USGS
science for a changing world

# Monitoring and testing of sensors for a prototype real-time early-warning system for water security

Eric F. Vowinkel

NJ District Drinking Water Quality Specialist and

Liaison to USEPA Region 2 and Rutgers University

vowinkel@usgs.gov

and Ronald J. Baker, Jacob Gibs, and Rachel A. Esralew

U.S. Geological Survey

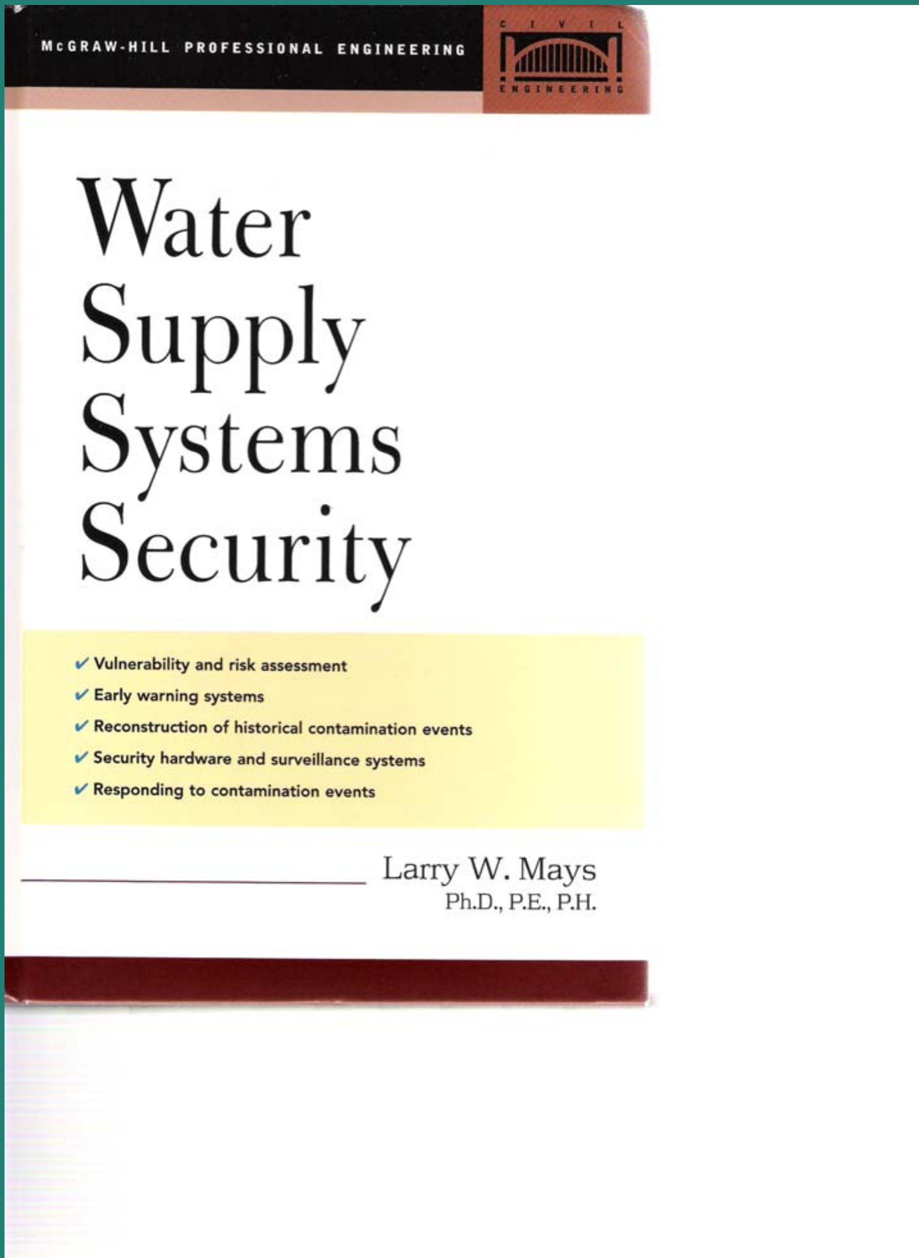
810 Bear Tavern Road, Suite 206, West Trenton, NJ 08628

U.S. Department of the Interior
U.S. Geological Survey

# Objectives of Presentation

- Describe plans for and preliminary results of Phase 1 study by the NJ Consortium team to field test sensors as part of a study to develop and implement a prototype early-warning system for water security
- Describe plans for Phase 2 study by Federal Consortium team to evaluate the optimization of sensors (number and locations) and variability in response of sensor signals in a distribution system

USGS




CHAPTER 8

# DEVELOPING AN EARLY WARNING SYSTEM FOR DRINKING WATER SECURITY AND SAFETY

Robert M. Clark,* Nabil Adam,† Vijayalakshmi Atluri,† Milton Halem,† Eric Vowinkel,‡ Pen C. Tao,§ Laura Cummings,¶ and Eva A. Ibraham**

## NJ Consortium

- USEPA REGION 2 -- oversight
- RUTGERS UNIVERSITY CENTER FOR INFORMATION MANAGEMENT INTEGRATION AND CONNECTIVITY (CIMIC)
- NJDEP
- USGS – NEW JERSEY DISTRICT
- 3 NJ WATER COMPANIES

# Objectives of Phase 1 NJ Consortium Study

**Sensor testing and monitoring in source waters and distribution systems**

**chemical, biological, and radiological (CBR)**

**USGS**

## Modeling

- TOT of source waters using RiverSpill.
- Distribution systems by EPA.net and WaterCAD

**USGS + CIMIC**

## Information Management

- Sensor data-management system
- Real-time data acquisition information network system
- Data validation and alert management system
- Web-based GIS user interface

**CIMIC and USGS**

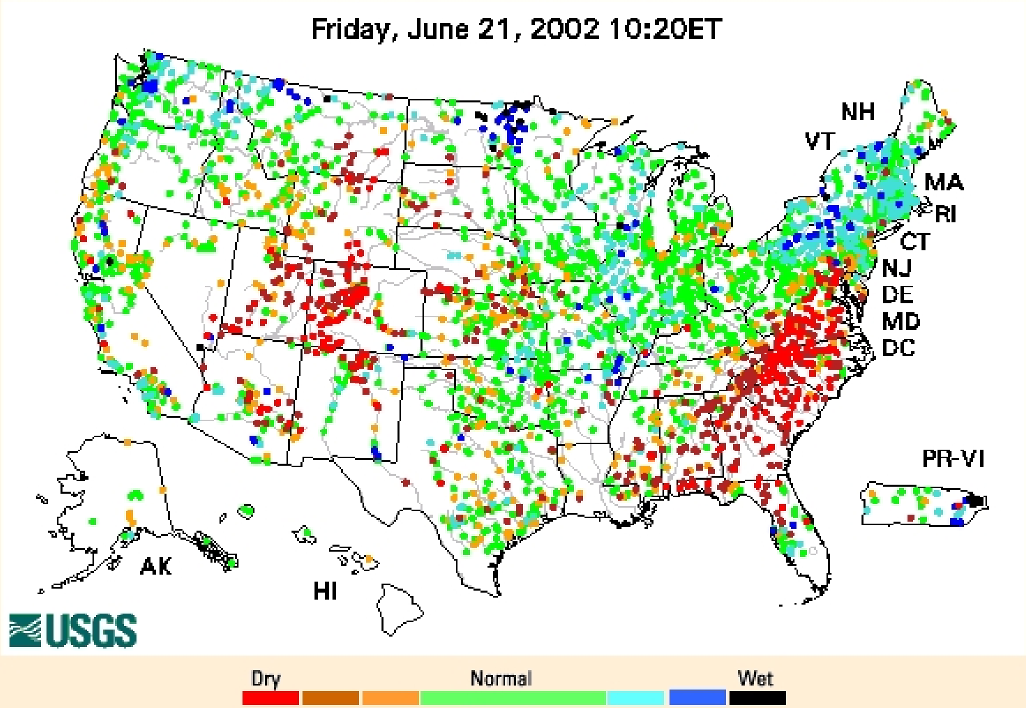
# OBJECTIVES OF PHASE 1 MONITORING AND SENSOR EFFORT

