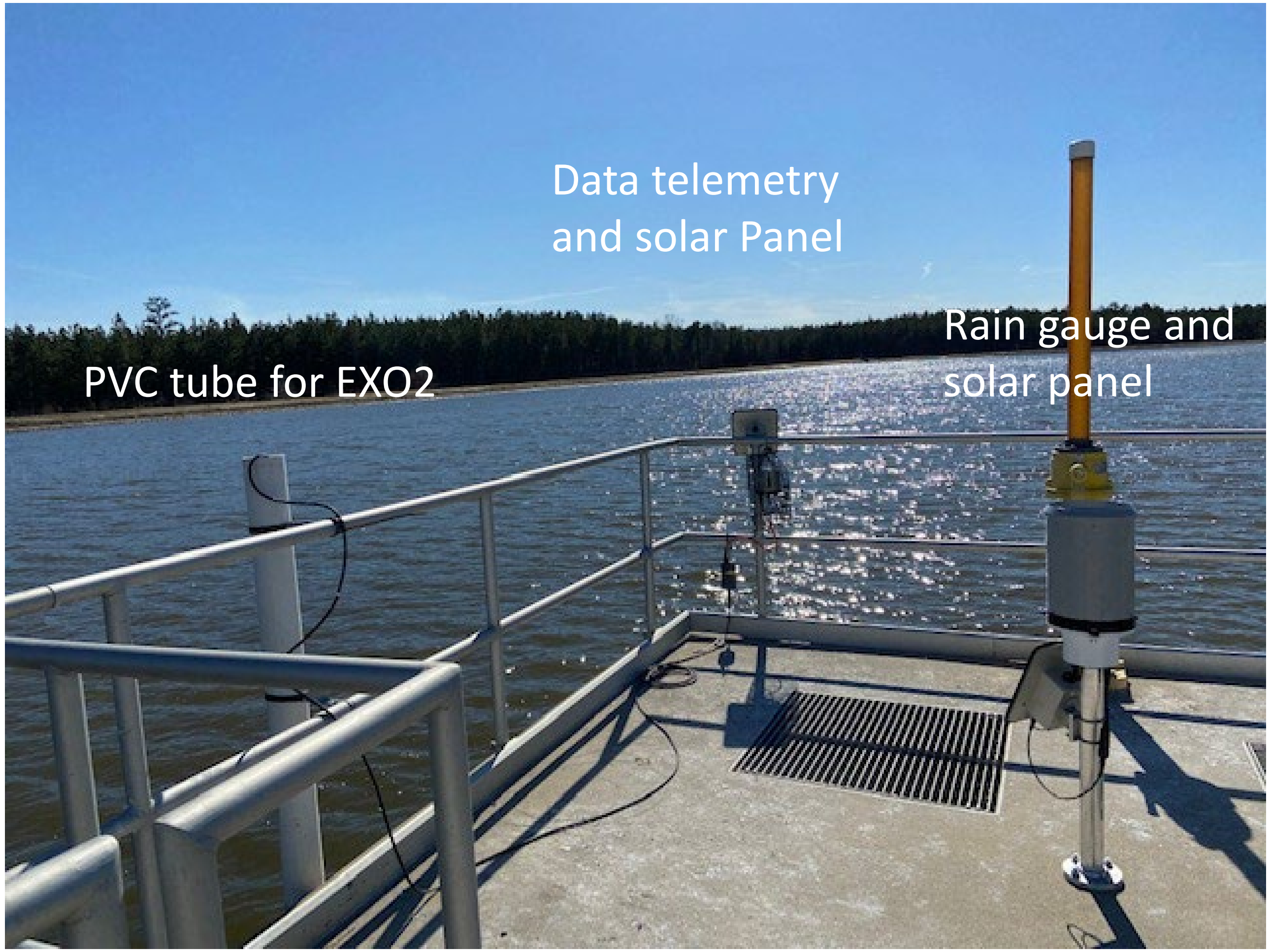
Problem:

