SENSORS: A NEW WAY TO COLLECT DATA FOR ENVIRONMENTAL DECISON-MAKING?

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HOW IS ENVIRONMENTAL DATA CURRENTLY OBTAINED?

☒Process

- Define where discrete samples are collected
- Collect samples
- Take samples to lab. for analysis
- Wait for results
- Validate results
- Evaluate results

☒Problems

- Limited amount of data
- Limited spatial coverage
- No short or long-term temporal trends are possible

WHAT IF?

- it was possible to get real-time, continuous environmental data without having to physically obtain a sample

- What are the benefits of this type of data?

- What types of applications would this type of information be useful for?

- If the technology exists, what are some of the issues with the use of sensors?

CURRENT SENSOR ACTIVITY

- Commercial marketplace is booming
- Extensive academic and commercial research
- EPA
  - Strategic Plan 2006-2011: Goal 4
- NSF
  - National Ecological Observatory Network (NEON)
  - Sensors for Environmental Observatories report: 2006
- Interstate Technology Regulatory Council (ITRC)

WHAT DO I MEAN BY "SENSOR"?

- A sensor is any device that collects environmental data on water or soil in situ without the need to obtain a discrete sample. Sensors collect large amounts of data on a continuous basis over time, with the sensor often placed in one location.

TYPES OF SENSORS

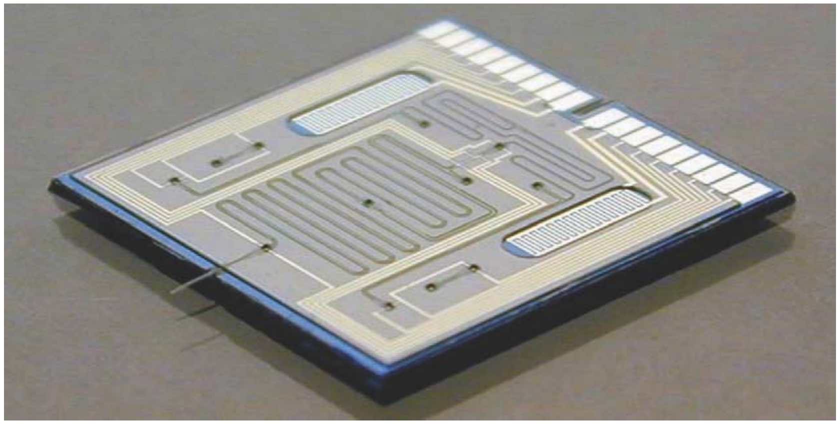
Sensor Category	Parameter	Cost ($)	Field-Readiness
Physical	Temperature	50-100	High
	Moisture, Content	100-500	High
	Flow Rate, Flow Velocity	1,000-10,000	High
	Pressure	500-1,000	High
	Light Transmission (Turbidity)	800 -2,000	High
Chemical	Dissolved Oxygen	800-2,000	High
	Electrical Conductivity	800-2,000	High
	pH	300-500	High
	ORP	300-500	Medium
	Major Ions (Cl^-, Na^+)	500-800	Low-Med
	Nutrients ($NO3^-$, $NH4^+$)	500-35,000	Low-Med
	Heavy Metals	NA	Low
	Small Organic Compounds	NA	Low
	Large Organic Compounds	NA	Low

Examples of environmental sensors: cost (NA=Not Available). (From: Distributed Sensing Systems for Water Quality Assessment and Management, WWC &CENS)

EXAMPLES OF SENSORS: PHYSICAL & CHEMICAL

Physical Sensors

Chemical Sensors



Lab. On a Chip

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BENEFITS TO SENSOR DATA COLLECTION

- ⌘Real time data availability
- ⌘Lower analytical cost
- ⌘Ability to evaluate trends
- ⌘Timely response to public concerns
- ⌘Transparency to data presentations