- Take advantage of existing USGS real-time networks
- Test new technology sensors (CBR)
  - Chemical
  - Biological
  - Radiochemical
- Evaluate different sampling methods—in situ vs. pumped flow in different water environments
  - Distribution systems
  - Source water
    - Delaware River (large drainage basin with tidal effects)
    - Passaic River (significant wastewater discharge)
    - Wanaque Reservoir (fairly pristine environment)
- Automatic water-sampling approach based on sensor signals
- Supply continuous stream of sensor data to users including data-management team and water utilities

USGS

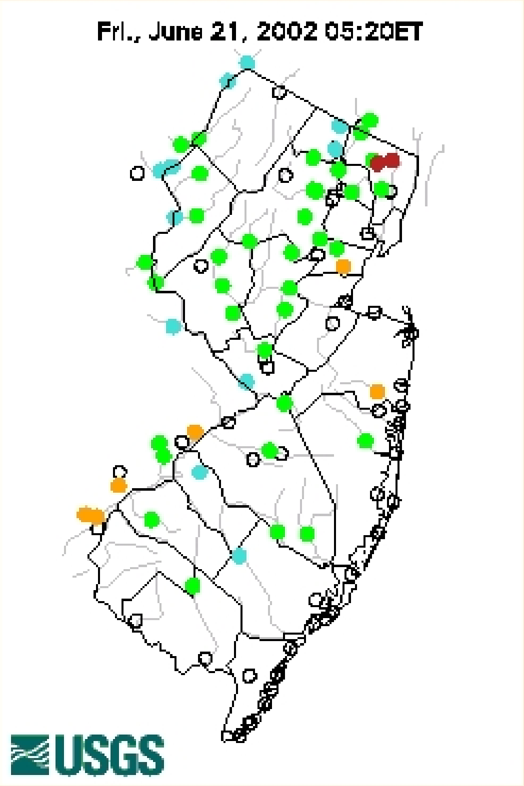
# Existing USGS real-time systems

## Map of real-time streamflow compared to historical streamflow for the day of the year (United States)




## Daily Streamflow Conditions

**Select a site to retrieve data and station information.**




USGS

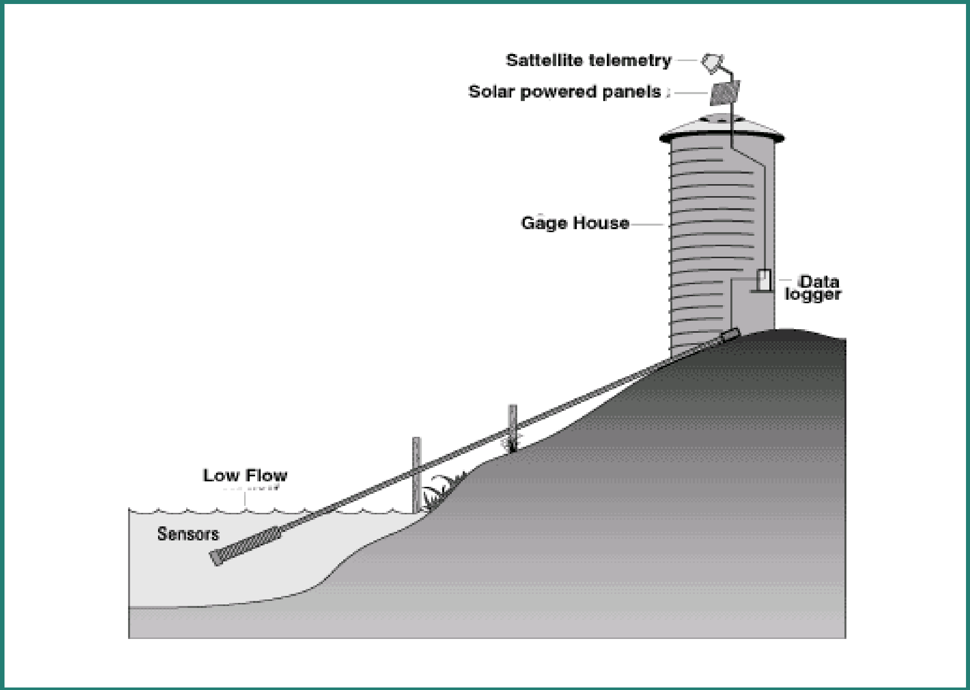
# Characteristics of an Early Warning System (EWS)

(from Clark and others, 2004)

- Rapid response time
- Fully automated
- Scans for a range of contaminants
- Specific for contaminants of concern
- Sufficient sensitivity
- Low occurrence of false positives
- High rate of sampling
- Reliable and rugged
- Requires minimal skill and training
- Affordable

USGS

# Evaluate different sampling strategies—in situ vs. pumped flow




Real-time continuous water-quality monitoring station
Source: Wagner and others, (2000); available at
http://water.usgs.gov/pubs/wri/wri004252