- Source water is the Cape Fear River
- Upstream bromide sources leading to brominated disinfection byproducts, elevated algae levels, and industrial sources near plant intake

Approach:

- Implement sensors near the plant intake

Approach: Sensors at the NC DW Treatment Plant reservoir



Approach: Sensors deployed at NC reservoir

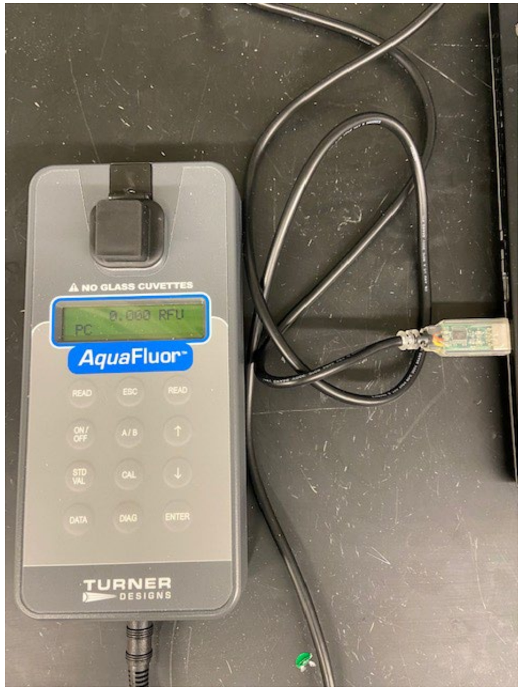
Multiparameter sensor with built in GPS

River source water survey for evaluating potential discharges

Evaluating reservoir algae & dissolved oxygen spatial concentrations and depth profiles

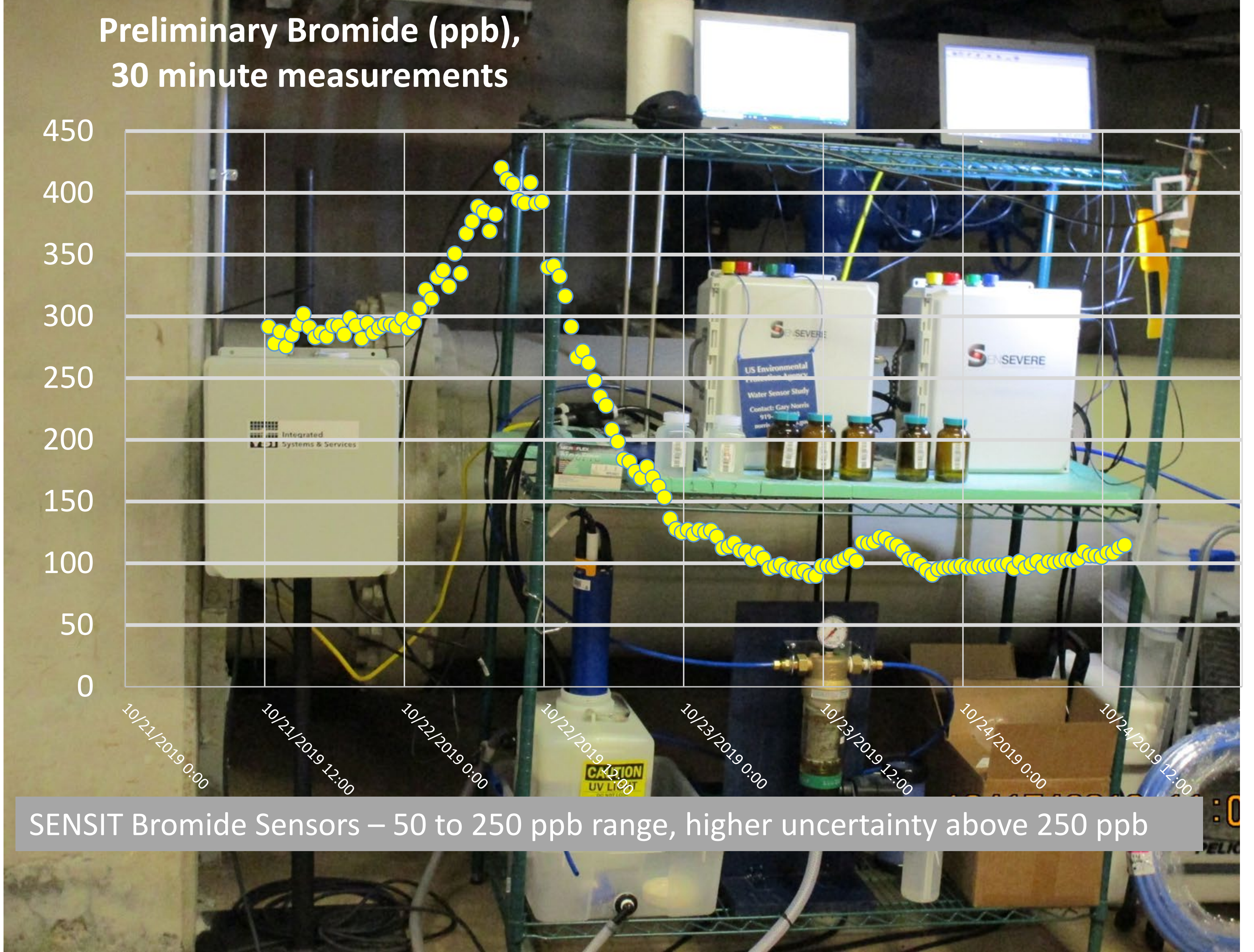
Algae fluorometer for grab sample analysis

