When to Monitor or Model

For Program Evaluation
in

TETRA TECH

complex world | CLEAR SOLUTIONS™

Your Watershed

USGS Circular 1270, 2004

Focus

- The big picture (i.e., delivery of nutrients to the Gulf)

Monitoring

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

Role of Monitoring

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

Strengths of Monitoring

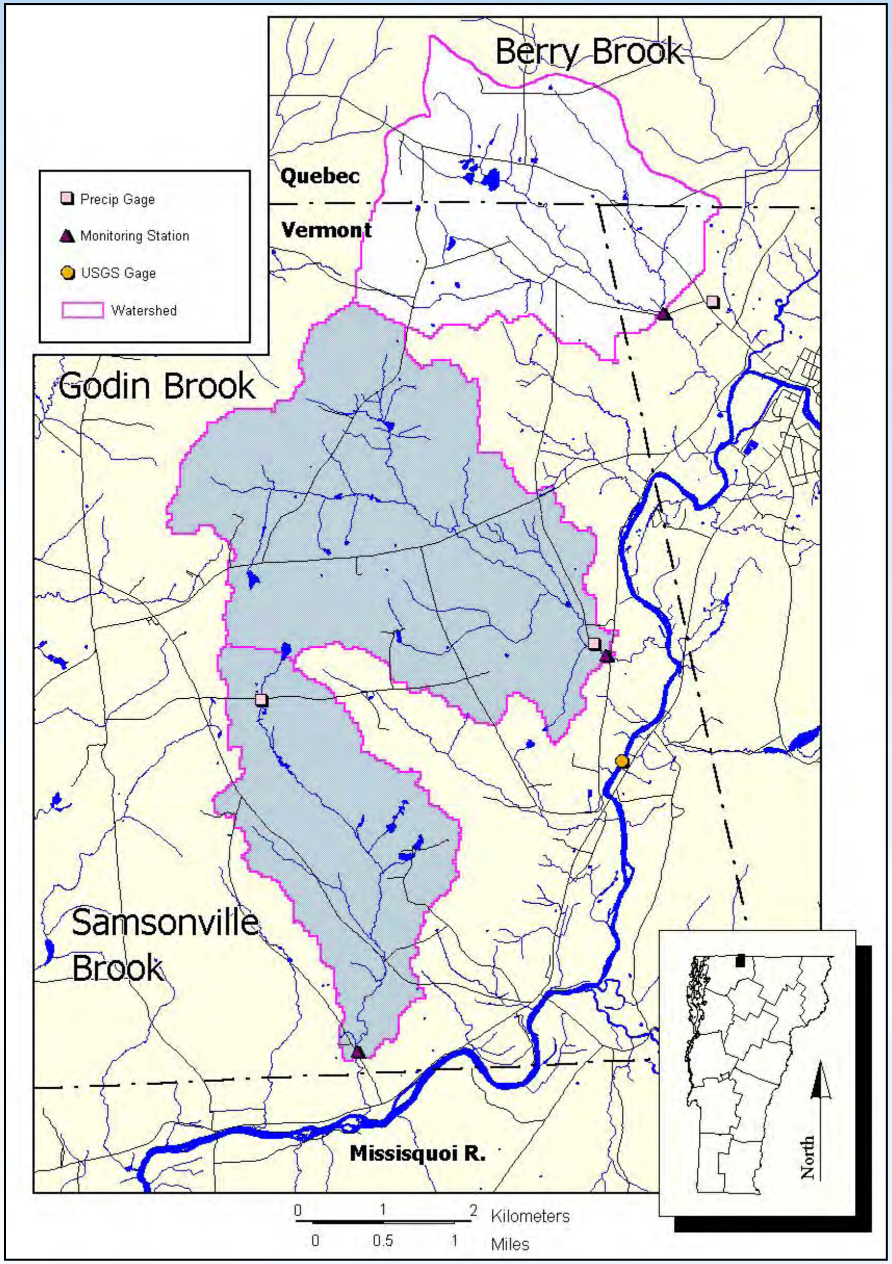
- Data that document water quality improvement lend credibility to project planning and implementation
- Information relevant to stakeholders
- Measurement of actual watershed conditions is powerful tool for changing behavior

VT Project 1993 – 2001
USEPA National Nonpoint Source Monitoring Program

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)
  - TP, TKN, TSS
- Bi-weekly grab sampling
  - Indicator bacteria, temp., conductivity, D.O.
- Annual biomonitoring
  - Bugs, habitat, fish
- Annual land use/management

Meals



Results

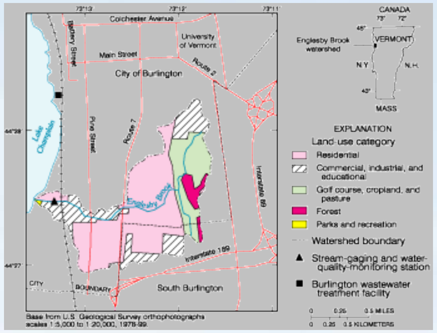
[TP]	-15%	
[TKN]	-12%	
[TSS]	-34%	
E. coli	-29%	
Temperature	-6%	
TP load	-49%	-800 kg/yr
TKN load	-38%	-2200 kg/yr
TSS load	-28%	-115,000 kg/yr

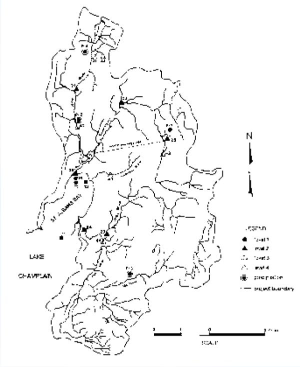
Macroinvertebrate IBI improved to meet biocriteria.
No significant change in fish community.

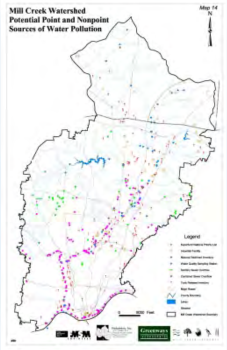
Monitoring Weaknesses

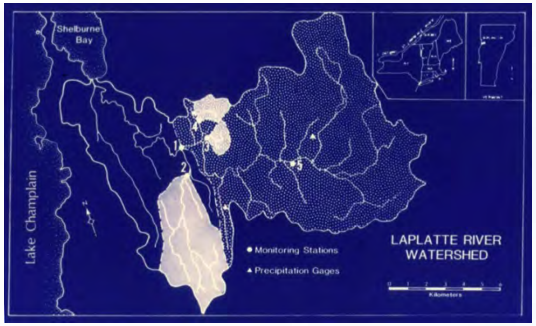
Several major watershed monitoring projects reported little or no improvement in water quality after extensive implementation of best management practices (BMPs) in the watershed:

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

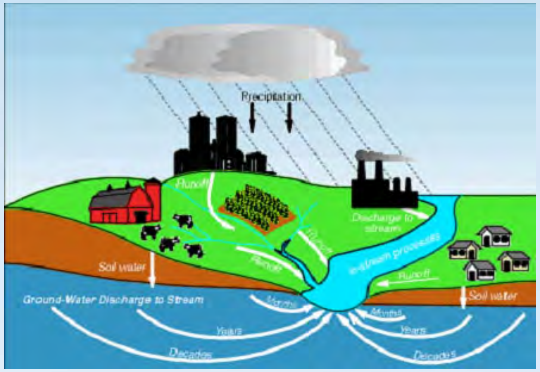








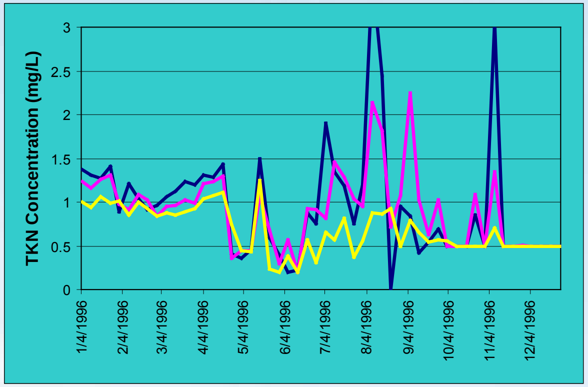
Monitoring Challenges



- ▶ 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



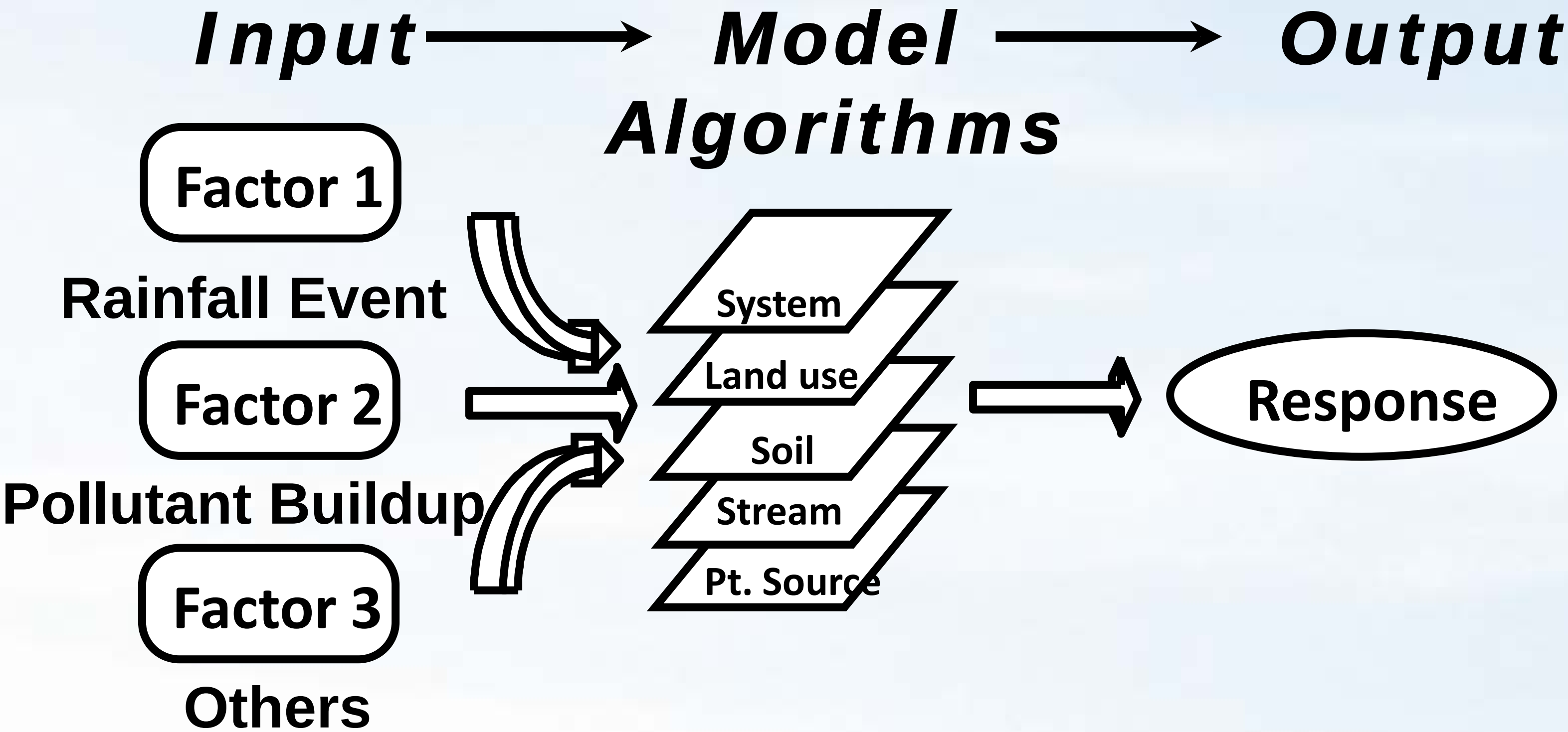
- ▶ Procedural problems
  - Failure to evaluate data regularly
  - Lack of collateral information
  - Poor institutional integration
  - Bad or misunderstood technology
  - Staffing and training

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

Monitoring Challenges

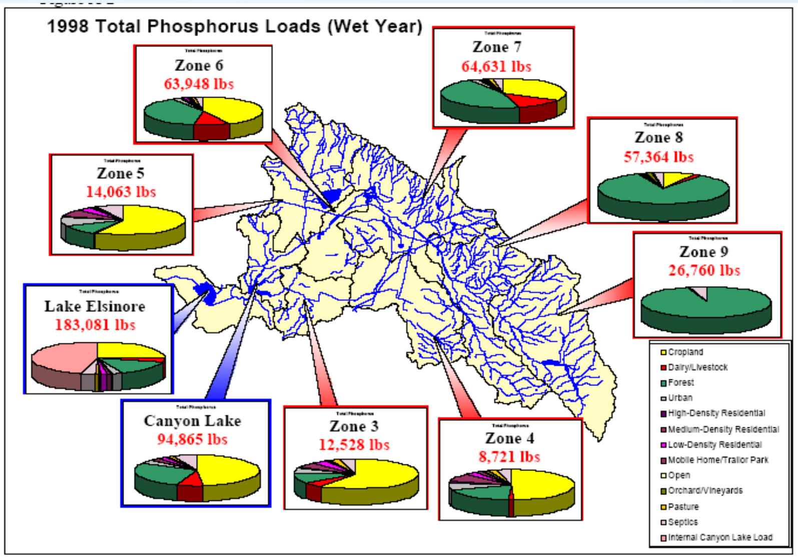
- Procedural problems can sabotage even a well-designed monitoring program
- Procedural problems can be corrected with good management, training, and resources
- **Flawed design can doom a monitoring program from the start**

Modeling


Input
Model Algorithms
Output
Factor 1
Rainfall Event
Factor 2
Pollutant Buildup
Factor 3
Others
System
Land use
Soil
Stream
Pt. Source
Response

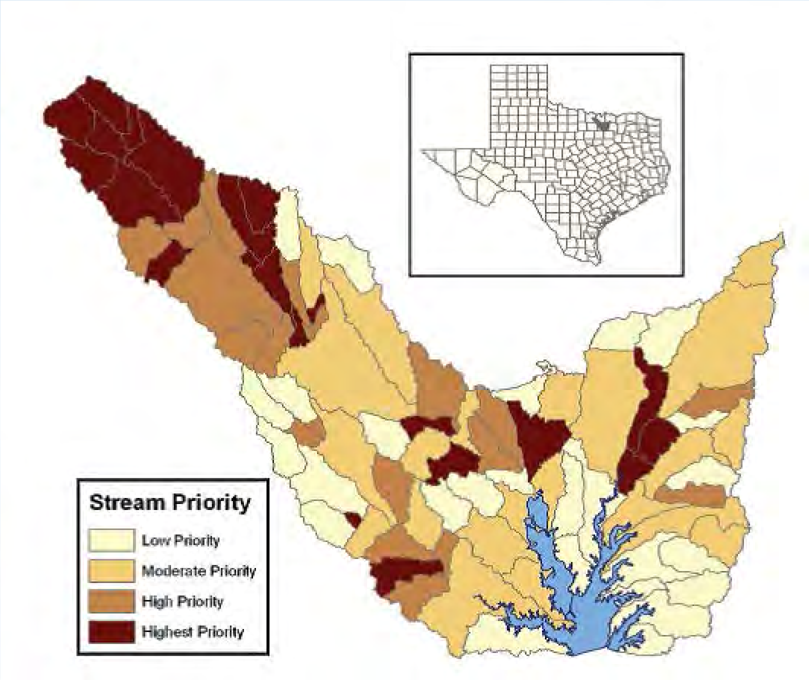
Role of Modeling

- Planning
  - Evaluate potential alternatives
- Screening
  - Initial estimates of flow and pollutant loads
- 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
  - Assess alternatives
- ► Waterbody response
  - Initial estimates of flow and pollutant loads