USGS

# Sensor and Monitoring Design

**Sensors**

**Background**

**Specific**

↓

**Information management**

**Modeling**

↓

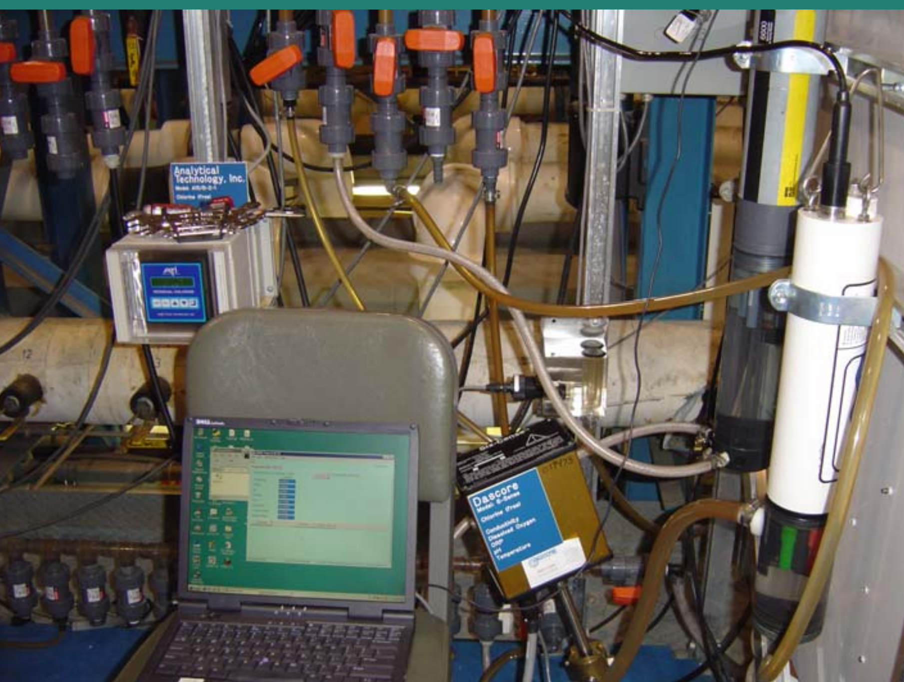
**Automatic sampler**

**Confirmation at lab**

- **Monitor water continuously for T, pH, DO, SC, turbidity, ORP, and chlorine**
- **Deploy "new" technology sensor after significant change in characteristics listed above;**
- **If specific sensor produces a positive signal, then automatically collect sample(s) for confirmation at approved laboratory according to USEPA Emergency Response protocols**

USGS

# Pipe Loop Experiment at USEPA Testing and Evaluation (T&E) Facility on 2/12/04



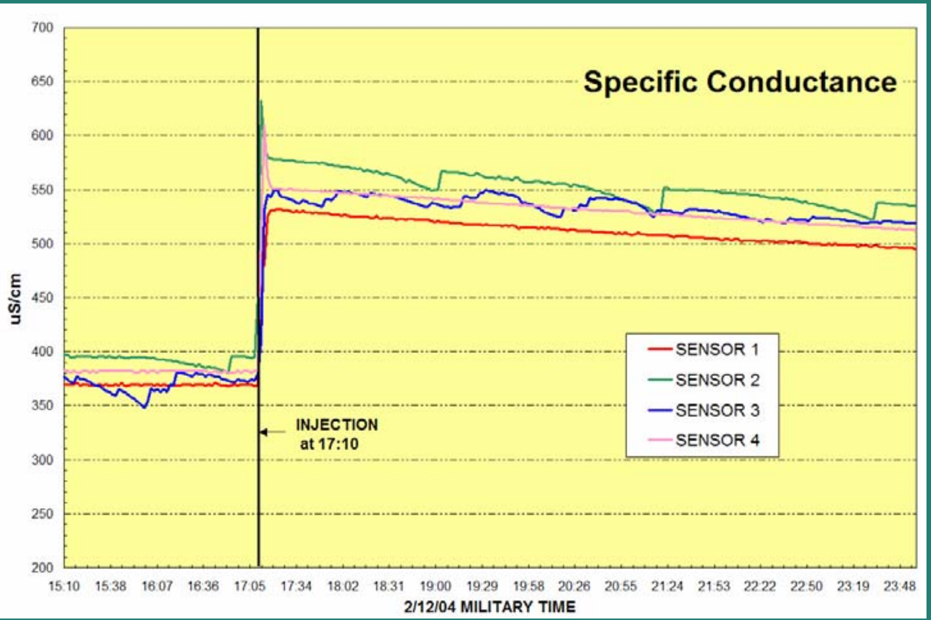

Introduced to 2 gals of loop water:

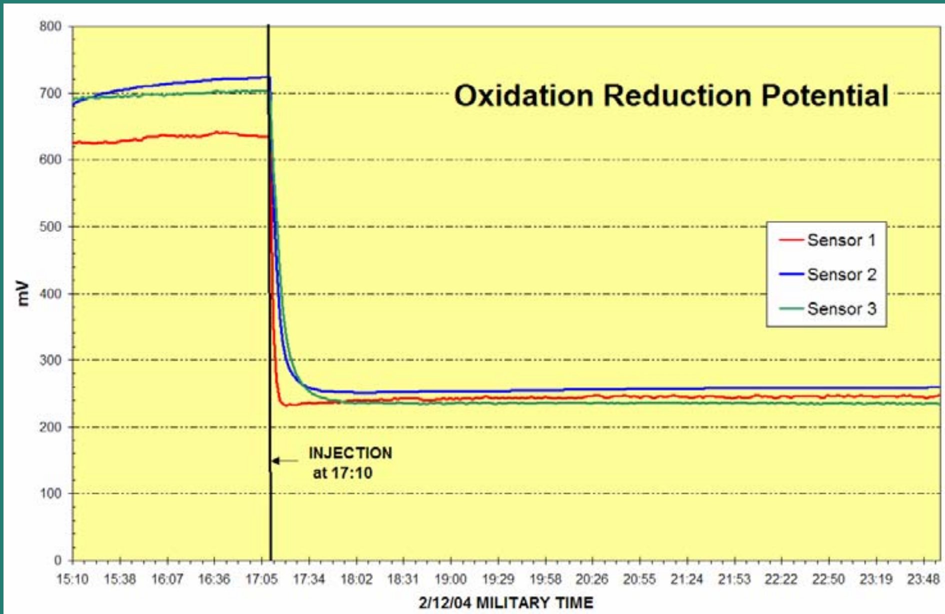
- Potassium ferrocyanide (12 g)
- Potassium chloride (70.5 g)
- Potassium ferricyanide (9.4 g)
- Ammonium chloride (2.6 g)
- Potassium nitrate (4.8 g)