- Chlorophyll
- Phycocyanin



Results

Sensors are providing live streaming data to plant operators



SENSIT Bromide Sensors – 50 to 250 ppb range, higher uncertainty above 250 ppb

Approach: Sensors for NC finished water

spectro::lyser V3; UV-Vis detector (190-750 nm)

- Turbidity (NTU or FTU) parameter
- Total Organic Carbon (TOC & DOC) parameter
- Single wavelength UV254 / UVT10 parameter
- Nitrate (NO_3-N or NO_3) parameter
- Chloramine parameter
- Wavelength absorbance data recorded every 2.5 nm

Image from s::can

Impact

Provides information for plant operators for understanding finished water quality and for making treatment decisions

Sensor Kayak Novel Sensor Deployment

Problem:

- Fugitive sources may be difficult to locate on moving rivers

Approach:

- Researchers have developed a towable array of sensors to identify sources
- An instrumented vessel is being outfitted with a spectro::lyzer V3 UV-Vis detector, a Turner Systems Cyclops (submersible fluorescence/turbidity sensor) and space for an Aquatroll multiparameter sonde (to be configured later).
- All sensors are commercially available off the shelf equipment
- Vessel will be towed by a manned boat

Results and Anticipated Impact:

- Sensors will be used to direct sampling for compliance and other uses

Computational Topology: A New Data Analysis Tool

Problem: **Sensors generate a large amount of information, and tools are needed to analyze and visualize the data**