Atkinson et al. 2010

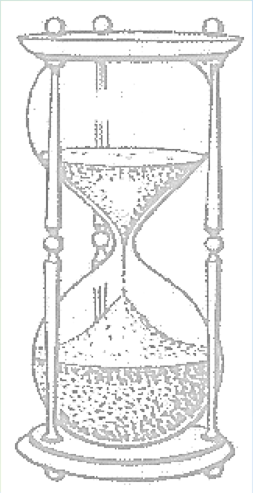
Role of Modeling

- Guide Monitoring Design
  - Help form testable hypotheses based on:
    - Estimation of source contributions
    - Projections of possible load reductions
  - Help determine monitoring locations by:
    - Identifying major agricultural and non-agricultural sources
    - Projecting locations where greatest improvements are likely from BMPs

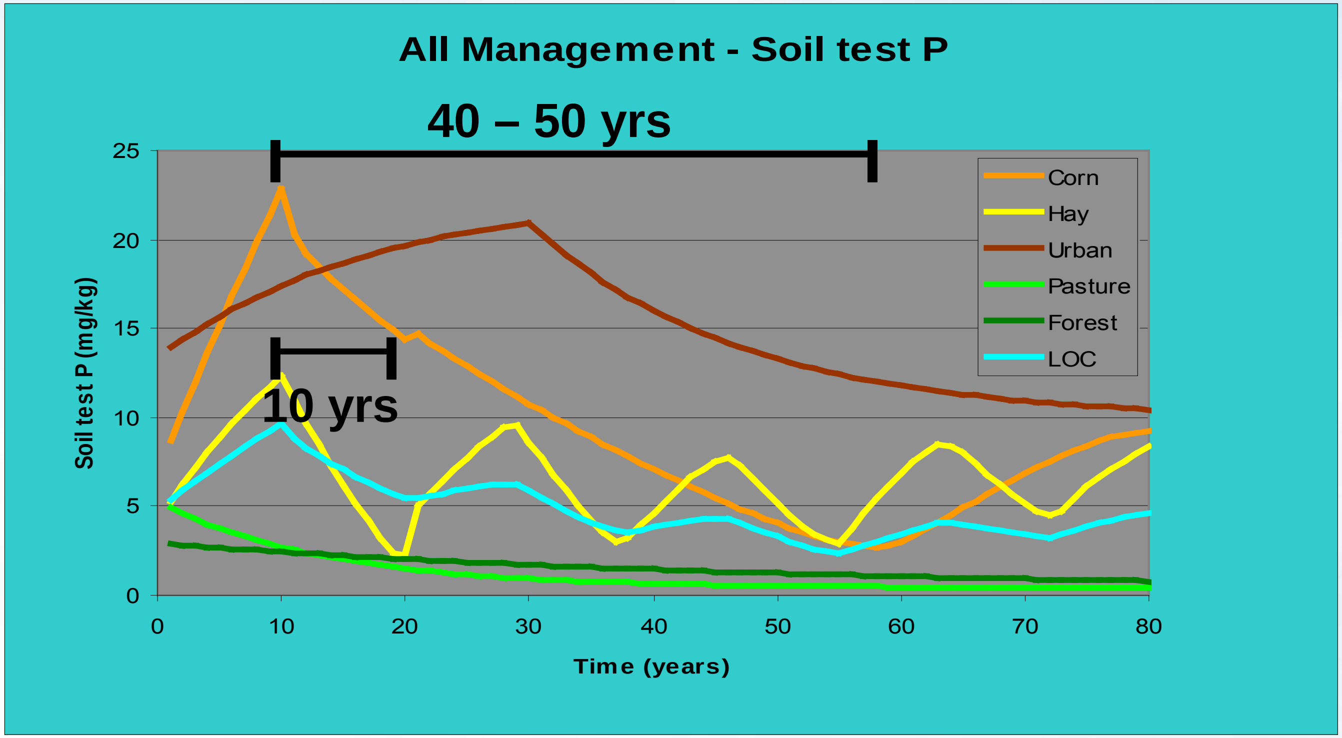
Role of Modeling

- ► Guide Monitoring Design (cont.)
  - ▪ Increase likelihood of achieving monitoring objectives
    - Minimize surprises such as non-agricultural sources that mask load reductions at agricultural sources
      - – E.g., St. Albans Bay, VT RCWP – measured improvements were due primarily to upgraded WWTP
    - Help determine monitoring frequency based on:
      - – Estimated change in pollutant loads
      - – Timeframe for estimated change (lag time estimation)
      - – Variability

Role of Modeling-Lag Time



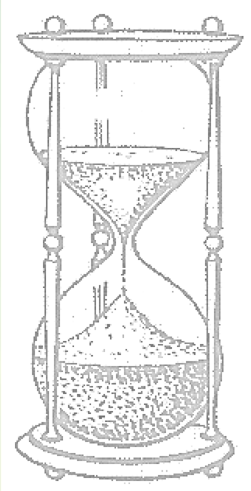
Predict future water quality changes to estimate time required to achieve results from watershed treatment programs, i.e., lag time.



Meals

Role of Modeling – Lag Time

- Garvin Brook, MN RCWP Project
  - 15 wells drilled for baseline monitoring were later found to yield water from 30 years earlier.
    - Didn't reflect current conditions
    - Would not reflect near-term land management
    - Would never see changes in a short-term monitoring project



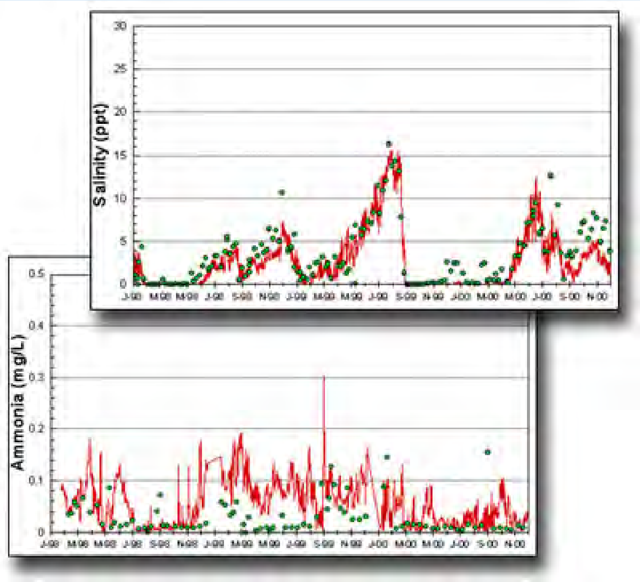
Wall et al 1992

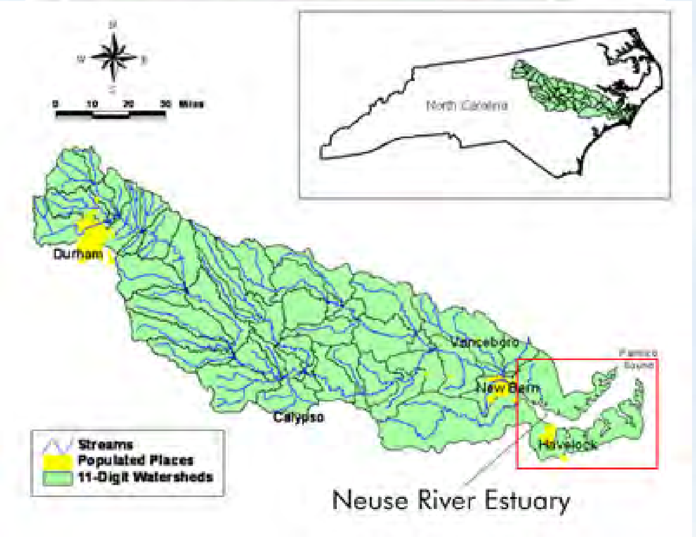
Modeling to assess potential lag time can help establish reasonable goals for measuring change in pollutant loads.

Helps determine where to monitor (shorter term changes) and where to model (longer term changes) within budget limitations.

