Emerging Tools for Continuous Nutrient Monitoring Networks:
Sensors Advancing Science and Water Resources Protection

Brian Pellerin
USGS, Office of Water Quality (bpeller@usgs.gov)

Ohio’s Workgroup for Water Resources Monitoring, 3/17/17
United States Geological Survey

- Government science agency (Dept. of Interior, est. 1879)

- USGS serves the nation by providing reliable scientific information to:
  - Describe and understand the earth,
  - Manage water, biological, energy and mineral resources,
  - Enhance and protect our quality of life.

- 8000 employees across every state

- Michigan-Ohio Water Science Center
  - Main Office is Columbus (includes National Program staff)
  - Field office in New Philadelphia
  - Close collaboration across all states and programs
  - Shared resources and expertise
Continuous Monitoring

- 24/7 data collection
- Intervals of seconds to hours
- Capture all events
- Real-time transmission
- Wide range of constituents with direct or surrogate measurements
- Remote access and control

USGS
# USGS Real-Time Water Quality Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th># of Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge</td>
<td>8,325</td>
</tr>
<tr>
<td>Temperature</td>
<td>2,273</td>
</tr>
<tr>
<td>Specific Conductance</td>
<td>1,007</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>569</td>
</tr>
<tr>
<td>Turbidity</td>
<td>474</td>
</tr>
<tr>
<td>pH</td>
<td>454</td>
</tr>
<tr>
<td>Nitrate</td>
<td>130</td>
</tr>
<tr>
<td>Chlorophyll fluorescence</td>
<td>55</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>15</td>
</tr>
</tbody>
</table>
Optical Sensors

Measure the interaction between light and optically-active constituents in the water
Continuous Nitrate Monitoring

- 100+ sites in 24 states
- Majority are cooperator funded
- Includes rivers, springs, groundwater, ...

Basin Type
- Coastal
- Large inland

USGS network site

USGS Sites with Continuous Nitrate Sensor
- Federally funded
- Cooperative
Examples of Primary Benefits

1. Real-time data for decision support

2. High temporal frequency of data
   - Observing processes that are otherwise missed
   - Quantify water-quality status and trends with improved accuracy and lower uncertainty
Real-Time Water Management

Nitrate sensor data used to determine the need for online nitrate removal for drinking water.
Short-Term Variability

Nitrate sensor data captures all variability including diurnal cycling and storm events.

Seasonal-annual variability

Discharge (CFS)

Nitrate (mg N/L)

Diurnal variability

Storm variability

Potomac River at Little Falls, Washington, DC, USA (USGS Station 01646500)
River Nutrient Loads

Continuous data improves the accuracy and reduces the uncertainty of nitrate load estimates to coastal waters compared to discrete sampling and regression based models.

Mississippi River at Baton Rouge

Pellerin et al., 2014. Environmental Science and Technology, 48 (21), pp 12612–12619; Hypoxia map from NOAA/LUMCON.
Spatial Mapping

- Spatial mapping to identify sources, sinks and mixing zones
- Can be used on a moving boat

Map of conductivity and nitrate in the Upper Mississippi River

Crawford et al., 2015. Environmental Science and Technology.
Wet Chemical Nutrient Sensors

- Field deployable sensors using standard colorimetric methods
- Available for orthophosphate, ammonium, nitrate, and silica
- USGS operates ~10 as part of testing / “proof-of-concept” for monitoring

### Example Sensor PO₄ Specs

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Limit</td>
<td>≤0.0023 mg/L PO₄⁻-P</td>
</tr>
<tr>
<td>Maximum Concentration Range</td>
<td>0-1.2 mg/L PO₄⁻-P</td>
</tr>
<tr>
<td>Maximum Sampling Rate</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Samples Per Reagent</td>
<td>~ 1000</td>
</tr>
</tbody>
</table>
USGS Monitoring Network in the Great Lakes
(24 sites)

- Emphasis on quantifying nutrient loads to the Lakes
- In situ orthoP sensors to be added to ~ 10 sites (several in OH)

Jon Hortness, USGS Great Lakes Program Coordinator, hortness@usgs.gov
Surrogate Models