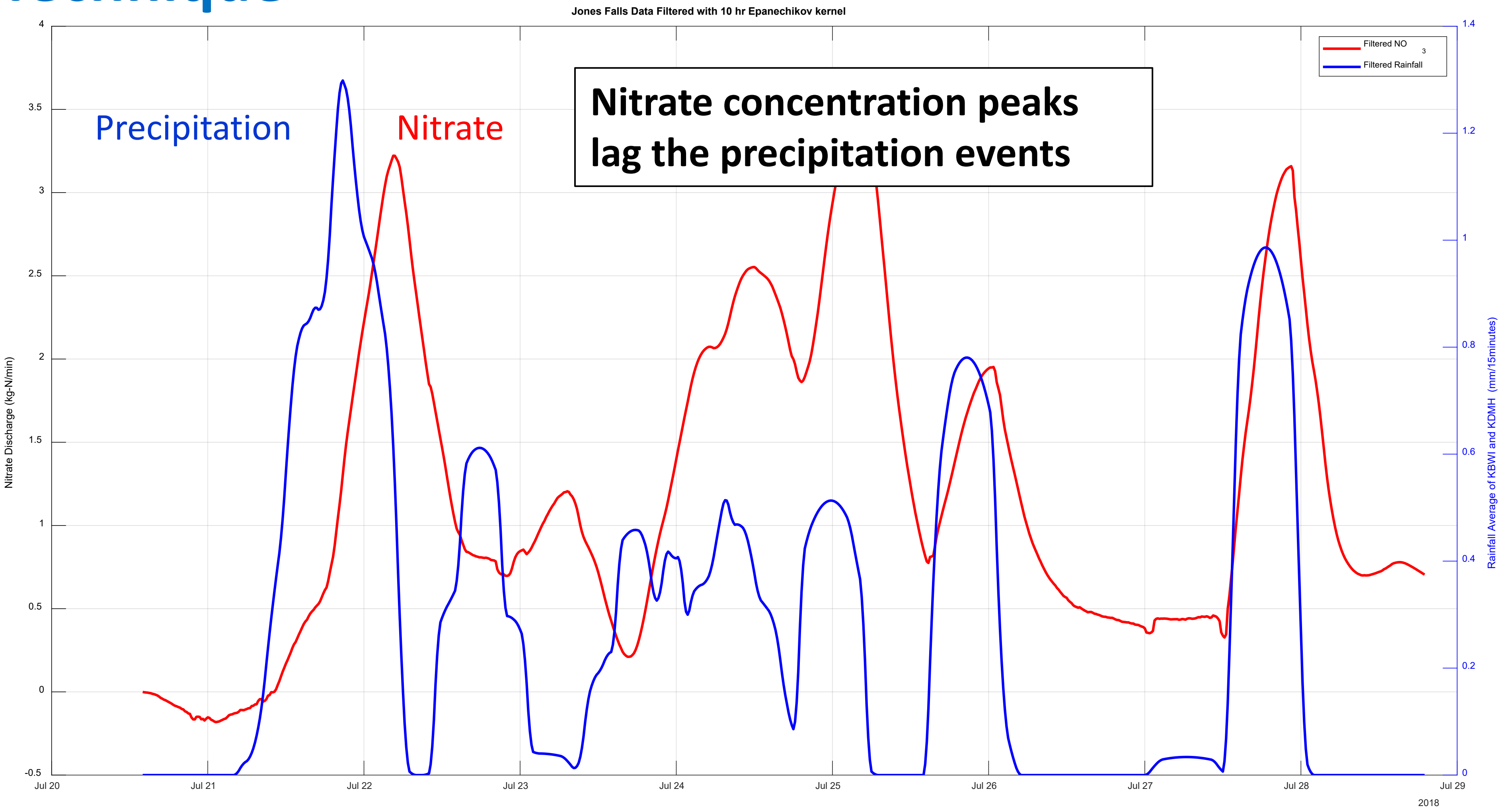
Approach:

- Computational topology is a method of looking at data using topographic analysis to gain deeper insight into sensor data
- Visualize data as a sum of fast, short, medium, or long time series depending on the window length; longer window lengths allow for quantifying trends and sensor issues such as fouling