Strengths of Modeling

- ► Can extend the knowledge gained from monitoring
- ► Forecast future response of alternative actions
- ► Integrates various data and information to further test our understanding





Davie, Tt 2006

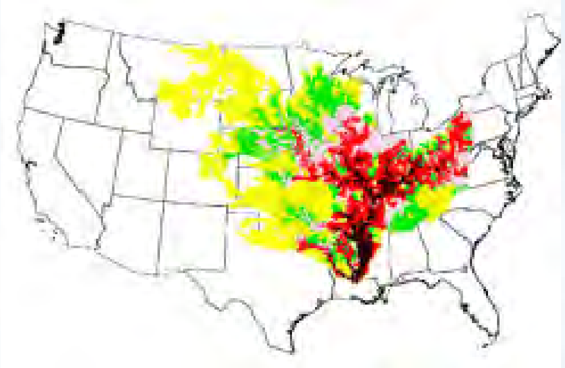
Modeling Weaknesses

- ► Application in the absence of observed data is problematic
- ► Skepticism and uncertainty can compromise utility for watershed planning

www.skepticnorth.com

SPARROW

- SPAtially Referenced Regression On Watershed attributes http://water.usgs.gov/nawqa/sparrow/
- Hybrid statistical/mechanistic watershed model.
- Used to estimate total P and total N yields from small watersheds (median size ~ 14,800 acres) to Gulf of Mexico



Alexander, et al. 2008. Differences in Phosphorus and Nitrogen Delivery to the Gulf of Mexico From the Mississippi River Basin. Environmental Science and Technology 42:822-830.

SPARROW

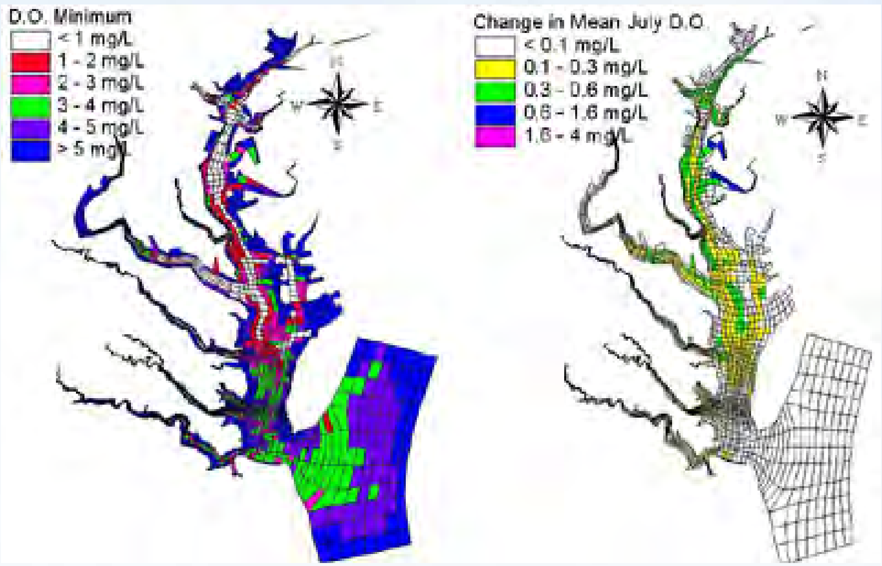
- Used to develop a statistically reliable method for identifying "high priority" areas for management, based on a probabilistic ranking of delivered nutrient yields from watersheds throughout a basin.

Robertson, et al. 2009. Incorporating Uncertainty Into the Ranking of SPARROW Model Nutrient Yields From Mississippi/Atchafalaya River Basin Watersheds. Journal of the American Water Resources Association (JAWRA) 45(2):534-549.)

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

Modeling

Chesapeake Bay Watershed Model

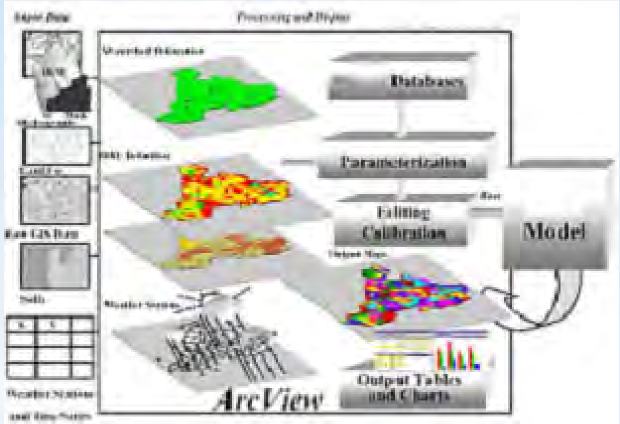


Bay Pollution Progress Overstated
Government Program's Computer Model Proved Too Optimistic
By Peter Whoriskey
Washington Post Staff Writer
Sunday, July 18, 2004; Page A01

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

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
    - Simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs.
    - Applicable in small watersheds, especially urbanizing watersheds
    - First issued by SCS in January 1975 as graphical peak discharge method. (uses NRCS runoff equation)
    - Completely revised as Windows version (WinTR-55) .

http://www.wsi.nrcs.usda.gov/products/w2q/h&h/tools_models/wintr55.html

Modeling Challenges

Range in Reported Removal Efficiences for Vegetated Filter Strips Treating Surface Runoff

Reference	TP%	TN%	SS%
Dillaha et al. 1988	2	1	31
Mendez et al. 1996	26	21	-
Daniels and Gilliam 1995	55	40	53
Chaubey et al. 1995	74	67	-
Dillaha et al. 1989	93	93	98
Coyne et al. 1995	-	-	99

Merriman et al 2009

- ► Require reliable data on practice effectiveness
- ► Must address variability of BMP effectiveness.
- ► How to model human behavior (e.g., O&M)?

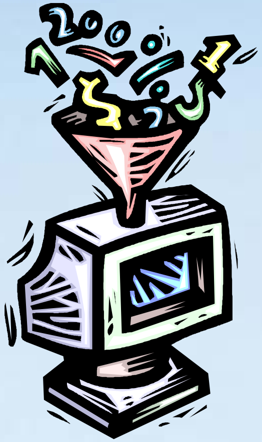
Modeling Challenges

- Application of expected BMP performance depends on knowledge of pre-BMP conditions *and* conditions under which BMP effectiveness was determined
  - Macatawa Watershed Project, MI (MACC 1999)
    - P reduction strategy based on modeling assuming cropland conventionally tilled
    - Review found 65% of cropland was under residue management system
    - Sediment and P from cropland overestimated in baseline
    - Incorrectly focused much of 80% reduction of P on increased residue management on cropland

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.

USEPA National Nonpoint Source Monitoring Program

Examples of Effective Use of Modeling

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.