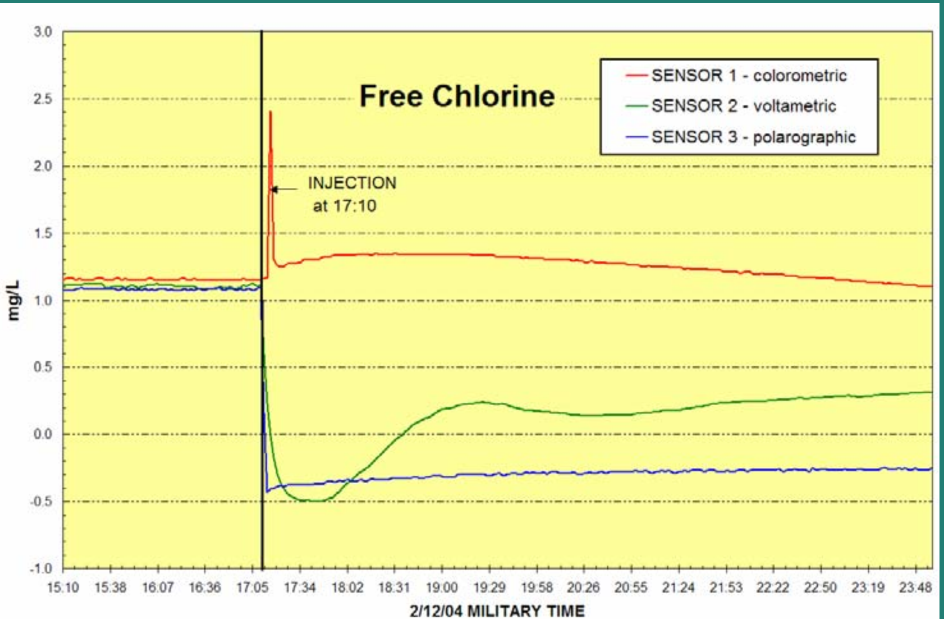
USGS

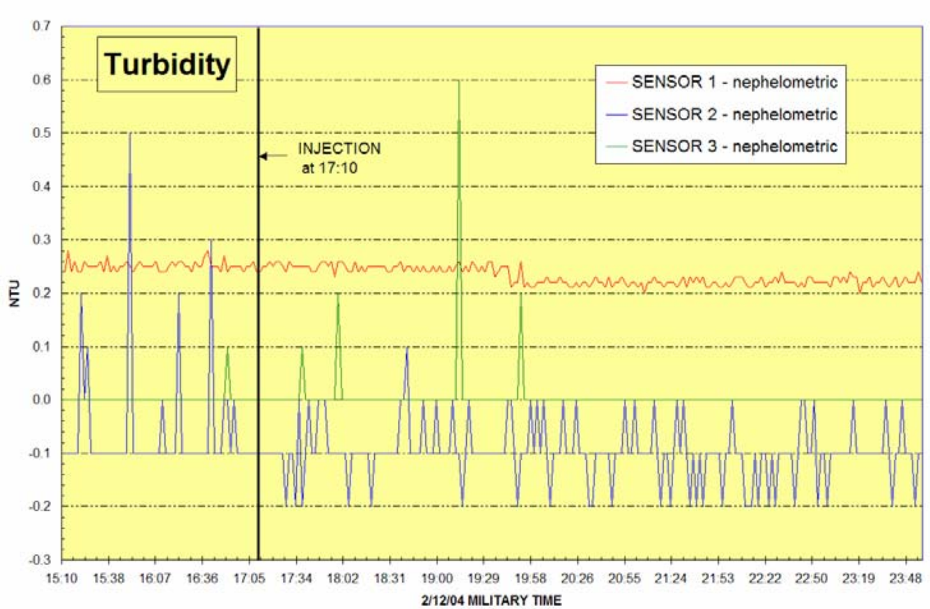
# Selected results of T&E Facility Experiment with selected sensors

## (Unpublished data—subject to revision)

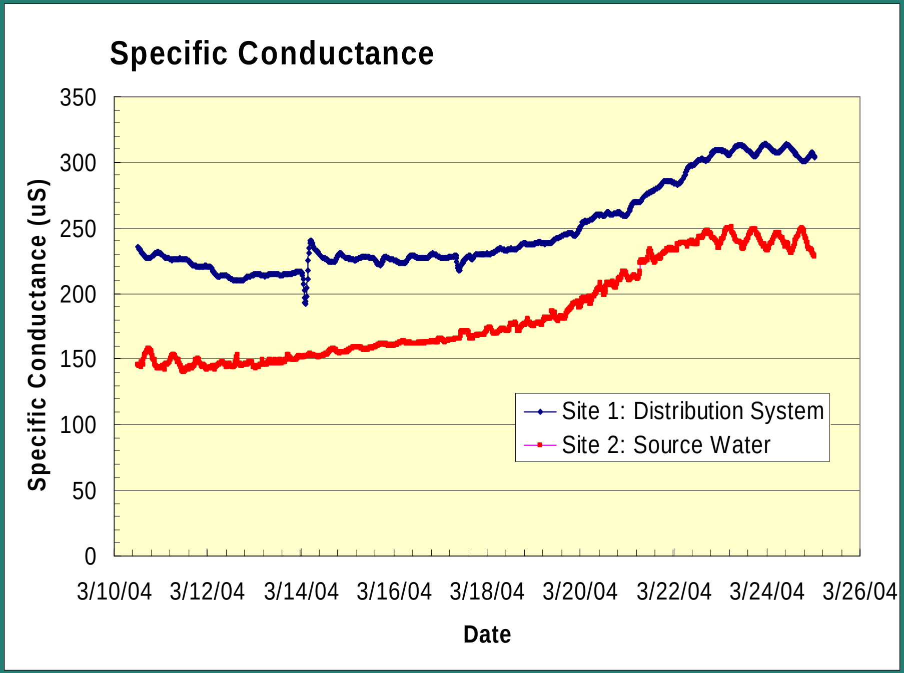


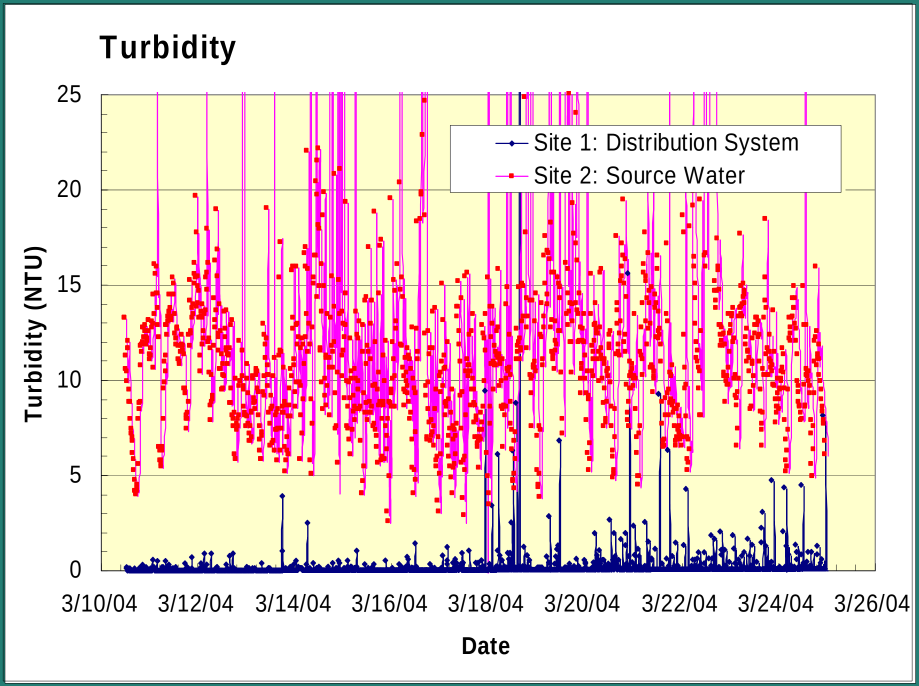



# Comparison between source-water and distribution-system real-time results from selected sensors at a USGS field site (unpublished data—subject to revision)




USGS

# What will be learned from Phase 1 prototype EWS sensors and monitors?

- Test available and new technology sensors in the field under variable hydrologic conditions
  - Do these sensors work only in “clean” water or do they perform well in streams with a high dissolved-solids content?
  - Do the sensors work well under harsh weather conditions year round?
  - How often do these sensors need servicing?
  - Do these sensors work effectively in chlorinated distribution systems?
  - What are background concentrations and variability?