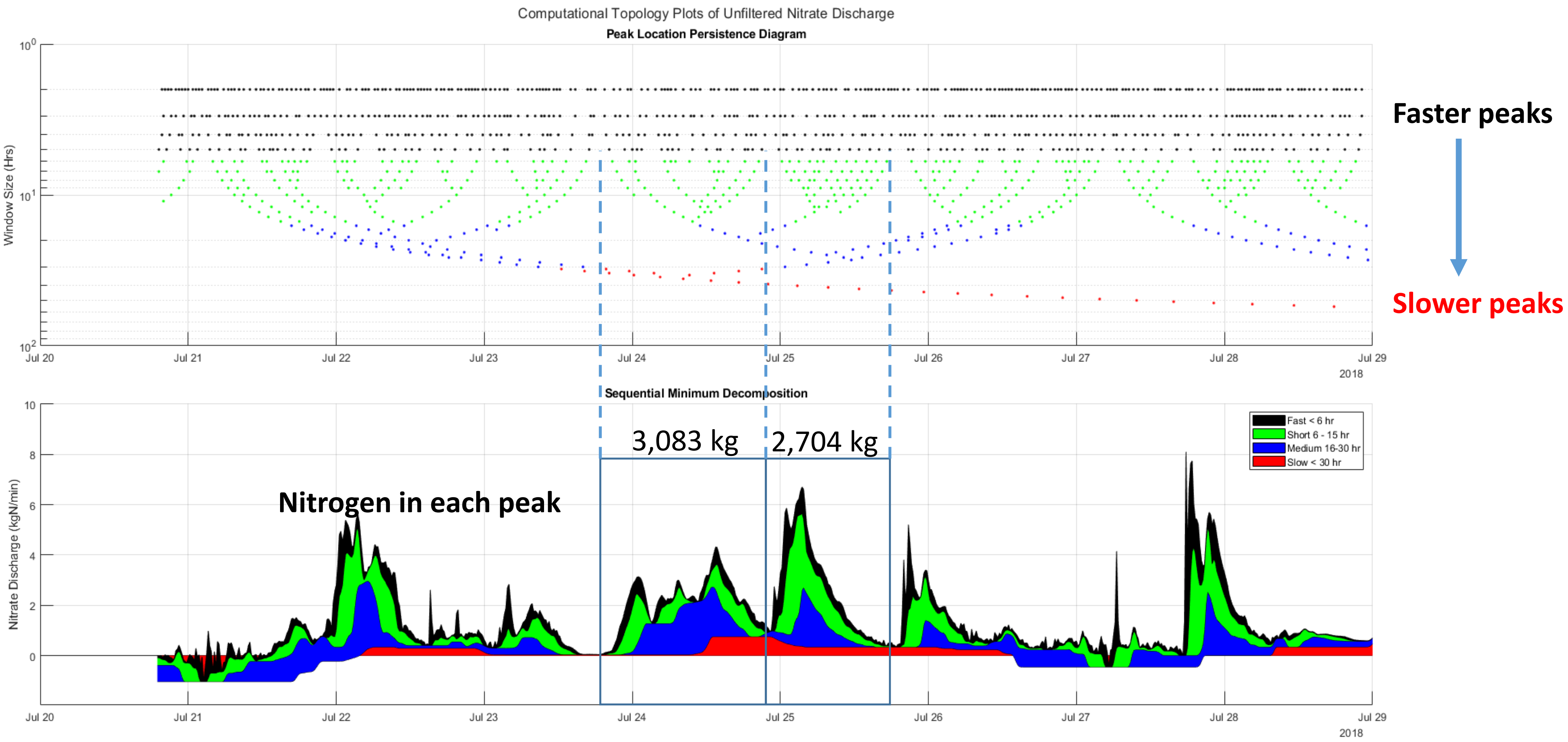
Result: Visualization and quantification of sensor signals associated with water quality changes. Information that reveals hidden structure in the data useful for identifying significant time periods and events such as spills

Impact: Provides sensor information that is useful for understanding water quality changes and for DW treatment plant operations.