What to Do In *Your* Watershed

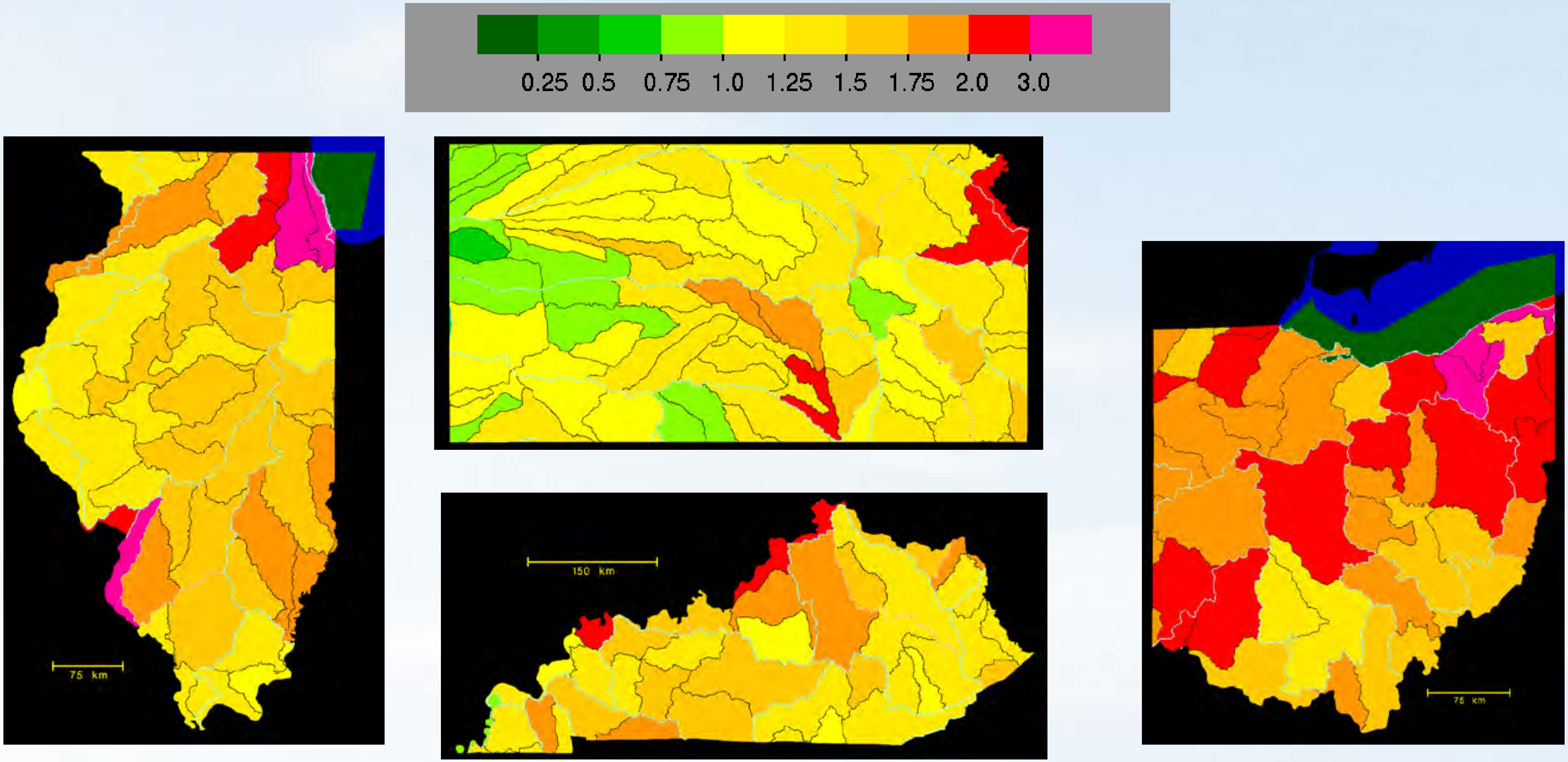
USGS Circular 1270, 2004

Diverse Land Use

State	County	Size (mi^2)	Population (2009)		Total Farm Land 2002		All Cattle and Calves (2007)	
			Total	(No./ mi^2)	(mi^2)	(%)	Total	(No./ mi^2)
IL	Jo Daviess	618	21,990	36	264,493	67	57,276	93
IL	Madison	725	268,457	370	295,677	64	15,024	21
IL	Vermilion	899	80,067	89	449,964	78	8,873	10
OH	Madison	465	42,539	91	245,886	83	10,364	22
OH	Scioto	612	76,334	125	96,449	25	9,490	16
WI	Douglas	1,309	44,274	34	84,858	10	7,333	6
WI	Grant	1,147	48,965	43	605,836	82	176,970	154
WI	Polk	917	44,252	48	292,860	50	46,162	50

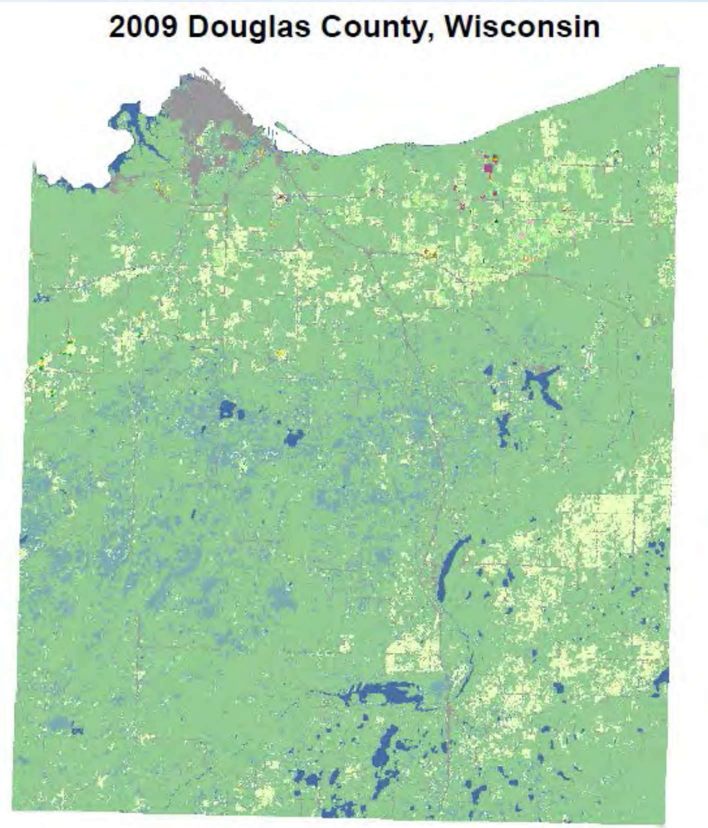
Ag Census and Population Census

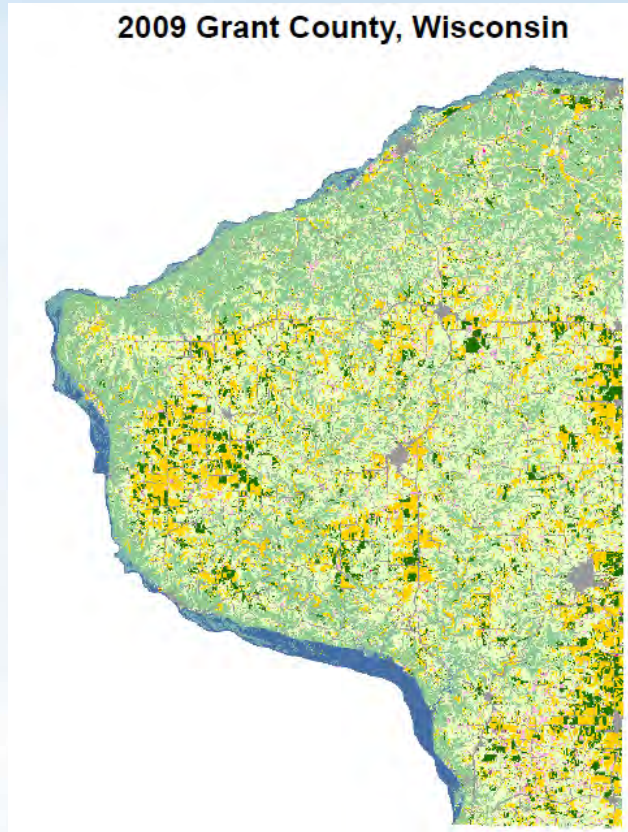
Varying Road Density

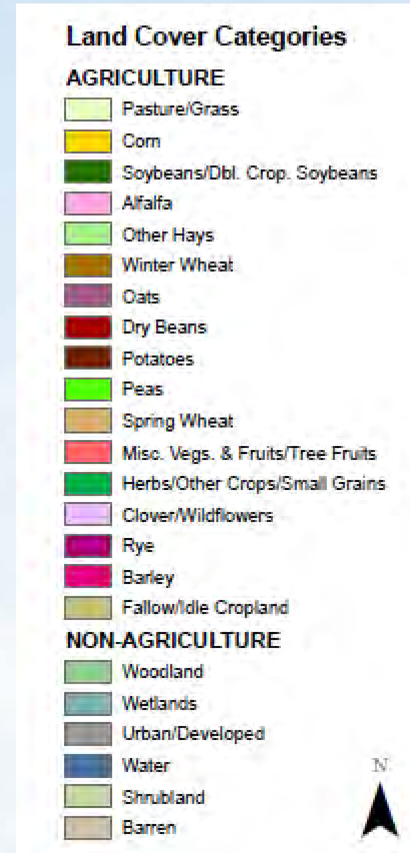


Montana State University Environmental Statistics Group.
http://www.esg.montana.edu/gl/huc/

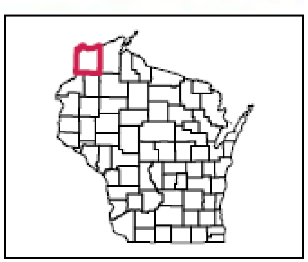
Widely Varying Agriculture



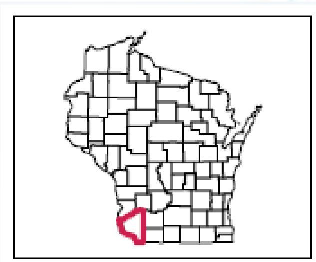




NASS



10% Farmland



82% Farmland

Many Factors to Consider

- Crop types, locations, acreages, yields
- Animal populations and waste management systems
- Manure application methods, dates, and rates
- Soil P levels
- Details of nutrient management plan execution
- Percent residue cover
- Field borders
- Erosion and sediment delivery rates
- Riparian zone protection (fencing, grazing management, etc.)

