# MONITORING, MODELING AND DECISION MAKING:

# MAKING IT WORK

Thomas E. Davenport, USEPA
Donald W. Meals and Steven A. Dressing, Tetra Tech, Inc.

TETRA TECH, INC.

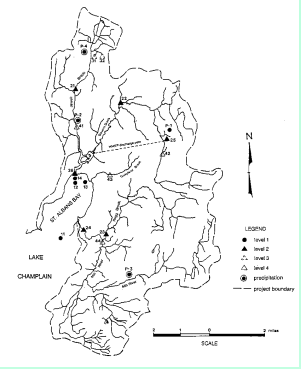
# Monitoring

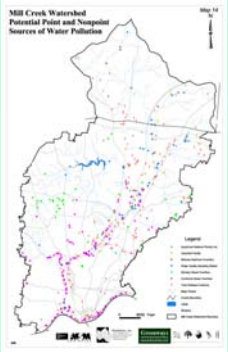
- Foundation of water quality management
- Provides essential data about the resource
- Can be expensive and challenging
- Requires careful design and execution to achieve objectives

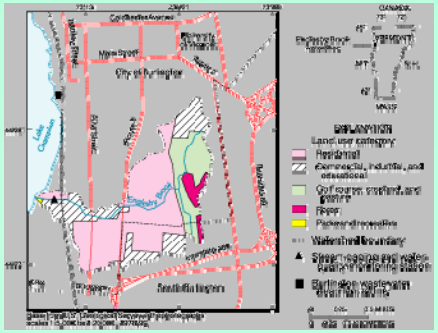
# Monitoring

Some major watershed monitoring projects have reported little or no improvement in water quality after extensive implementation of best management practices (BMPs) in the watershed:

- Uncooperative weather
- Improper selection of BMPs
- Mistakes in understanding of pollution sources
- Poor experimental design
- Lag time



# Monitoring

Increased integration of fragmented environmental monitoring efforts to improve the collection, analysis, and reporting of data:

- Strategic assessment of objectives
- Focus on utility of resulting data

THE H. JOHN HEINZ III CENTER FOR SCIENCE, ECONOMICS AND THE ENVIRONMENT

THE HEINZ CENTER

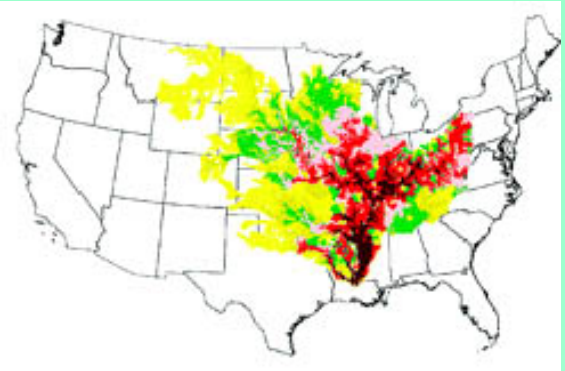
2006. Filling the gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Conditions

# Modeling

- Forecasting
- Evaluating potential alternatives
- Requires data
- Application in the absence of observed data is problematic
- Skepticism and uncertainty can compromise utility for watershed planning

# Modeling

SPARROW



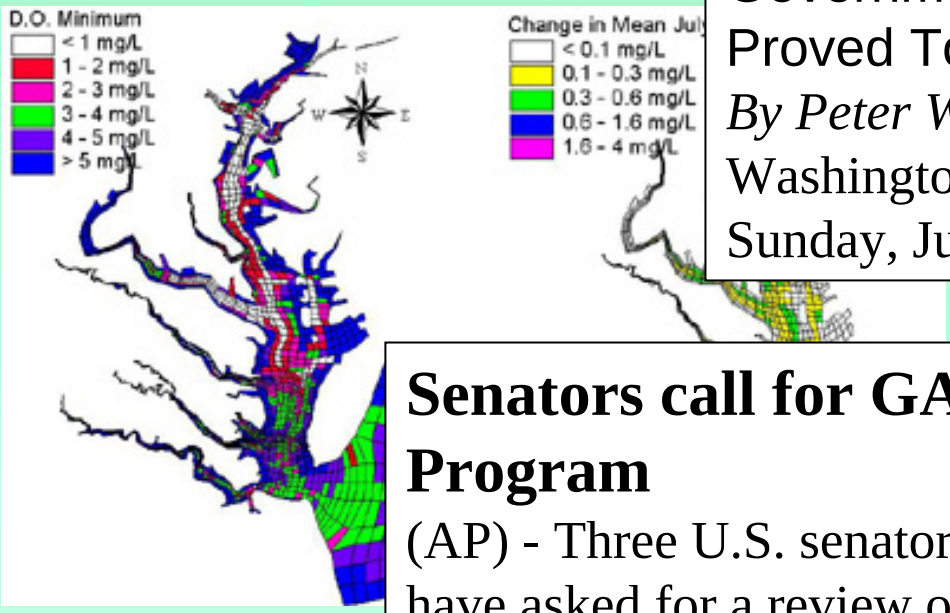
Predicts contaminant flux, concentration, and yield in streams http://water.usgs.gov/nawqa/sparrow/

Used to evaluate alternative hypotheses about the important contaminant sources and watershed properties that control transport over large spatial scales.