AREAS OF APPLICATION: SEPTIC SYSTEMS

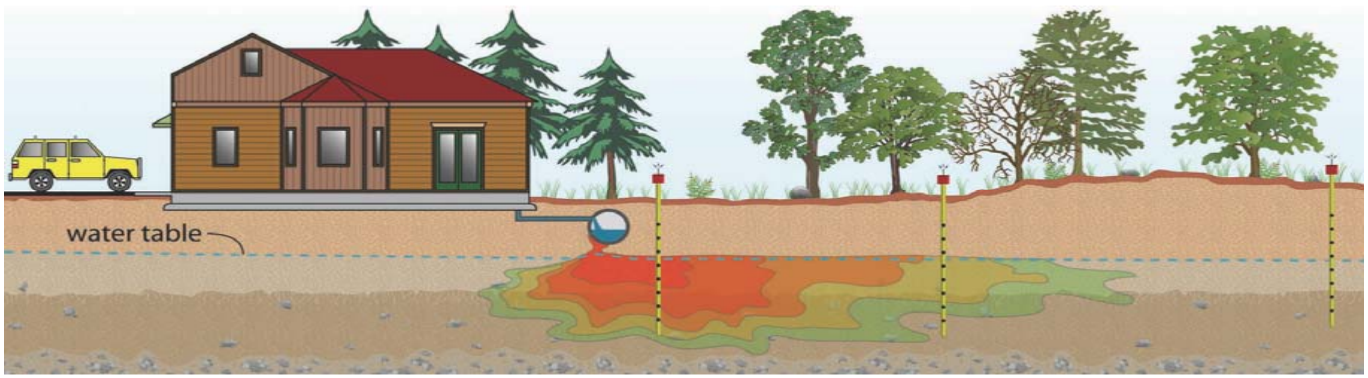

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Illustration of a sensing system used to monitor aqueous contaminants in soil and groundwater. Sensors embedded in the soil and groundwater monitor a chemical plume spreading from a source, such as a septic tank. If concentrations become too high, the system generates an alert. *Illustration: J. Fisher, UC Merced.*

- Septic Systems
  - Malfunctions are unpredictable & detrimental effects slow to accumulate
  - Temporal data provides info. on wastewater composition
  - "Meter Readers" could monitor septic systems

AREAS OF APPLICATION: NON-POINT SOURCE RUNOFF

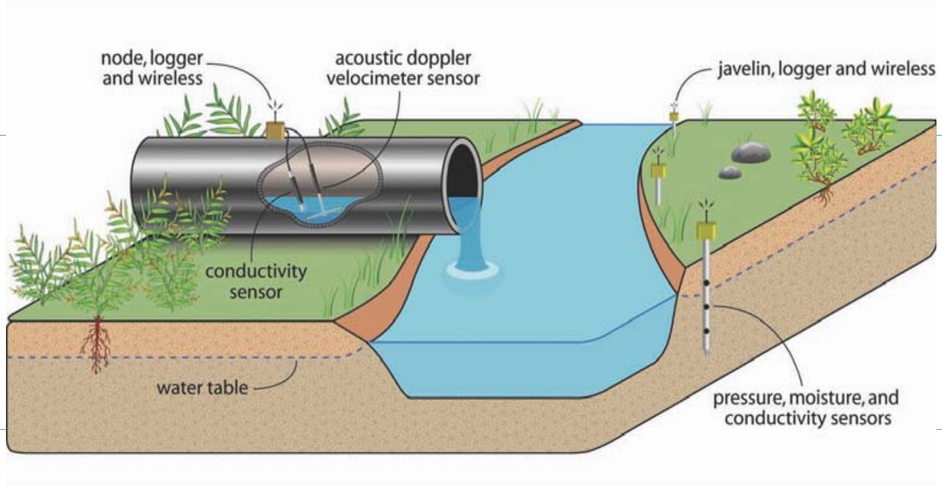

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Figure 4.2 Illustration of a hypothetical non-point source runoff drain and javeline-based monitoring system.
Illustration: J. Fisher, UC Merced.