Many Factors to Consider (cont.)

- Antecedent moisture
- Precipitation intensity and totals
- Drainage water management
- Timing of fertilizer and manure applications relative to storm events
- Non-agricultural sources
  - WWTPs (new, upgraded, under-performing)
  - MS4s, CSOs, other NPDES sources
  - Development, construction, roads
  - Lawns, golf courses, etc.
  - Other activities that contribute nutrients, change hydrology, or deliver sediment

Many Challenges

- Great expectations
  - Big improvements
    - What level of load reduction is possible?
    - What is likely?
  - Quick results
    - When will load reductions happen?
    - When will reductions be detectible?
  - Within budget
    - What will the total budget be?
    - What is the smallest budget to assume in planning?

Many Challenges (cont.)

- All-Star Cast
  - Land Treatment
    - Landowners
    - Federal, state, and local agencies/groups
  - Monitoring
    - Agriculture, natural resources, remote sensing
    - Water quality, flow
  - Modeling
    - State and federal agencies
    - Grants and contracts

Many Challenges (cont.)

- Mountains of Data
  - Data Collection
    - Who does what?
    - How are monitoring and modeling needs coordinated?
  - Data Management
    - When and how are data shared? QA/QC?
    - Single database? Integrated databases?
  - Data Analysis and Reporting
    - Who analyzes the data?
    - How are reports generated, approved, released?

Meeting the Challenge

- The need to protect the Gulf will outlast us all
- Get organized
- Plan wisely

Develop an evaluation strategy that targets monitoring and modeling activities to give the best indication of progress that is possible within scientific, budgetary, and logistical limitations.

Developing a Monitoring and Modeling Strategy

1. Program Objectives

- **Begin With a Clear Set of Nutrient Reduction *Program* Objectives**
  - Are they quantitative? (e.g., reduce N load by X%)
  - Do they incorporate time frames and scales for which accountability is needed? (e.g., reduce N loads at state line or at each 2-digit or 4-digit HUC level by X% within Y years)
  - Is there a need to attribute changes to activities on the land? (e.g., reduce N loads at state line or at each 2-digit or 4-digit HCU level by X% within Y years by implementing nutrient management on Z acres/% of agricultural land)

If this isn't done, you won't know how, where, when, or what to monitor or model.

2. Evaluation Objectives

- **Establish a Clear Set of *Evaluation* Objectives**
  - Are they quantitative? (e.g., reduce N load by X%)
    - ***Monitoring:*** To measure N load reductions with a minimum detectable change of 20%
    - ***Modeling:*** To estimate and project N load reductions within 15% of actual loads

Define the specific questions to answer with monitoring and modeling

2. Evaluation Objectives (cont.)

- Do they incorporate time frames and scales for which accountability is needed? (e.g., reduce N loads at state line or at each 2-digit or 4-digit HUC level by X% within Y years)
  - ***Monitoring:*** To measure N load reductions with a minimum detectable change of 20% in select smaller watersheds within 10 years and assess with an MDC of 30% long-term N load trends at mouths of larger watersheds and the state line.
  - ***Modeling:*** To estimate and project N load reductions within 15% of actual loads in select smaller watersheds within 10 years and estimate and project within 15% of actual long-term N load trends at mouths of larger watersheds and the state line

Monitoring and modeling objectives should be complementary

2. Evaluation Objectives (cont.)

- Is there a need to attribute changes to activities on the land? (e.g., reduce N loads at state line or at each 2-digit or 4-digit HUC level by X% within Y years by implementing nutrient management on Z acres/% of agricultural land)
  - ***Monitoring:*** To measure N load reductions with a minimum detectable change of 20% in select smaller watersheds within 10 years and assess with an MDC of 30% long-term N load trends at mouths of larger watersheds and the state line.
    - Associate measured changes with land use and land management variables related to both agricultural and non-agricultural sources.

Address uncertainty at the outset and include uncertainty in all monitoring and modeling reporting.

2. Evaluation Objectives (cont.)

- ***Modeling:*** To estimate and project N load reductions within 15% of actual loads in select smaller watersheds within 10 years and estimate and project within 15% of actual long-term N load trends at mouths of larger watersheds and the state line incorporating input variables that reflect land use and land management associated with both agricultural and non-agricultural sources.

Address uncertainty at the outset and include uncertainty in all monitoring and modeling reporting.

Harmel et al (2009) estimated cumulative uncertainty in individual discharge, concentration and load values.

Walker (2001) presents methods for incorporating uncertainty into the MOS term of a TMDL.

3. Monitoring Design(s)

- **Establish the Monitoring Design(s)**
  - Long-term trend analysis, upstream-downstream, etc.
  - Scale, variables, sample type, station locations
  - Sampling frequency
  - Collection/analysis methods
  - Land use/treatment monitoring
  - Data management

4. Modeling Approach(es)

- **Select the Modeling Approach(es)**
  - The model(s) to use
  - Input data processing requirements and data sources
  - Model testing locations and data sources
  - Output analysis

5. Identify Common Needs

- Identify common needs of monitoring and modeling
  - Share discharge and precipitation data
  - Use monitoring water quality data to calibrate/validate model
  - Share land use/land treatment data

6. Integrate Data Management

- Integrate data management
  - Facilitate sharing and consolidate QA/QC

7. Data Analysis and Reporting

- Integrate data analysis and reporting
  - Discharge calculations
  - Load estimation from monitoring data
  - Land use/treatment data
    - GIS framework for modeling
    - Indices for modeling = explanatory variables for monitoring? (e.g., combined variables such as corn with B soils on moderate slopes, pastures with C soils on steep slopes, etc.)

7. Data Analysis and Reporting (cont.)

- Have a plan for integrating and interpreting monitoring and modeling results
- Have a plan for scientific review
- Establish a sign-off procedure for all reports
- Small-scale monitoring and modeling to develop input parameters for large-scale modeling
- Small-scale monitoring to calibrate/validate small-scale modeling
- Large-scale monitoring to calibrate/validate large-scale modeling

8. Communication Strategy

- Develop a communication strategy
  - Control expectations from the beginning
    - Address lag time
    - Address monitoring and modeling uncertainty
  - Communicate clearly and honestly
    - Incorporate uncertainty into all press releases and publications
    - Express data limitations consistently
  - Avoid overly optimistic projections

9. TMOAQAPPS*

- Develop a QAPP that integrates monitoring and modeling

EPA Requirements for Quality Assurance Project Plans,* *http://www.epa.gov/quality/qs-docs/r5-final.pdf

Guidance for Quality Assurance Project Plans for Modeling,* *http://www.epa.gov/QUALITY/qs-docs/g5m-final.pdf