Disputes or misunderstandings over modeled vs. measured pollutant loads in economic and political conflicts over source identification and choices of potential actions for remediation

# Modeling

Chesapeake Bay Watershed Model




**Bay Pollution Progress Overstated**

Government Program's Computer Model Proved Too Optimistic

*By Peter Whoriskey*

Washington Post Staff Writer

Sunday, July 18, 2004; Page A01

**Senators call for GAO review of Chesapeake Bay Program**

(AP) - Three U.S. senators, including Virginia's John Warner, have asked for a review of the EPA's Chesapeake Bay Program following reports that the federal agency directing bay restoration efforts has overstated environmental achievements.

http://www.chesapeakebay.net/model.htm

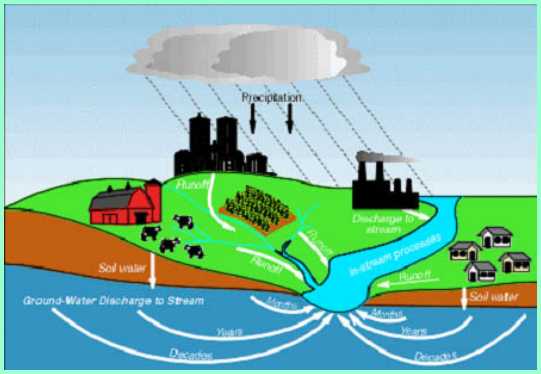
# Role of Monitoring

- Identify problems
- Establish baseline conditions
- Document change
- Assess program/project effectiveness
- Inform stakeholders
- Assess compliance
- Provide information/data to support models

# Role of Monitoring

- Data that document water quality improvement lend credibility to project planning and implementation
- Information relevant to stakeholders
- Measurement of actual watershed conditions is powerful tool for changing behavior

# Monitoring challenges

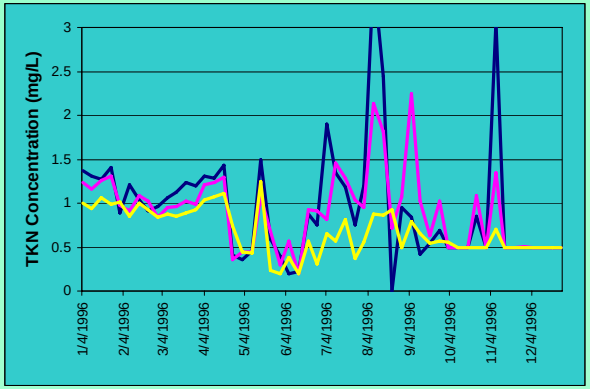



## Design problems

- ✓ Failure to measure what is needed
- ✓ Inadequate problem identification
- ✓ Misunderstanding of the system being monitored
- ✓ Statistically weak design

L.M. Reid. 2001. The epidemiology of monitoring. *J. AWRA* 37(4):815-820.

# Monitoring challenges




## Procedural problems

- ✓ Failure to evaluate data regularly
- ✓ Lack of collateral information
- ✓ Poor institutional integration
- ✓ Bad or misunderstood technology
- ✓ Staffing and training

L.M. Reid. 2001. The epidemiology of monitoring. *J. AWRA* 37(4):815-820.