USGS

# OBJECTIVES OF PHASE 2 MONITORING AND SENSOR EFFORT

- Task 1: Select utility for distribution-system model
  - Collect data for model calibration
  - Use model to optimize for number and locations of sensors
- Task 2: Design sensor network
  - Select sensors
  - Install sensors
  - Collect data for 2 months
- Task 3: Collect data and conduct statistical analysis

USGS

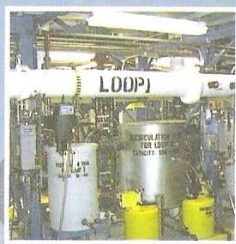
# Phase 2 Team

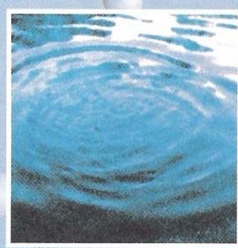
- USGS
  - Eric Vowinkel—Program Coordinator
  - Ron Baker—Project Chief
  - Jack Gibs—Water-quality specialist
  - Rachel Esralew—Hydrologist
  - Eric Best—Hydrologist
- American Water Company
- USEPA
  - Office of Science and Technology (Jafrul Hasan)
  - Homeland Security Research Center (John Herrmann, Jim Uber, Rob Janke)
- Sandia National Laboratories (SNL)

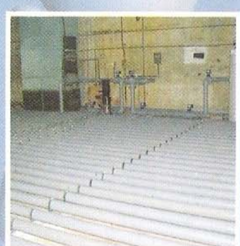
USGS

# Distribution System Research Consortium

## Collaborating to Achieve Drinking Water Security





EPA United States Environmental Protection Agency

## Technical Work Groups


- ***Early Alert and Warning Systems*** - Develops and evaluates real-time hardware and software systems and procedures that provide early warning of drinking water distribution system contamination.
- ***Systems Modeling*** - Improves models for hydraulics and water quality monitoring in water distribution systems to assess their vulnerability. Develops early warning systems, improves utility operations, and supports decontamination efforts.
- ***Water Treatment*** - Explores conventional and innovative treatment techniques for chemical and biological contaminants to safeguard drinking water quality and address water disposal concerns.
- ***Decontamination*** - Identifies and develops effective techniques and protocols for decontaminating piping systems that contain chemical and biological contaminants.

## Member Organizations and Contacts


***U.S. Environmental Protection Agency, (U.S. EPA) National Homeland Security Research Center***
Jonathan Herrmann, herrmann.jonathan@epa.gov
Robert Janke, janke.robert@epa.gov

***U.S. EPA, Water Security Division***
Grace Robiou, robiou.grace@epa.gov

***U.S. EPA, Standards and Risk Management Division***
Kenneth Rotert, rotert.kenneth@epa.gov

***U.S. EPA, Health and Ecological Criteria Division***
Jafrul Hasan, hasan.jafrul@epa.gov

***Centers for Disease Control and Prevention, (CDC) National Center for Infectious Diseases***
Dennis Juranek, djuranek@cdc.gov

***CDC, National Center for Environmental Health***
Rick Gelting, rug7@cdc.gov

***U.S. Army Corps of Engineers, Engineering Research and Development Center***
Kirankumar Topudurti, K-topudurti@cecer.army.mil

***Department of Homeland Security***
Lance Brooks, lance.brooks@dhs.gov

***U.S. Air Force, Wright Patterson AFB***
Scott Hall, scott.hall@wpafb.af.mil

***U.S. Army, Edgewood Chemical Biological Center***
Irv Baumel, irwin.baumel@us.army.mil

***U.S. Geological Survey***
Eric Vowinkel, vowinkel@usgs.gov

***U.S. Navy, Naval Facilities Engineering Service Center***
Ernest Lory, ernie.lory@navy.mil

***Awwa Research Foundation***
Rick Karlin, rkarlin@awwarf.org

***Department of Energy, (DOE) Lawrence Livermore National Laboratory***
Nina Rosenberg, rosenberg4@llnl.gov

***DOE, Los Alamos National Laboratory***
Penny Hitchcock, pennyh@lanl.gov

***DOE, Sandia National Laboratories***
Ray Finley, refinle@sandia.gov

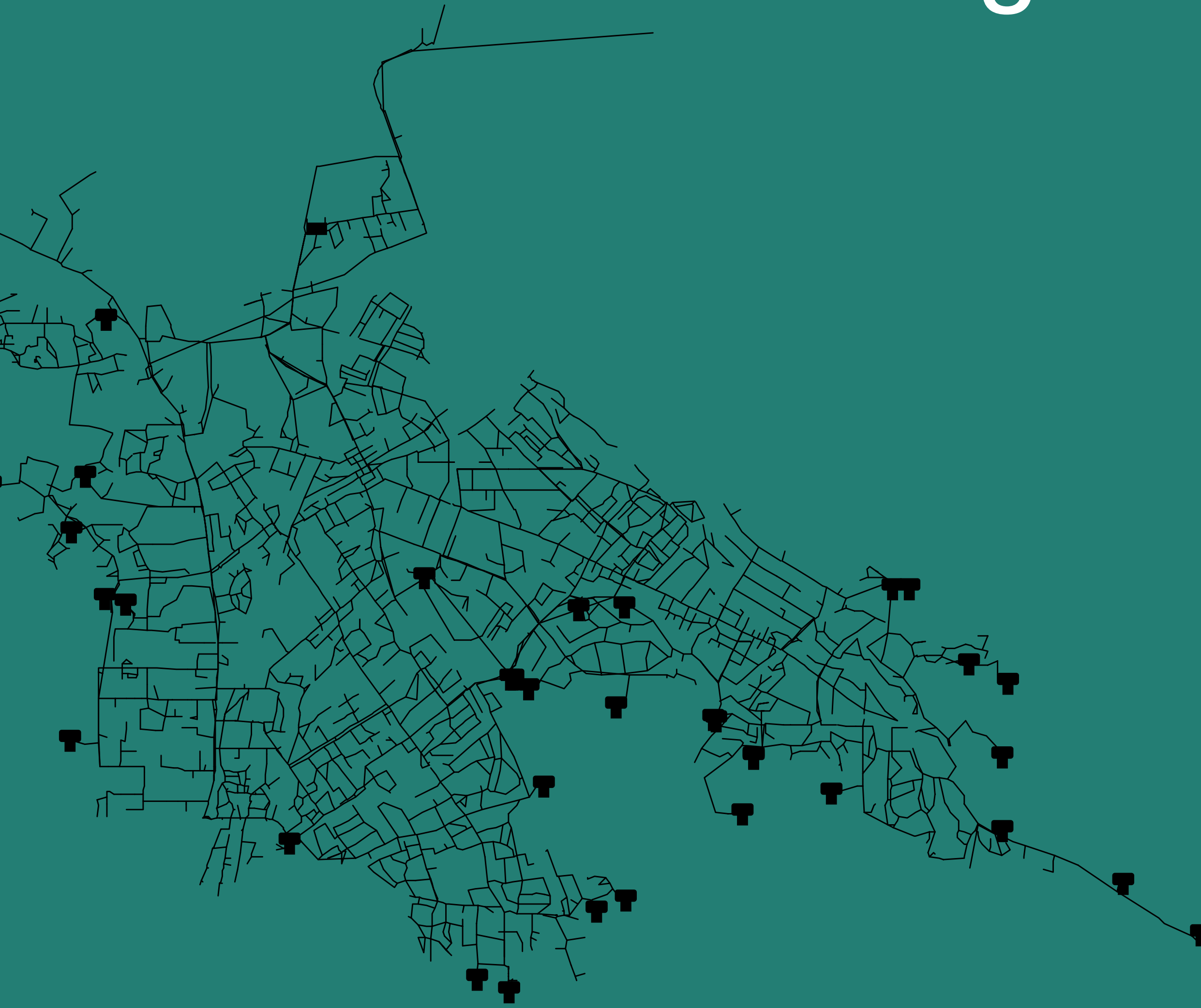
***For More Information, Please Contact:***
Jonathan Herrmann or Robert Janke
National Homeland Security Research Center
Office of Research and Development
U. S. Environmental Protection Agency
26 W. Martin Luther King Drive
Cincinnati, OH 45268