- Non-Point Source Runoff
  - By its nature, NPS pollution is distributed over wide areas
  - Two scenarios: NPS discharges into ditches or through soils

AREAS OF APPLICATION: BEACH WATER QUALITY

Photo: G. Kleinheiz UW Oshosh

- Fecal levels do not correspond to actual pathogen levels
- Immunoassay promising; only detects live organisms
- More complete coverage will save $$$

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AREAS OF APPLICATION: COMBINED SEWER OVERFLOWS

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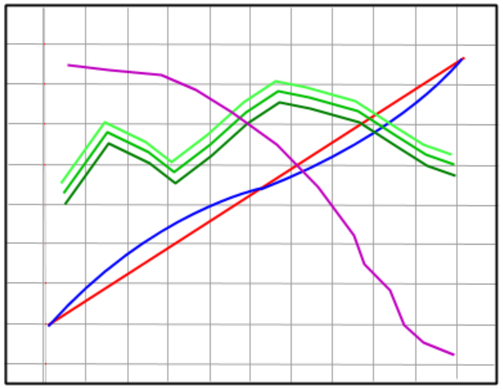
Photo © Stockphoto.com/JacobH

- Combined Sewer Overflows
  - Characterize effluent distribution
  - Actuation to minimize/avoid overflows

AREAS OF APPLICATION: GOLF COURSE MAINTENANCE

- Golf courses require lots of water, which is often a scarce resource
- Use of moisture sensors can minimize useage

ISSUES RE. SENSOR USE IN A REGULATORY ENVIRONMENT



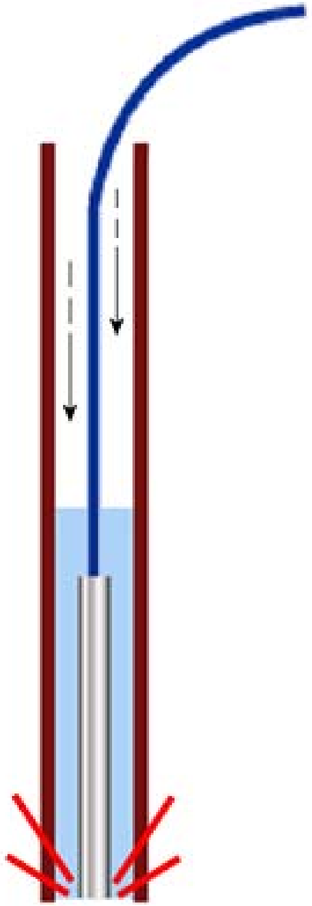
- ⌘Regulatory Acceptability
- ⌘Operational Reliability
- ⌘Ability to Generate Data of Defined Quality
- ⌘Limit of Detection Issues
- ⌘Data communication, management and storage

REGULATORY ACCEPTABILITY

- There do not seem to be any statutory barriers that would prevent most States from using sensor technologies to gather data for regulatory decision-making

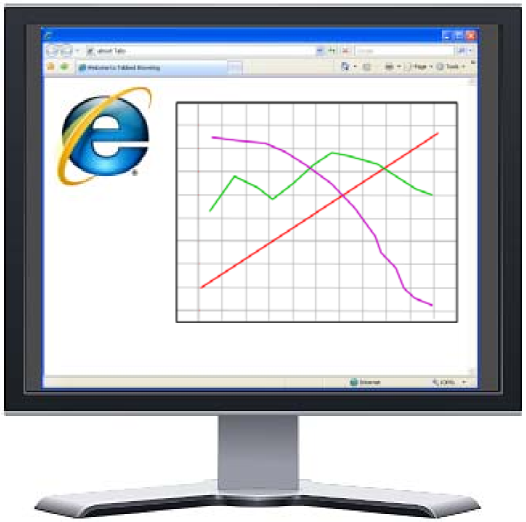
- Individual operating permits (with a typical 5 year renewal cycle) may need to be changed to enable sensor use