- Relate continuous parameters to concentrations from samples
- Periodic samples (monthly) for model verification
- USGS Techniques and Methods Report forthcoming
HABs Detection

- Variety of instruments and approaches for in situ, real-time and/or high frequency detection of toxins, pigments or cells:
  - Pigment fluorescence (single or multiple excitation-emission)
  - Cell Imaging instruments (e.g. Imaging Flow Cytobot)
  - Environmental Sample Processor (ESP)
  - Hyperspectral remote sensing
  - …
- Costs ranging from <$5K to >$300K

Applications for Fluorescence Sensors

- Commonly used as proxies for dissolved organic carbon and relative algal pigment concentrations
- Also show promise as a proxy for:
  - Mercury
  - Disinfection byproduct formation potential (trihalomethanes, haloacetic acids)
  - Wastewater presence (e.g., coli, bacteroides)
  - ...
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**Market Stimulation**

- **Coalition of federal agencies, universities, and non-profits bringing incentive prizes and open innovation to the problem of water quality**

  - **Goal:** Accelerate development and commercial availability of affordable, reliable, and accurate sensors

  - **Prizes / Challenges:**
    - Nutrient Sensor Challenge
    - Arsenic Sensor Challenge
    - Septic System Nitrogen Sensor Challenge
    - Sensors in Action Prize
    - Visualizing Nutrients Challenge
    - TN/TP, E. Coli, HABs Challenges

**Market Stimulation**

There are **CHALLENGES** underway to accelerate the development of new affordable technologies for measuring nutrients. **WHY?**

Nutrients are essential for ecosystems and many products we need. But **TOO MUCH** nitrogen and phosphorus in water can cause algal blooms, contaminate drinking water, and kill fish. These wide-ranging effects mean:

**Nutrient pollution is one of America’s BIGGEST environmental problems.**

- **65%** of assessed estuaries and coastal areas have moderate to high **WATER QUALITY IMPACTS** from nutrient pollution.
- Freshwater nutrient pollution costs the nation **$2.2 BILLION** per year.
- Reported drinking water violations for nitrates have nearly **DOUBLED** in the last decade.

How can we address this problem? For one thing, we need more information. We need to **REDUCE THE HIGH COST and COMPLEXITY** of collecting data, so we can measure nutrients and track progress.

Federal agencies, the Alliance for Coastal Technologies (ACT), and other partners **CHALLENGE YOU** to join the effort to develop **AFFORDABLE, ACCURATE, and RELIABLE NUTRIENT SENSORS!**

The Nutrient Sensor Challenge will mobilize markets and provide laboratory and field verification at no cost to you—and an opportunity to showcase your innovation.

**Nutrient Sensor Features**

- Measures dissolved nitrogen and/or phosphorus
- Provides real-time data

**Nutrient Sensor Challenge Schedule**

- **Launch:** Winter 2014
- **Testing:** Summer 2015 – Fall 2016
- **Awards:** Winter 2016
An Interoperable Sensor Network

- Sensors are owned/operated by diverse organizations
- Use data standards to promote data interoperability
- Data can be available real-time, and also archived for future reference

From Dwayne Young, EPA
Cost of ambiguous metadata

Ambiguous nutrient data are a valuable resource worth billions of dollars to secondary users

- parameter name
- units
- chemical form
- sample fraction
- data quality / BDL codes
- ...

Common Guidelines and Protocols

Keys to an accurate, comparable real-time national network for water quality

http://water.usgs.gov/owq/FieldManual/

pubs.usgs.gov/tm/01/d5
Conclusions

1. Sensors are changing the way we monitor and manage water-quality

2. Not needed everywhere and for all questions, but critical for some
   - More examples of both types needed

3. Many opportunities for innovation
   - Sensors, data collection platforms, integration into models, …

4. Need for National consistency

How could continuous, real-time nutrient data change what you know or do about water quality?
Thank you…

Brian Pellerin
Office of Water Quality
bpeller@usgs.gov
(703) 648-6865

Keith Banachowski
Deputy Director
kbahachowski@usgs.gov
(614) 430-7707