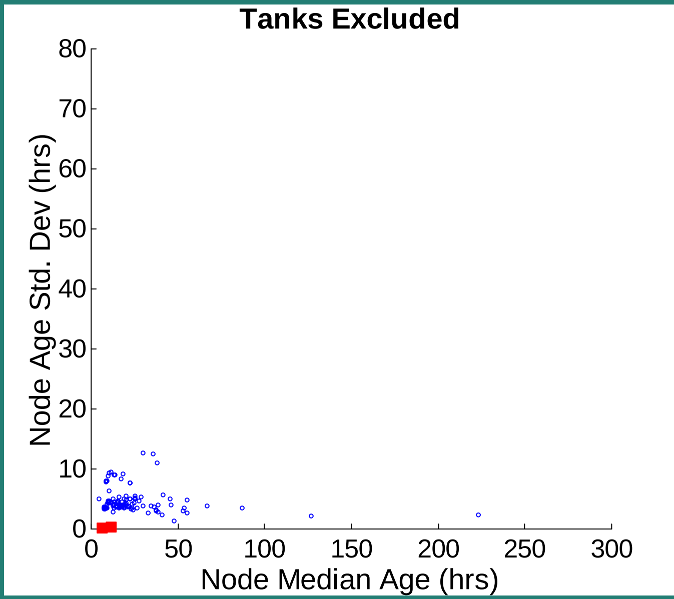
# What will be learned from the Phase 2 sensor optimization and variability study?

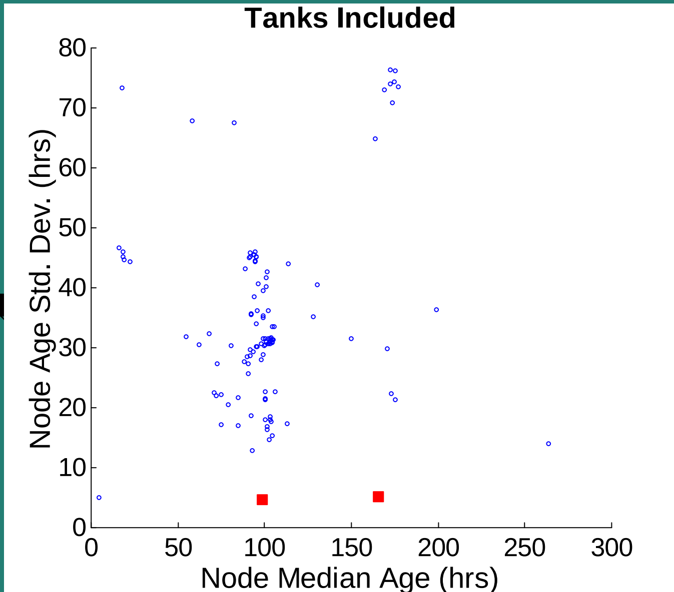
- How can a distribution system model be used to optimize for the number and location of sensors?
- What are background [ ] and variability within the distribution system?
- How often do these sensors need servicing?
- What is the variability of similar sensors from other studies in distribution systems nationwide?
- Is there any transfer value between results of experiments using known contaminants at the USEPA T&E facility pipe loops and responses in the field?

USGS

# Node Water Age Statistics






**Example of distribution system and nodes**

# Monitoring and testing of sensor studies

| Phase 1 | Phase 2 Study |
|---|---|
| NJ Consortium | Federal Distribution Systems Research Consortium |
| Many sensors | Few sensors |
| Few sites at 3 water utilities | Many sites (15-20) at 1 water utility |
| Real time at all sites | Not real time at all sites |
| Source water and distribution sites | Distribution sites only |
| Spatial and temporal variability at a few sites at different facilities | Spatial and temporal variability of sensors within 1 distribution system |