- **If the TNI FSMO is adopted, this could ease the regulatory acceptance of sensors**



OPERATIONAL RELIABILITY

- ⌘ Conditions where sensor will be deployed
- ⌘ Durability
- ⌘ Ease of installation
- ⌘ Power considerations
- ⌘ Communications Issues
- ⌘ Calibration and Maintenance

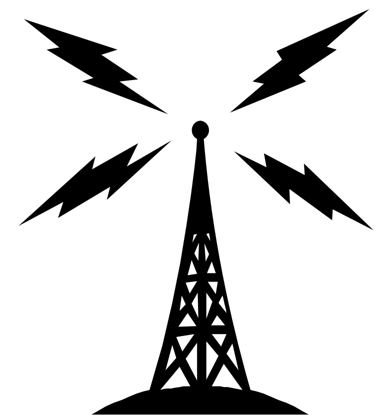


DATA QUALITY AND LIMITS OF DETECTION

- These are the key issues to most regulators
- On paper, most sensors can match the specs. of traditional measurement systems
- However, the LOD/LOQ may not be sufficient for some sensors to achieve regulatory requirements
- All of these issues must be thoroughly vetted before any sensor could replace a traditional data gathering system

DATA COMMUNICATION, MANAGEMENT AND STORAGE

- When asked, most State regulatory agencies say that their data management and storage systems can handle the potentially extremely large amounts of data sensors can provide



- Communications between the sensor and the recipient can be handled in several ways, and reliability is getting much better

SENSOR IMPLEMENTATION HURDLES

- ⌘Regulators are by nature risk-averse, skeptical and conservative; they all may not be from Missouri, but most all will ask: “show me”

- ⌘The only way the administrative and technical concerns about sensors can be overcome is via **pilot studies** that directly compare traditional data gathering approaches to sensors

SENSOR PILOT

- Funded for $75K via a competitive grant from EPA, Office of the Science Advisor
- Project team is a consortium of Federal and State regulators, consultants and instrument vendors
- Site: CAFO in Iowa under USDA oversight
- GW monitoring for nitrate has been conducted ~4X/year
- Existing analytical results vary widely (spatially & temporally)

SENSOR PILOT COMPONENTS

- ⌘Operations and communications
- ⌘ETV verification test
- ⌘GW plume monitoring

ETV VERIFICATION TEST

- The Environmental Technology Verification (ETV) Program **(www.epa.gov/etv)** verifies the performance of innovative technologies.
- ETV accelerates the entrance of new environmental technologies into the market.
- An ETV verification test will be conducted concurrently with this project (1 out of the 6 months)
- A peer-reviewed verification report will be issued on the studied technology (nitrate sensors)

SENSOR PILOT OBJECTIVES AND TIMEFRAME

- ⌘ Deploy nitrate sensors in at several monitoring wells @ IA CAFO in late 2009
- ⌘ Collect data for 6 months
- ⌘ Compare results and costs to traditional methods of collection and analysis
- ⌘ Examine the operational reliability of sensors in difficult weather conditions

SOME ADDITIONAL SENSOR OBJECTIVES

- Evaluate the GHG impact of data gathering traditionally vs. sensors
  - Proposed project with the USEPA and The College of New Jersey
- Study the long-term impacts of nitrate contamination to DW and GW for application to monitoring and reduction of deleterious health effects in developing countries

TAKE-HOME MESSAGES

- Sensors such as pH are already being used (and regulated) to gather environmental data
- The greater data density sensors provide may make their cost less than traditional approaches over time
- Sensors could be viewed as “environmentally friendly” alternative to traditional data gathering
- Sensors concerns need to be vetted via pilot studies before they can become part of the regulatory measurement framework