# Monitoring challenges

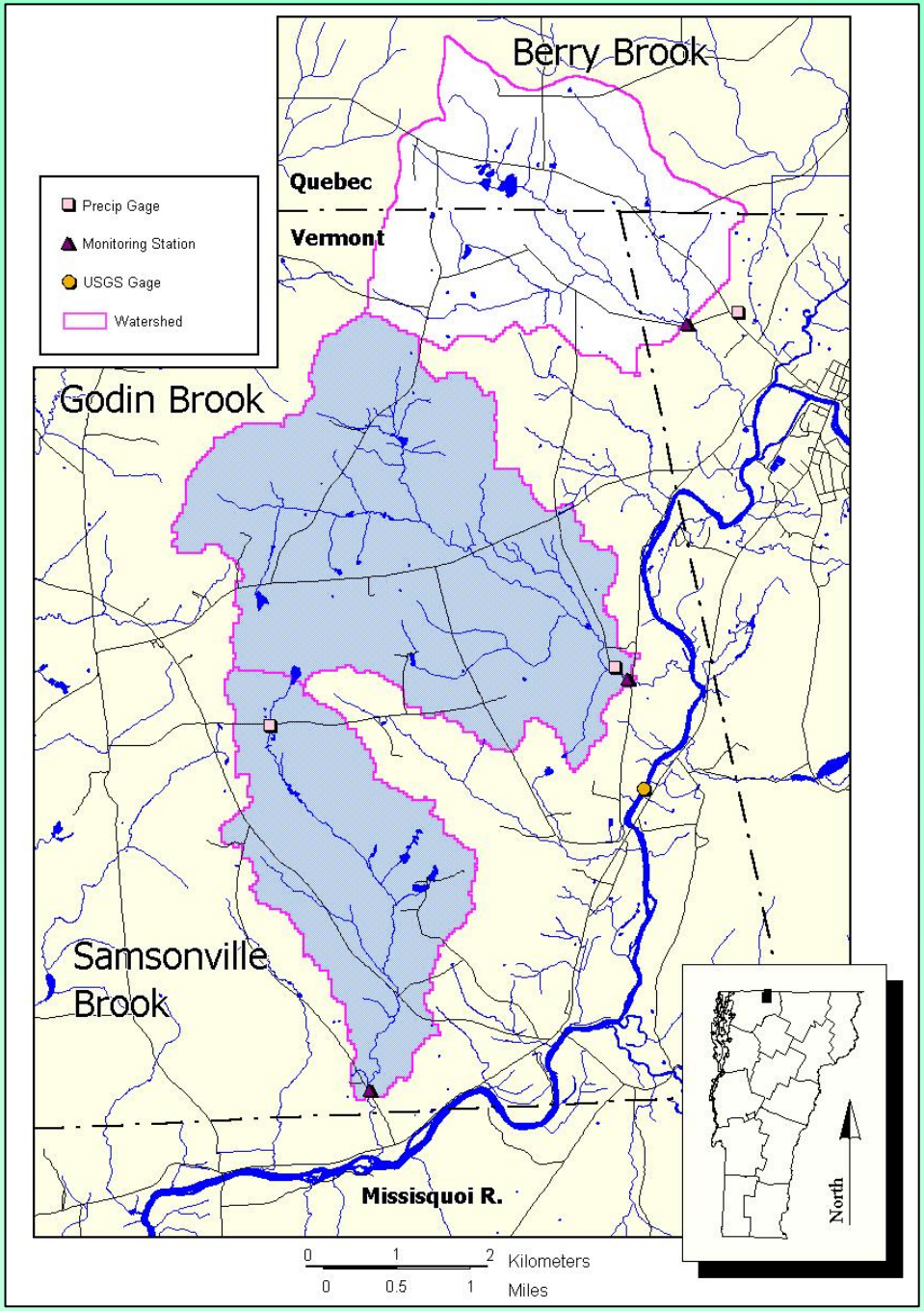
- Procedural problems can sabotage even a well-designed monitoring program
- Procedural problems can be corrected with good management, training, and resources
- **Flawed design can doom a monitoring program from the start**

# Examples of effective watershed monitoring from the USEPA National Nonpoint Source Monitoring Program

# VT Lake Champlain Basin NMP Project 1993 - 2001

Evaluate effectiveness of livestock exclusion, streambank protection, and riparian restoration in reducing runoff of nutrients, sediment, and bacteria from agricultural land to surface waters

- **Paired watershed design**
- Continuous discharge
- Flow-proportional automated composite sampling (weekly)
  - ✓Total Phosphorus (TP)
  - ✓Total Kjeldahl Nitrogen (TKN)
  - ✓Total Suspended Solids (TSS)
- Bi-weekly grab sampling
  - ✓ Indicator bacteria
  - ✓ Temp., conductivity, D.O.
- Annual biomonitoring
  - ✓ Macroinvertebrates
  - ✓ Habitat
  - ✓ Fish
- Annual land use/management