**The Mother of all QAPPS*

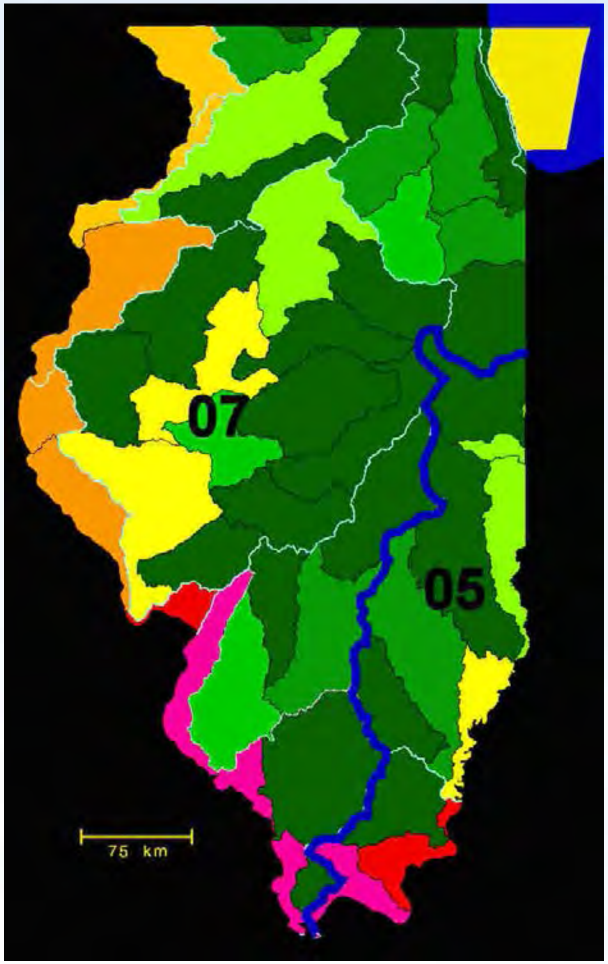
Some Details

Monitoring Details

- ► Which scale(s) to use?
  - Large Scale
    - Depends on state
    - 8-digit HUCs in the Upper Mississippi Region (08) range from 225,280 acres (07140108 in southern IL/KY) to 2,080,000 acres (07070003 in south-central WI)
      - – 120 8-digit HUCs in Ohio River Basin (05)
      - – 131 8-digit HUCs in Upper Mississippi Region (07)
  - Smaller Scale
    - 16-digit HUCs? (12-digit HUCs in Iowa - Ingels)
    - Depends on objectives and monitoring/modeling needs

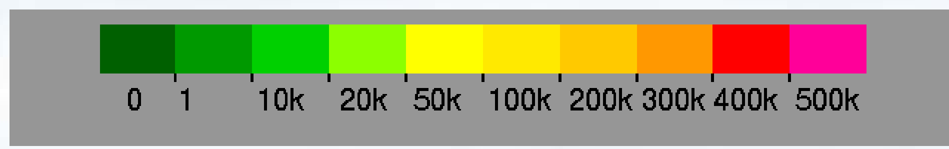
ccinsider.comedycentral.com

8-Digit HUCs in Illinois



40 8-digit HUCs in 07
10 8-digit HUCs in 05
3 8-digit HUCs in 04 (Great Lakes)

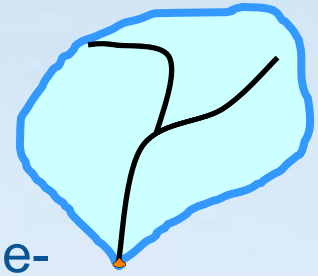
Upstream Area: km^2 ($1\ km^2 = 0.3861\ mi^2$)



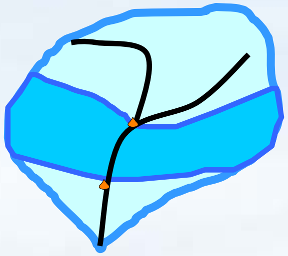
Environmental Statistics Group, http://www.esg.montana.edu/

Monitoring Details (cont.)

- Which monitoring design(s) to use?
  - Large Scale
    - Long-term trend for load measurement and large-scale model calibration/validation



  - Smaller Scale
    - Upstream-downstream, paired-watershed, and input-output for targeted effectiveness assessments as input to modeling
    - Single-station for model calibration/validation and targeted small-scale load measurement



Monitoring Details (cont.)

- ▶ Which variables to monitor?
  - Large Scale
    - Discharge
    - Total N and total P
    - Land use/land treatment (including contributions from permitted dischargers)
  - Smaller Scale
    - Discharge
    - Total N, total P, and other forms of N and P as needed for effectiveness studies
    - Land use/land treatment (including contributions from permitted dischargers)

www.sontek.com

www.hydrolab.com

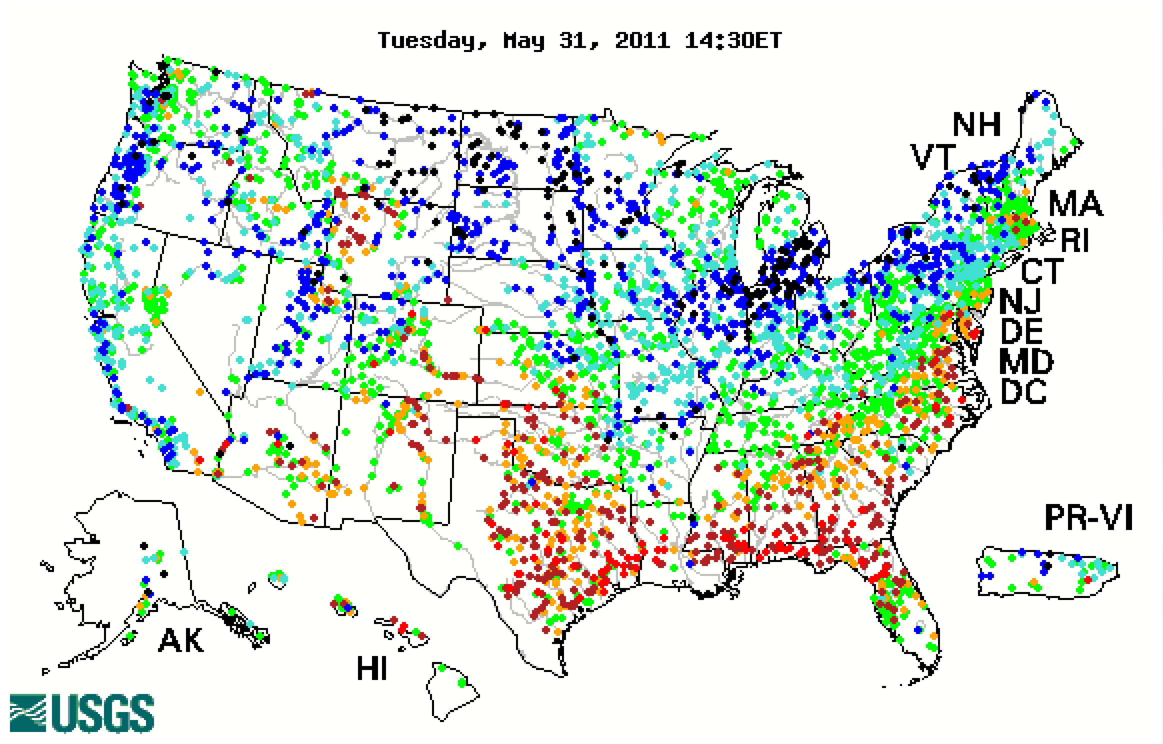
Monitoring Details (cont.)