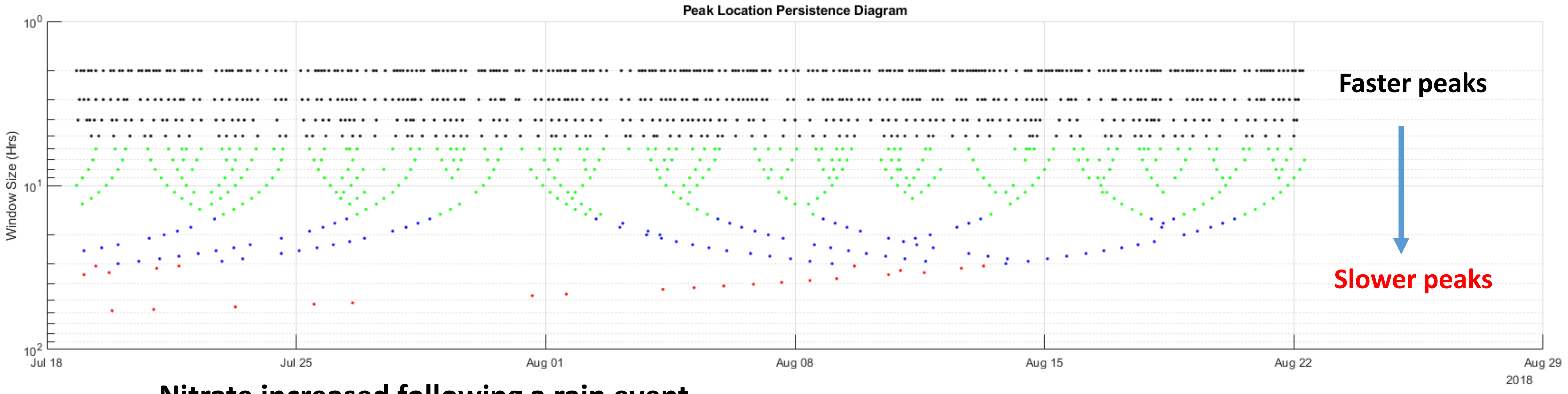
Baltimore River Example for use in a New Data Analysis Technique



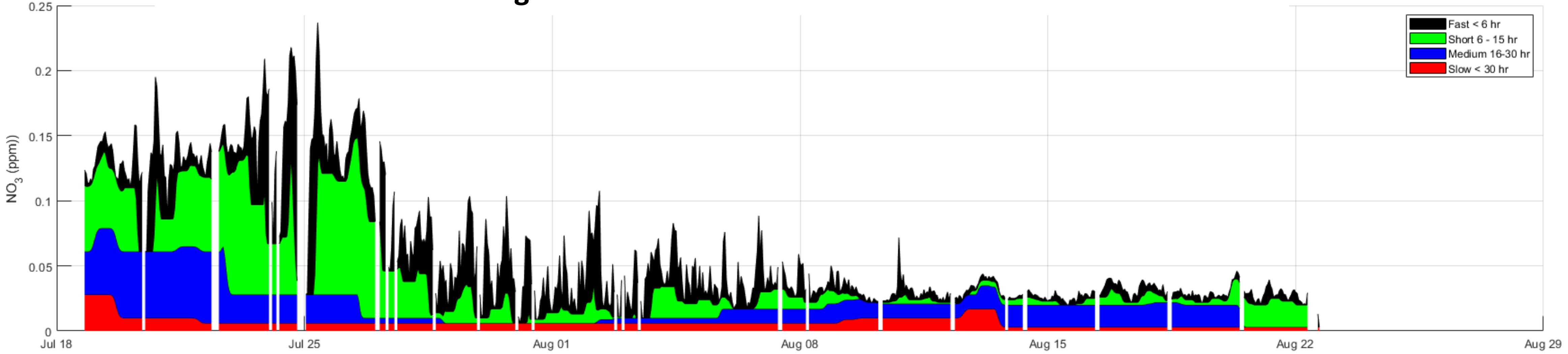
Baltimore River Nitrogen Loading (conc * discharge)