# RESULTS

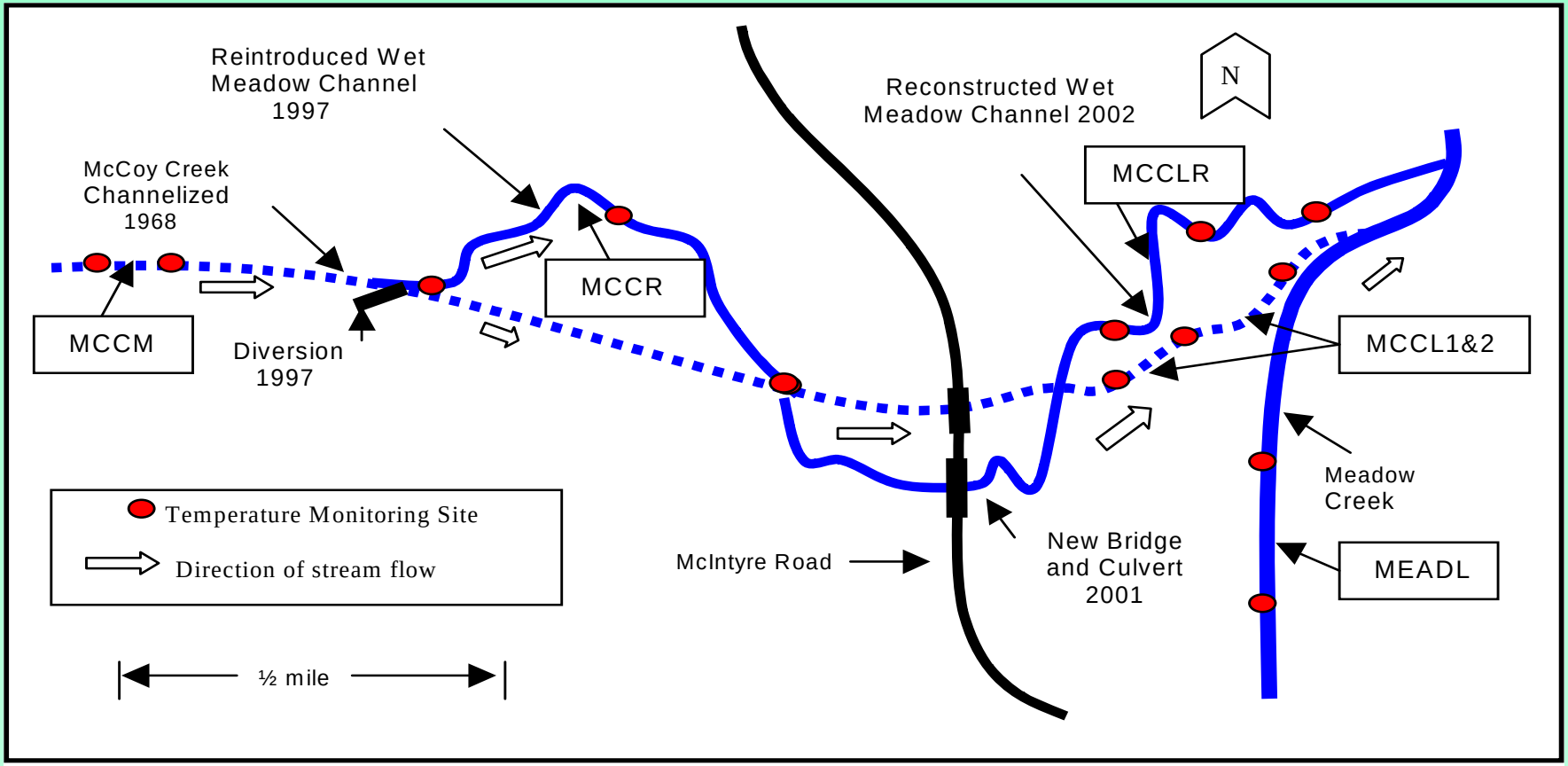
| | | |
|---|---|---|
| [TP] | -15% | |
| [TKN] | -12% | |
| [TSS] | -34% | |
| *E. coli* | -29% | |
| Temperature | -6% | |
| TP load | -49% | -800 kg/yr |
| TKN load | -38% | -2200 kg/yr |
| TSS load | -28% | -115,000 kg/yr |

Macroinvertebrate IBI improved to meet biocriteria
No significant change in fish community

# OR Upper Grande Ronde NMP Project 1995 - 2003

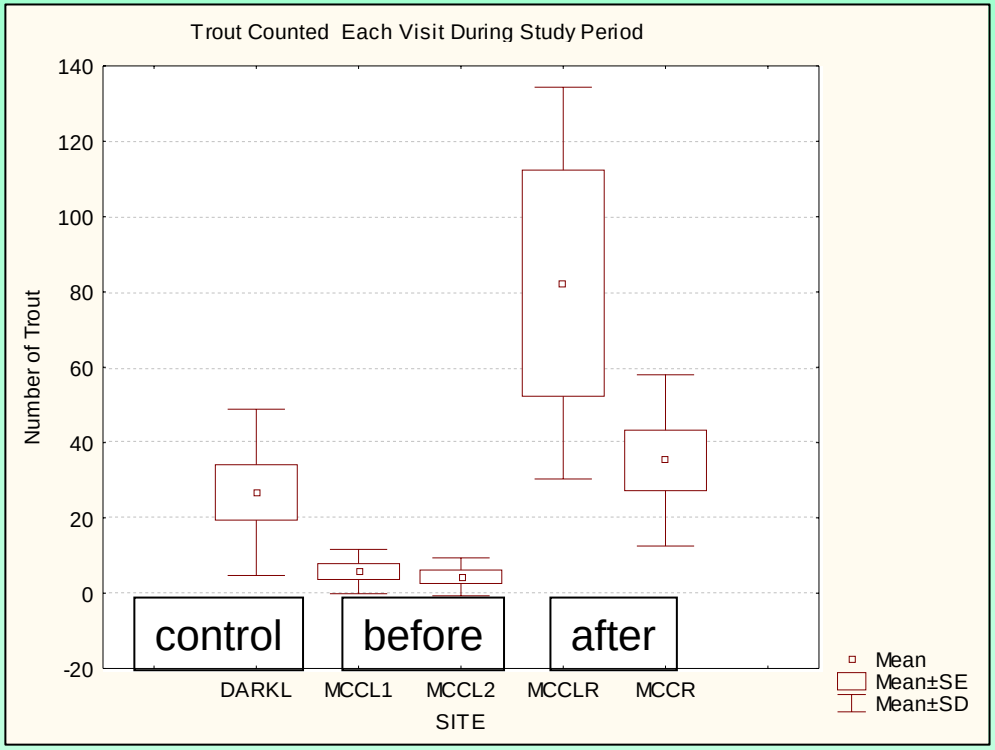
Improve salmonid community through restoration of habitat and stream temperature regime

Document effectiveness of channel restoration on water temperature and salmonid community




- **Before/after channel restoration, with control**
- Continuous air & water temperature, periodic habitat assessment, snorkel surveys for fish monitoring