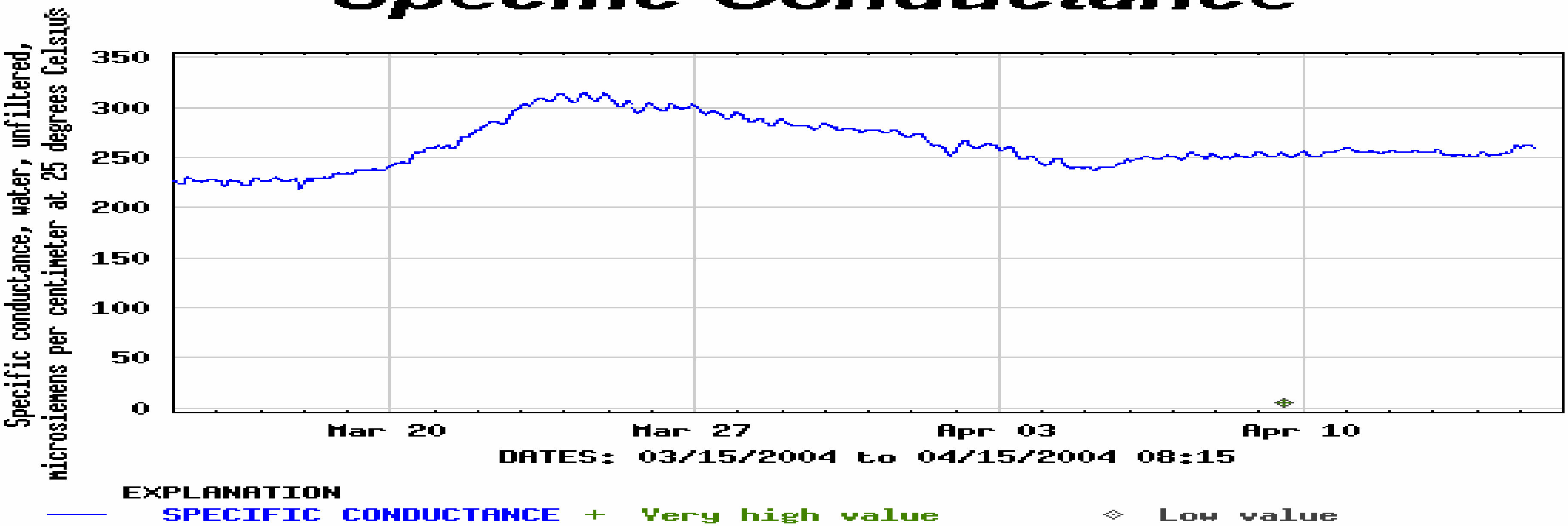
USGS

# SUMMARY

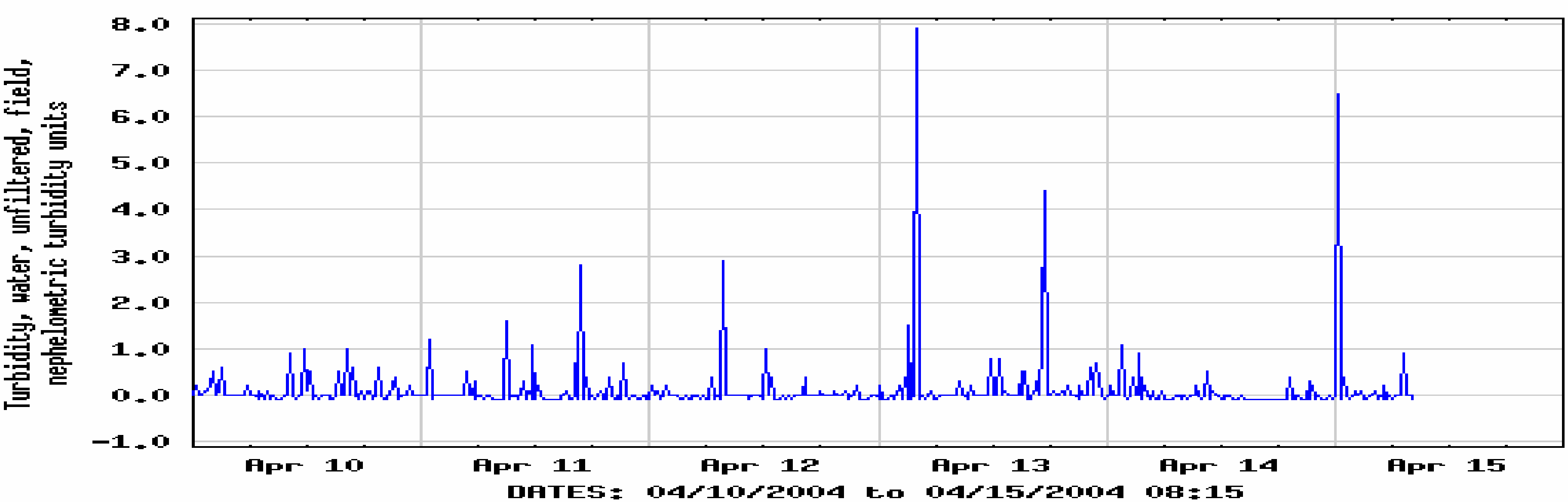
- Using expertise of Consortium teams for Phase 1 and Phase 2
- Using a comprehensive research approach
  - Monitoring and sensors
  - Modeling support
  - Information management
- Taking advantage of existing USGS real-time technology and networks
- Partnering with other Federal and State agencies and private sector for sensor testing in field under variable conditions in source waters and in distribution systems