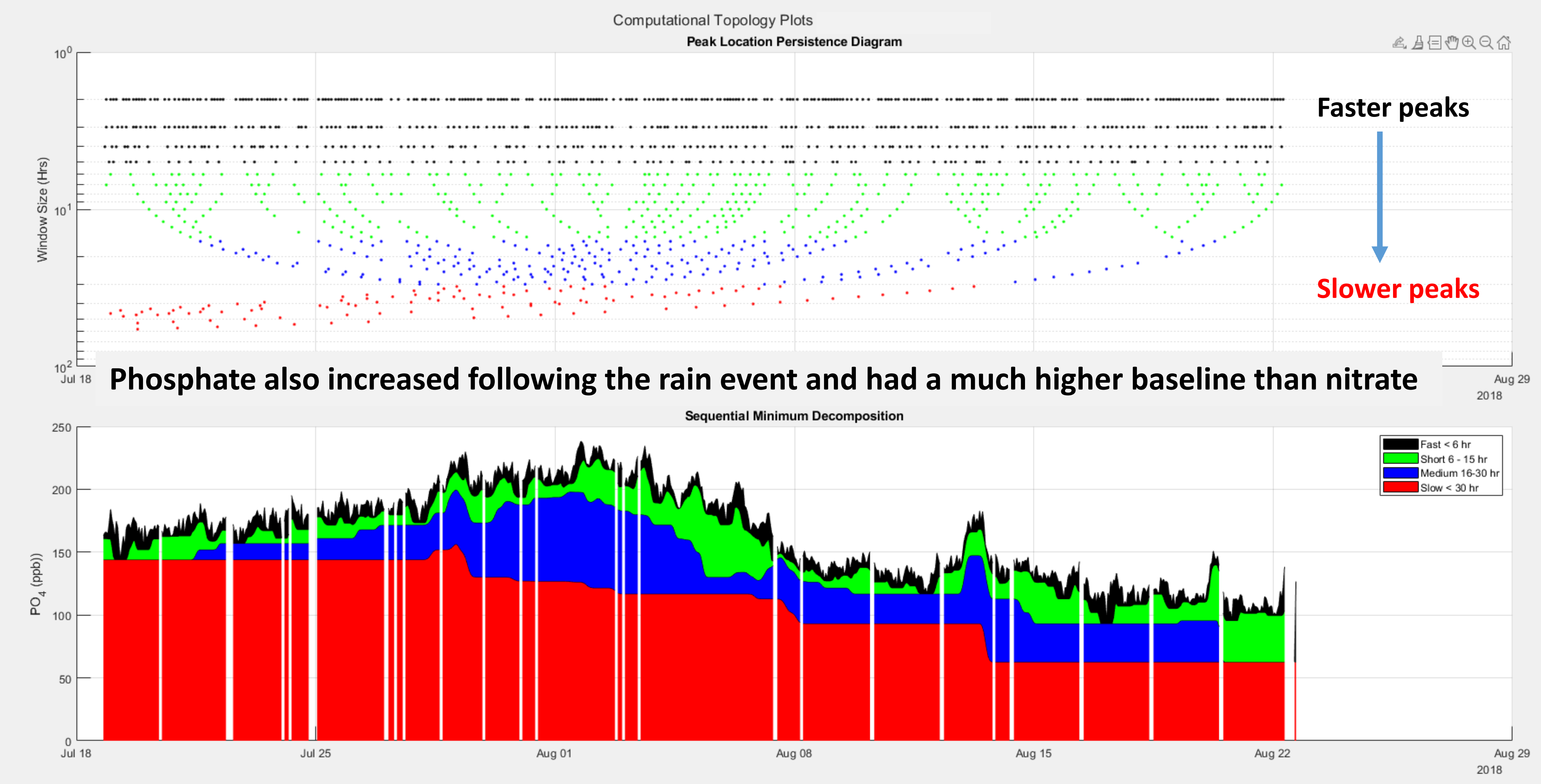
Ohio Reservoir Nitrate



Nitrate increased following a rain event

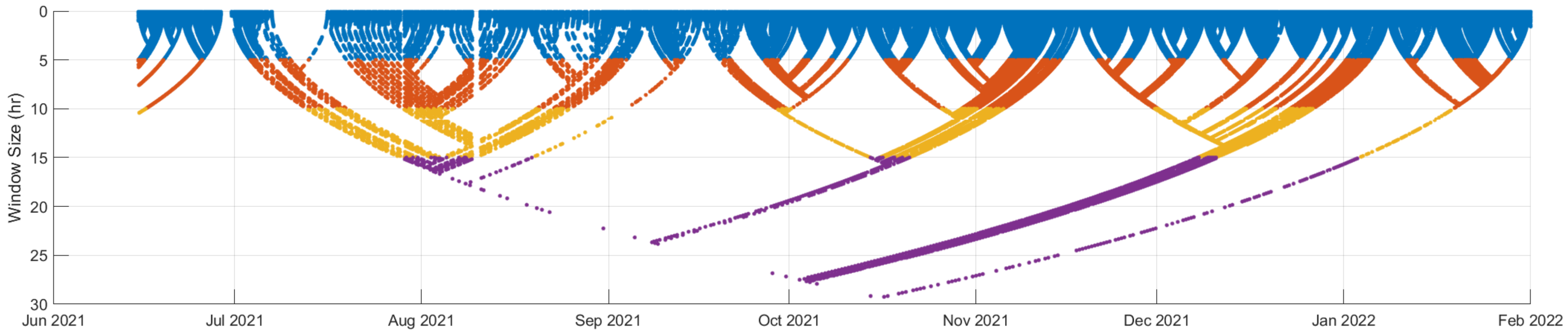


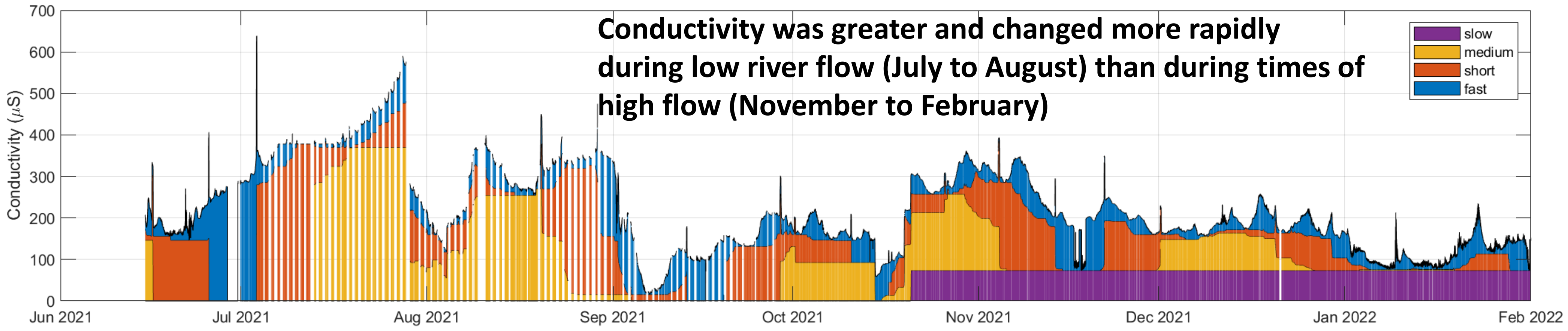
Ohio Reservoir Phosphate



Phosphate also increased following the rain event and had a much higher baseline than nitrate

Example DW treatment plant data collected in West Virginia for spill detection – Conductivity





Conductivity was greater and changed more rapidly during low river flow (July to August) than during times of high flow (November to February)

Current Projects

- Collaborations with West Virginia Department of Environmental Protection, Pennsylvania Department of Environmental Protection, and 7 drinking water treatment plants that collect water sensor measurements for spill detection and monitoring water quality trends

- Partnering with DW plants in North Carolina and Ohio with a focus on sensors and data analysis methods for algae, nutrients, bromide, and disinfection byproducts

- ***Opportunity:*** Interested in developing additional partnerships

Lessons Learned

- We learn much more from working with drinking water professionals, than they do from us
- Communications with local drinking water professionals is extremely important
- In plant measurements require consideration of space, water flow, turbidity/cleaning, power requirements, communication (e.g., WiFi, cellular) and safety
- Quality assurance and calibration issues need to be addressed at the outset and throughout the deployment

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Water Sensor Toolbox Feedback

Please let us know if we missed anything or got something wrong, or if there is something else you'd like to see in EPA's Water Sensors Toolbox

Email questions and suggestions to:

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