# RESULTS




- Cooler water temperatures in pools and deeper runs
- Reduced width-depth ratios compared to unrestored reaches
- Rainbow trout numbers increased in restored reaches, while constant or decreasing in unrestored and control reaches

# Monitoring basics

- Understanding of WQ problems, pollutants, and sources;
- Clear monitoring objectives;
- Specific experimental design that accounts for weather, land use, and other external factors;
- Where, when, how, and how often samples will be taken;
- How samples will be analyzed;
- How the resulting data will be stored, retrieved, analyzed, and interpreted; and
- How the results will be communicated

# Role of Modeling

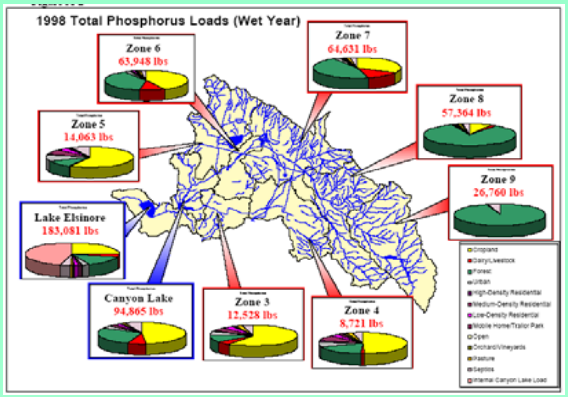
Planning = making informed choices about which path to take toward the future

Modeling:

Tools for visualizing potential results during the planning process

Means to forecast the likely impacts of alternative management options

# Role of Modeling




Screening

- Initial estimates of flow and pollutant loads
- Guide for monitoring

Characterization

- Link sources to water quality impacts
- Evaluate relative magnitude of sources

# Role of Modeling

Land Treatment

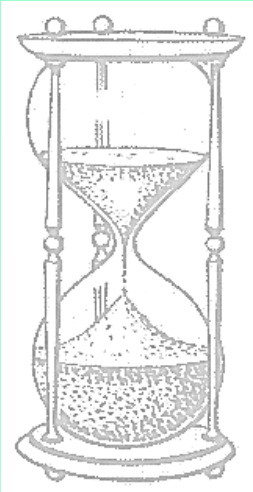
- Simulate pollutant transport processes
- Identify critical areas
- Predict pollutant reductions
- Analyze effectiveness and cost of alternatives

Waterbody response

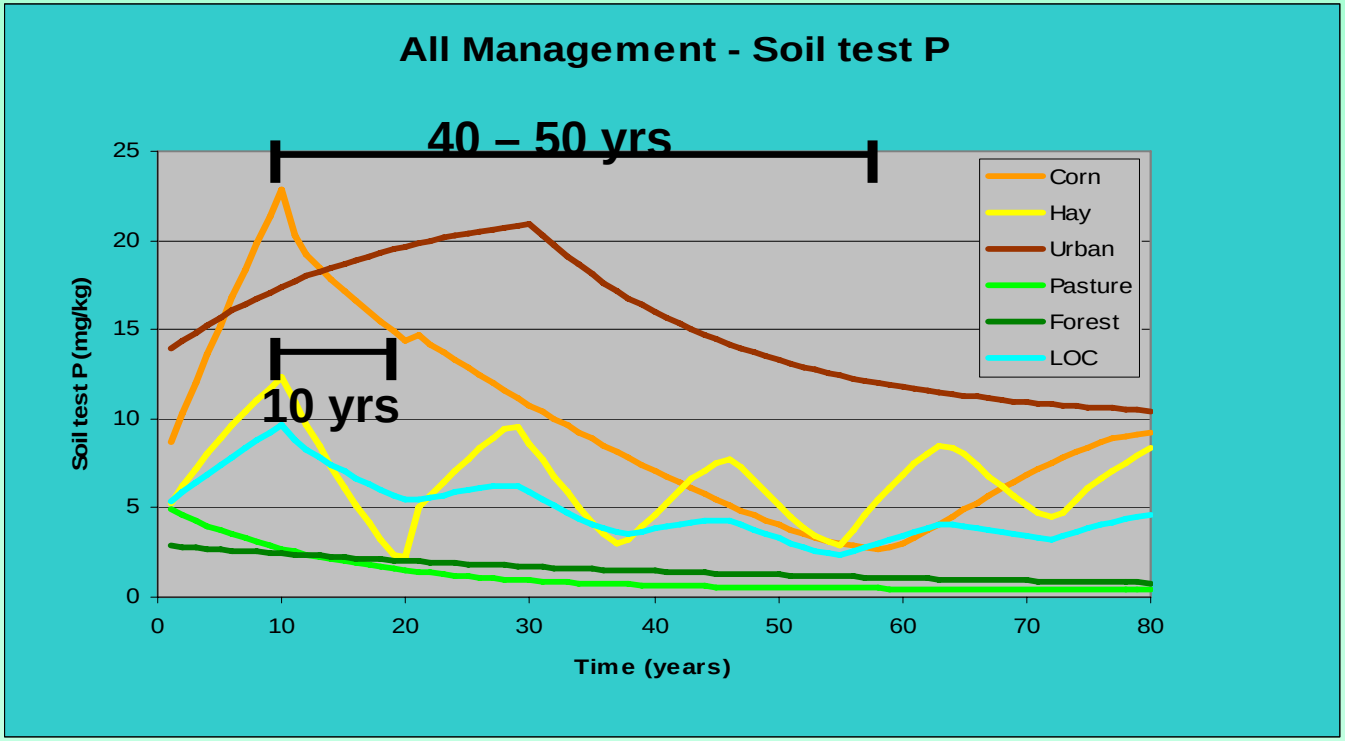
Guide monitoring programs

- Testable hypotheses
- Establish monitoring locations, frequency, etc.