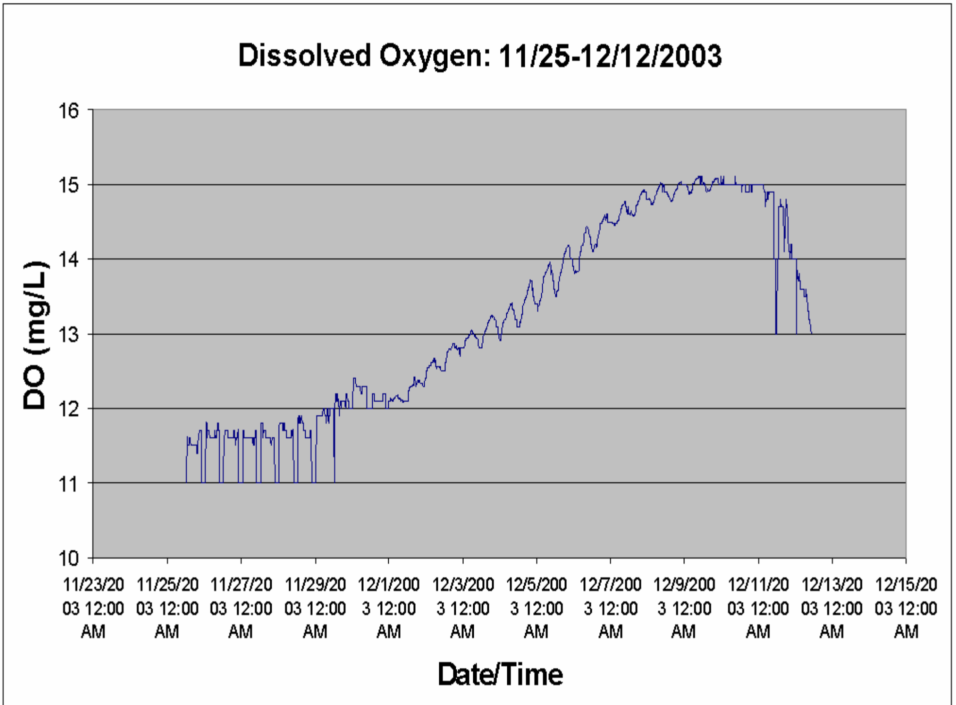
USGS

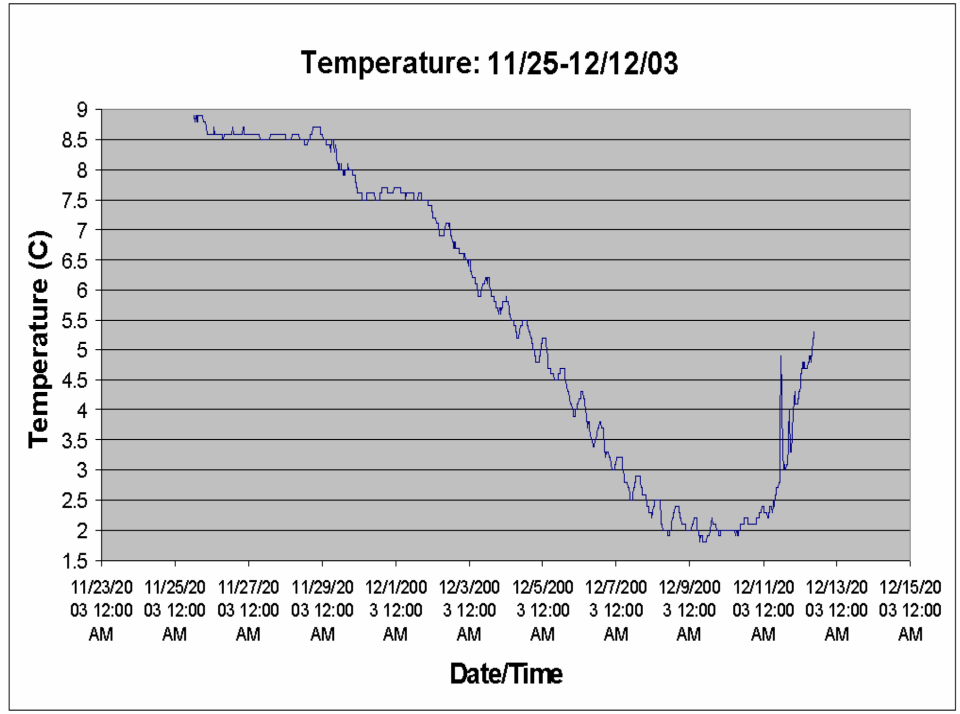
# Specific Conductance

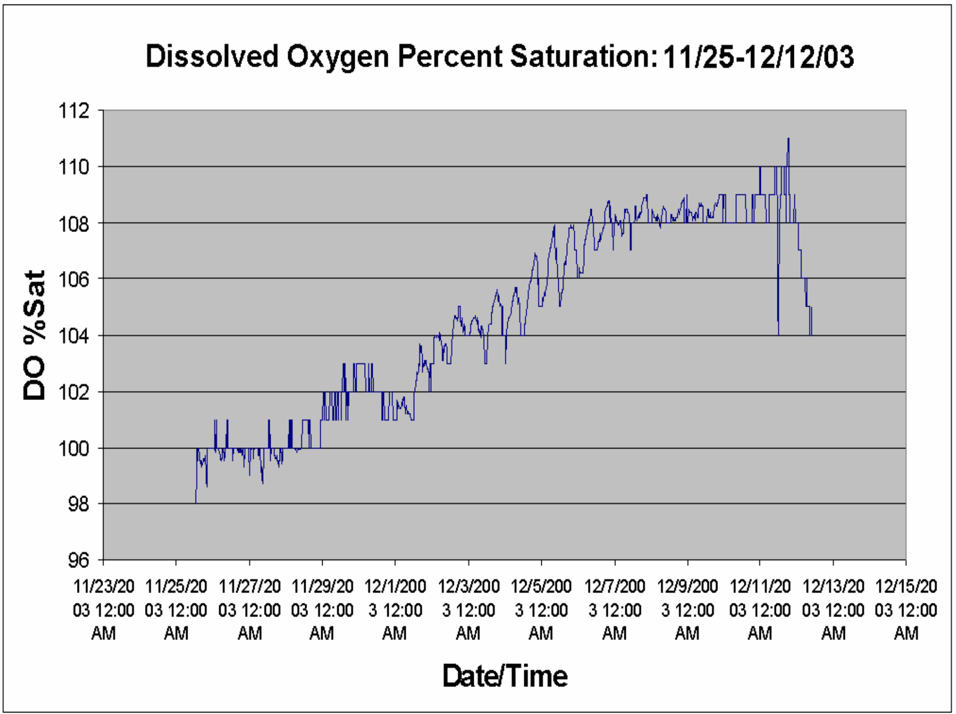


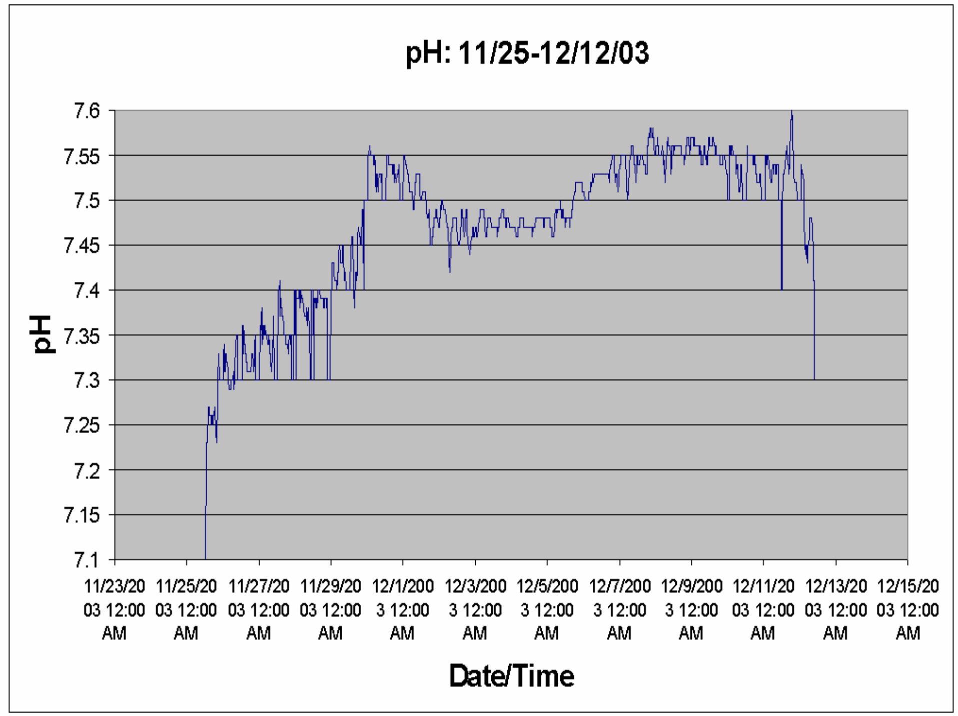

# Turbidity




Dissolved Oxygen: 11/25-12/12/2003
DO (mg/L)
16
15
14
13
12
11
10
11/23/2003 12:00 AM
11/25/2003 12:00 AM
11/27/2003 12:00 AM
11/29/2003 12:00 AM
12/1/2003 12:00 AM
12/3/2003 12:00 AM
12/5/2003 12:00 AM
12/7/2003 12:00 AM
12/9/2003 12:00 AM
12/11/2003 12:00 AM
12/13/2003 12:00 AM
12/15/2003 12:00 AM
Date/Time


Temperature: 11/25-12/12/03
Temperature (C)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
11/23/2003 12:00 AM
11/25/2003 12:00 AM
11/27/2003 12:00 AM
11/29/2003 12:00 AM
12/1/2003 12:00 AM
12/3/2003 12:00 AM
12/5/2003 12:00 AM
12/7/2003 12:00 AM
12/9/2003 12:00 AM
12/11/2003 12:00 AM
12/13/2003 12:00 AM
12/15/2003 12:00 AM
Date/Time


Dissolved Oxygen Percent Saturation: 11/25-12/12/03
DO %Sat
112
110
108
106
104
102
100
98
96
11/23/2003 12:00 AM
11/25/2003 12:00 AM
11/27/2003 12:00 AM
11/29/2003 12:00 AM
12/1/2003 12:00 AM
12/3/2003 12:00 AM
12/5/2003 12:00 AM
12/7/2003 12:00 AM
12/9/2003 12:00 AM
12/11/2003 12:00 AM
12/13/2003 12:00 AM
12/15/2003 12:00 AM
Date/Time


pH: 11/25-12/12/03
pH
7.6
7.55
7.5
7.45
7.4
7.35
7.3
7.25
7.2
7.15
7.1
11/23/2003 12:00 AM
11/25/2003 12:00 AM
11/27/2003 12:00 AM
11/29/2003 12:00 AM
12/1/2003 12:00 AM
12/3/2003 12:00 AM
12/5/2003 12:00 AM
12/7/2003 12:00 AM
12/9/2003 12:00 AM
12/11/2003 12:00 AM
12/13/2003 12:00 AM
12/15/2003 12:00 AM
Date/Time