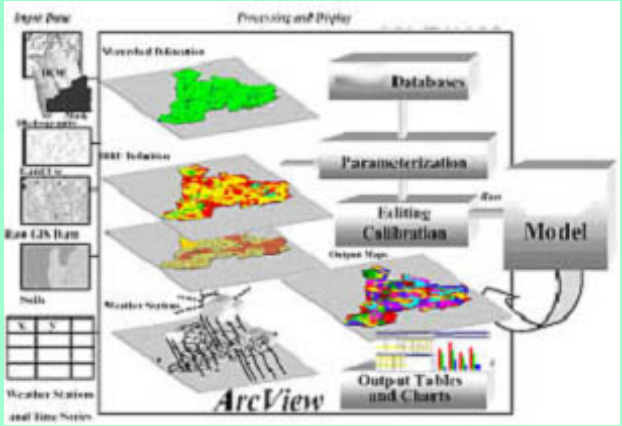
# Role of Modeling



Predict future water quality changes to estimate time required to achieve results from watershed treatment programs, i.e., lag time.



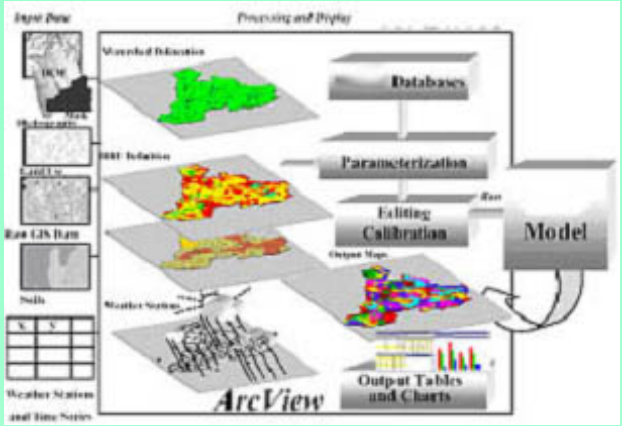
# Modeling challenges




- Data required
  - ✓ Setting model parameters
  - ✓ Calibration
  - ✓ Validation

- Technical and financial resources required

# Modeling challenges




- May be impaired by inappropriate or outdated data
  - ✓ Soil surveys
  - ✓ Curve number
  - ✓ TR-55

# Modeling challenges

- Model results require analysis and interpretation to be useful

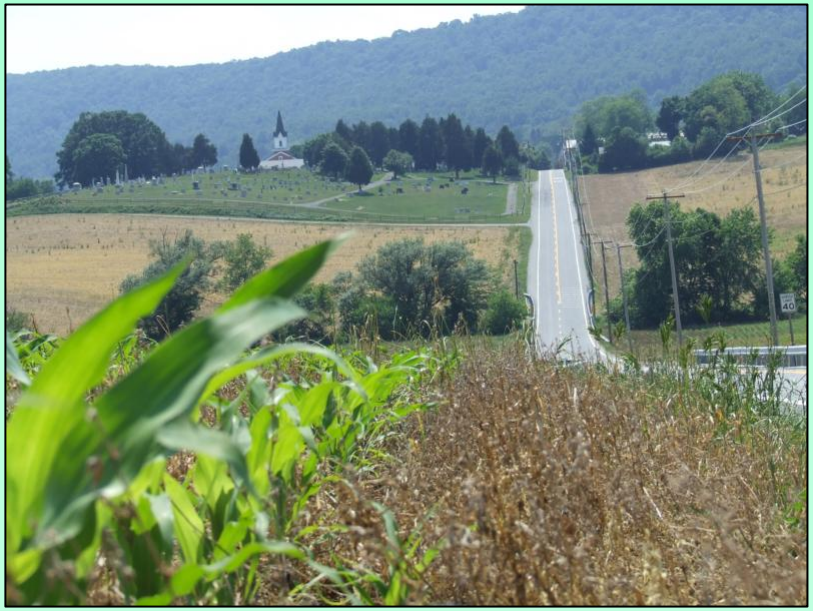
# Modeling challenges

Use of models cannot replace monitoring, especially for project evaluation.

The most convincing evidence of watershed project effectiveness is actual measurement of conditions in the watershed and in the water body

# Examples of effective use of modeling from the USEPA National Nonpoint Source Monitoring Program

# Warner Creek, MD



Demonstrate cropland BMP effectiveness and determine parameters for SWAT model for application to similar watersheds elsewhere in the state

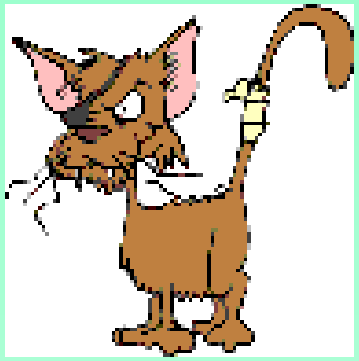
# Peacheater Creek, OK

Used SIMPLE (*Spatially Integrated Models for Phosphorus Loading and Erosion*) to identify high-risk P sources in watershed to design land treatment plan

# Otter Creek, WI

BARNY model used to supplement site assessment to rank critical dairies based on phosphorous loadings from animal confinement areas.

# Integrating Monitoring & Modeling



Monitoring and modeling are not mutually exclusive.

Each tool has strengths and weaknesses.

Neither by itself can usually provide all of the information needed for water quality decision-making.

# Integrating Monitoring & Modeling

**Monitoring**

Real evidence of water quality impairment

Best evidence of water quality restoration

**Modeling**

Extend and apply the knowledge

Forecast future response to alternatives

# Integrating Monitoring & Modeling

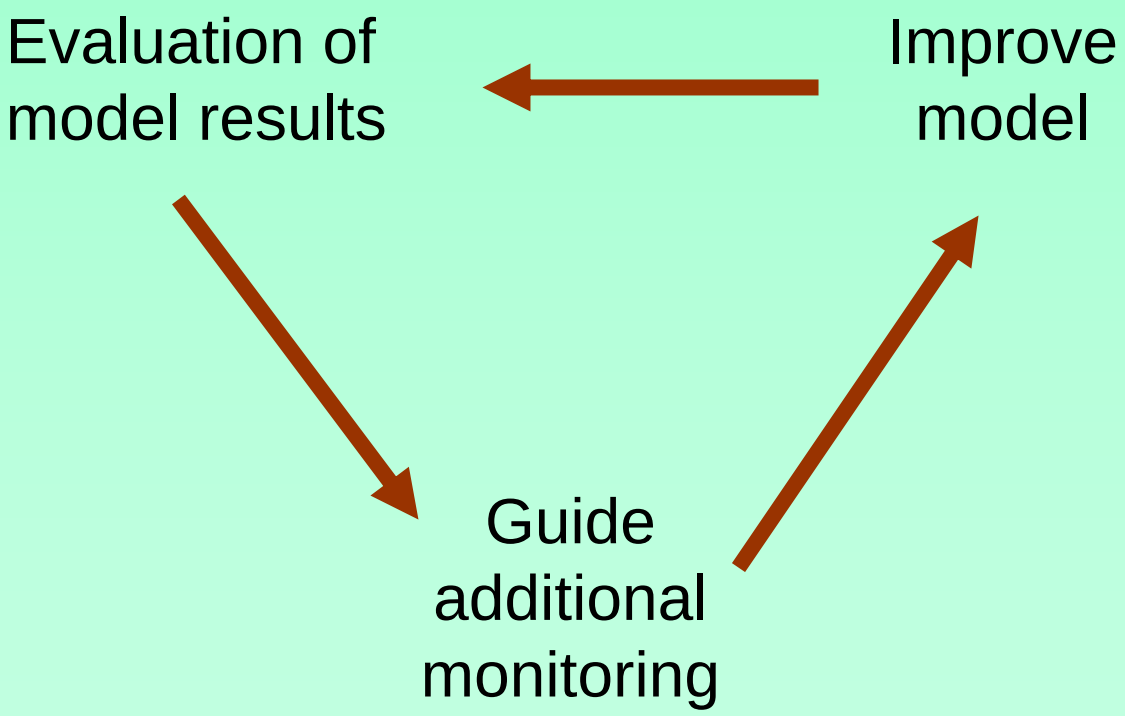
**Monitoring**

Fundamental knowledge about generation, fate, and transport of nonpoint source pollutants

**Modeling**

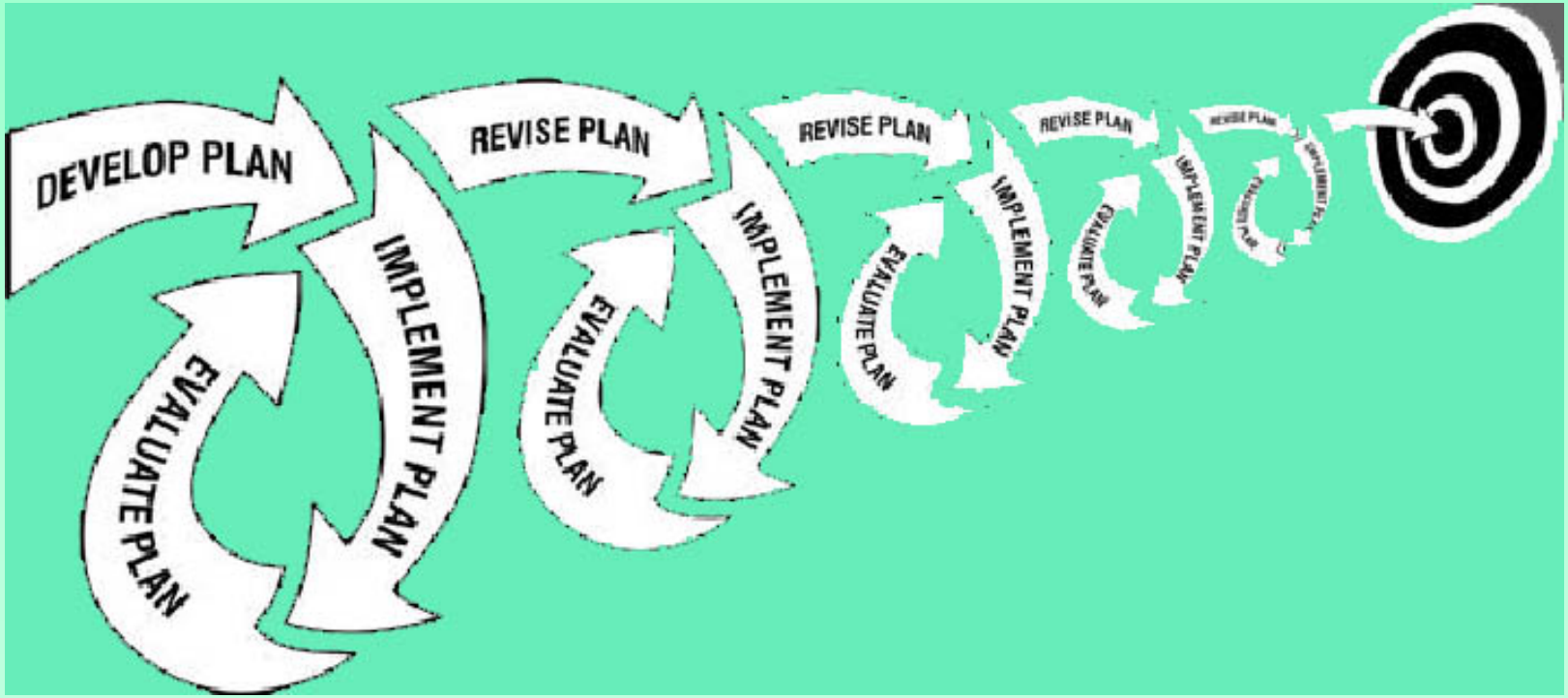
Means to assemble, express, and test current state of understanding

# Integrating Monitoring & Modeling



# Integrating Monitoring & Modeling

Adaptive management




Systematic process for continually improving management approaches by learning from the outcomes of the BMPs having been installed

# Recommendations

**Use the strengths of both**

- Simulations and extrapolations must not replace on-the ground monitoring
- Modeling can provide guidance on where and how the on-the-ground monitoring is best conducted
- Monitoring cannot practically compare numerous scenarios or extrapolate effects far into the future
- Data collected through monitoring is essential for calibration and validation of models.

# Simple example

VUSP
VILLANOVA URBAN STORMWATER PARTNERSHIP

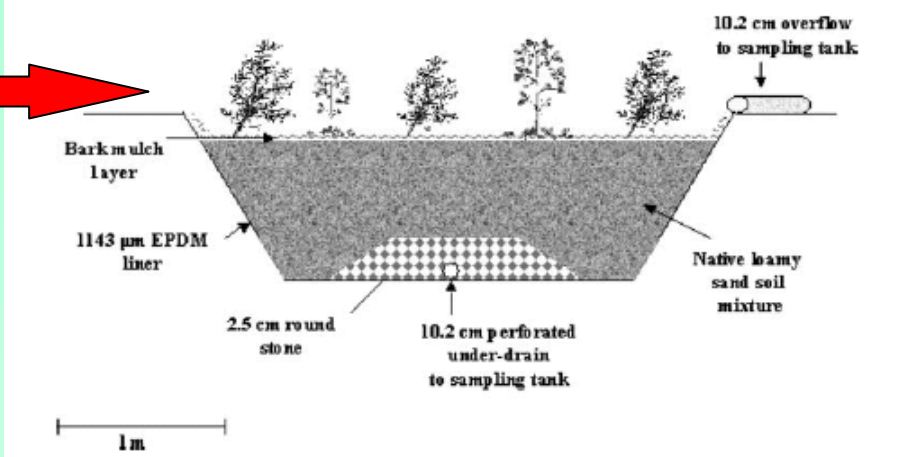



*Figure 1.* Cross-section of rain garden in Haddam, CT.

# Recommendations

**Start from objectives, not budget**

- Models selected by cost before setting objectives are unlikely to meet needs
- A monitoring program based solely on budget may collect too few samples, too infrequently, yielding data that cannot serve project objectives

★ **Begin with objectives and design the program to do what can be done well to meet those objectives**

# Recommendations

## Pay attention to source data

Availability of data at consistent scales and of known quality is essential to an integrated monitoring-modeling effort.

# Recommendations

**Include a model documentation plan**

- Model name and version
- Source of model
- Purpose of model application
- Model assumptions
- Data requirements and source of data sets
- Uncertainty (confidence levels) of modeling results

# Recommendations

**Develop a QAPP**

**… and use it!**