- Sampling Frequency
  - Large Scale
    - Weekly composites for loads
  - Smaller Scale
    - Storm events for models?
    - Weekly composites for loads

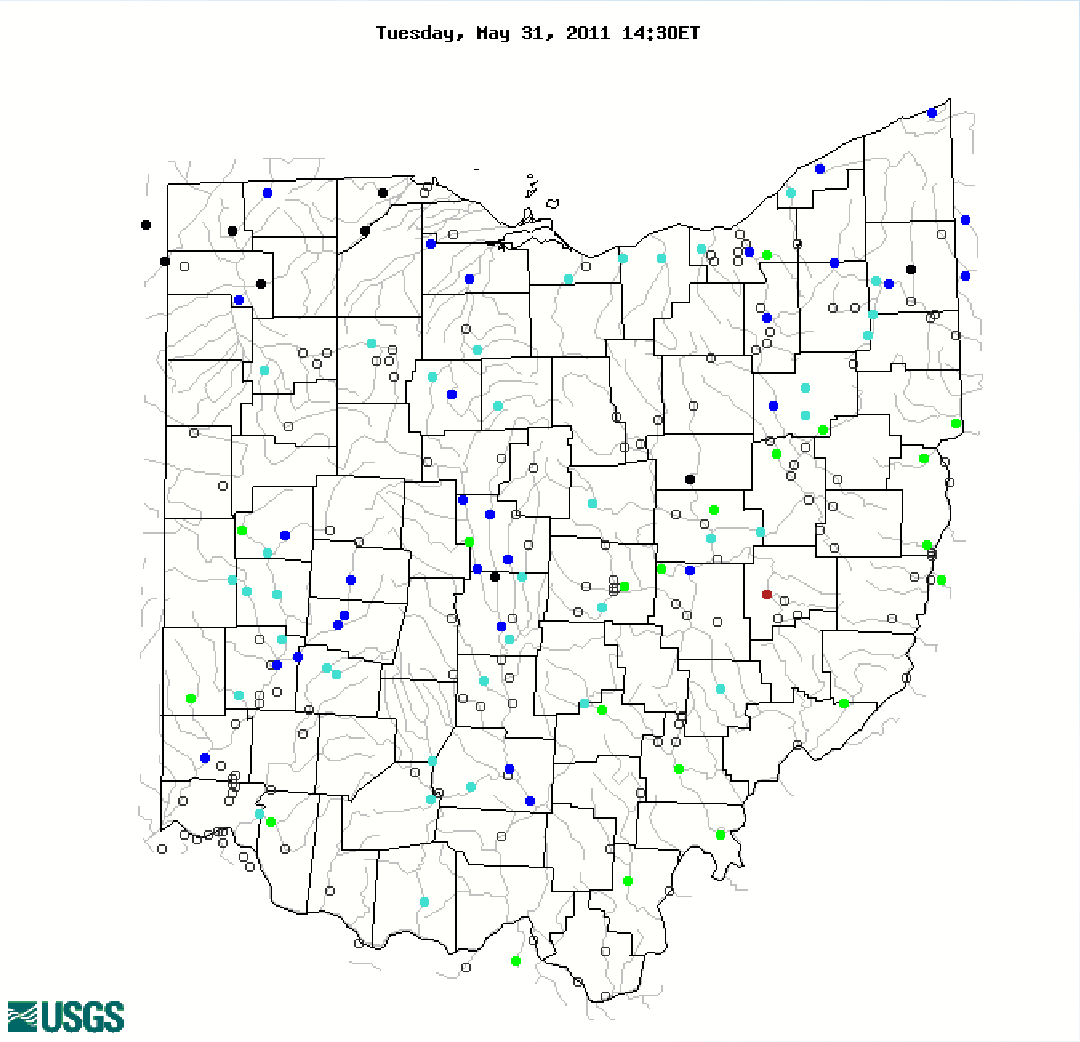
www.hach.com

Build from Existing Monitoring

USGS Streamflow Stations in U.S.

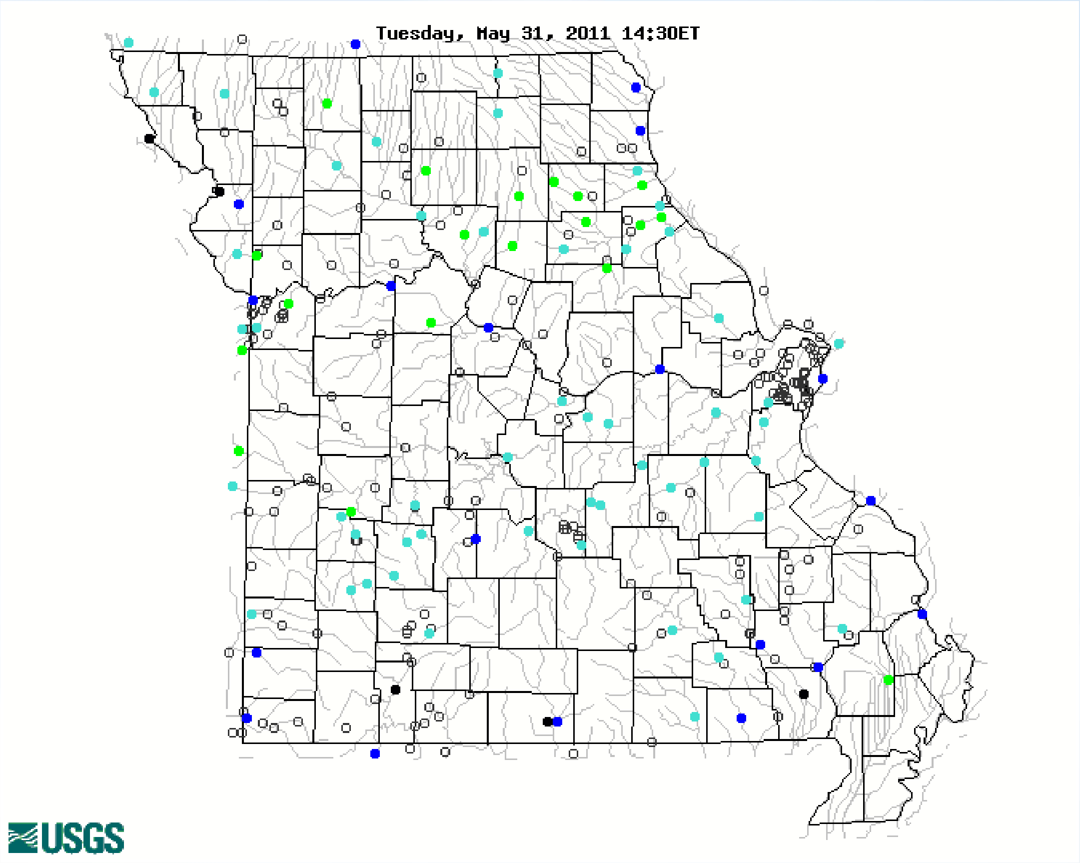


http://il.water.usgs.gov/



USGS Streamflow Stations in Ohio

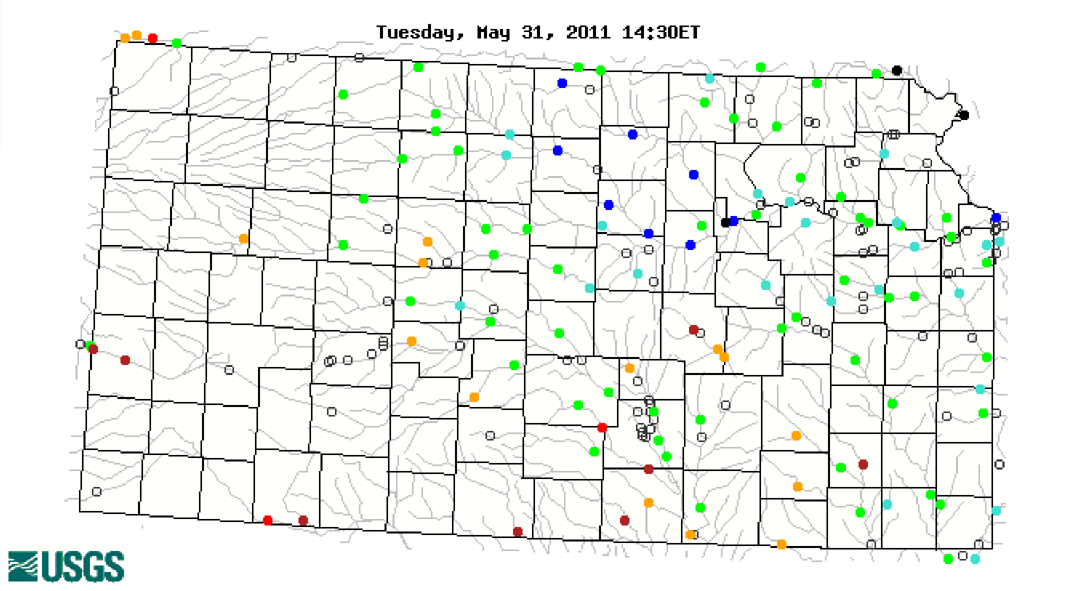
http://il.water.usgs.gov/



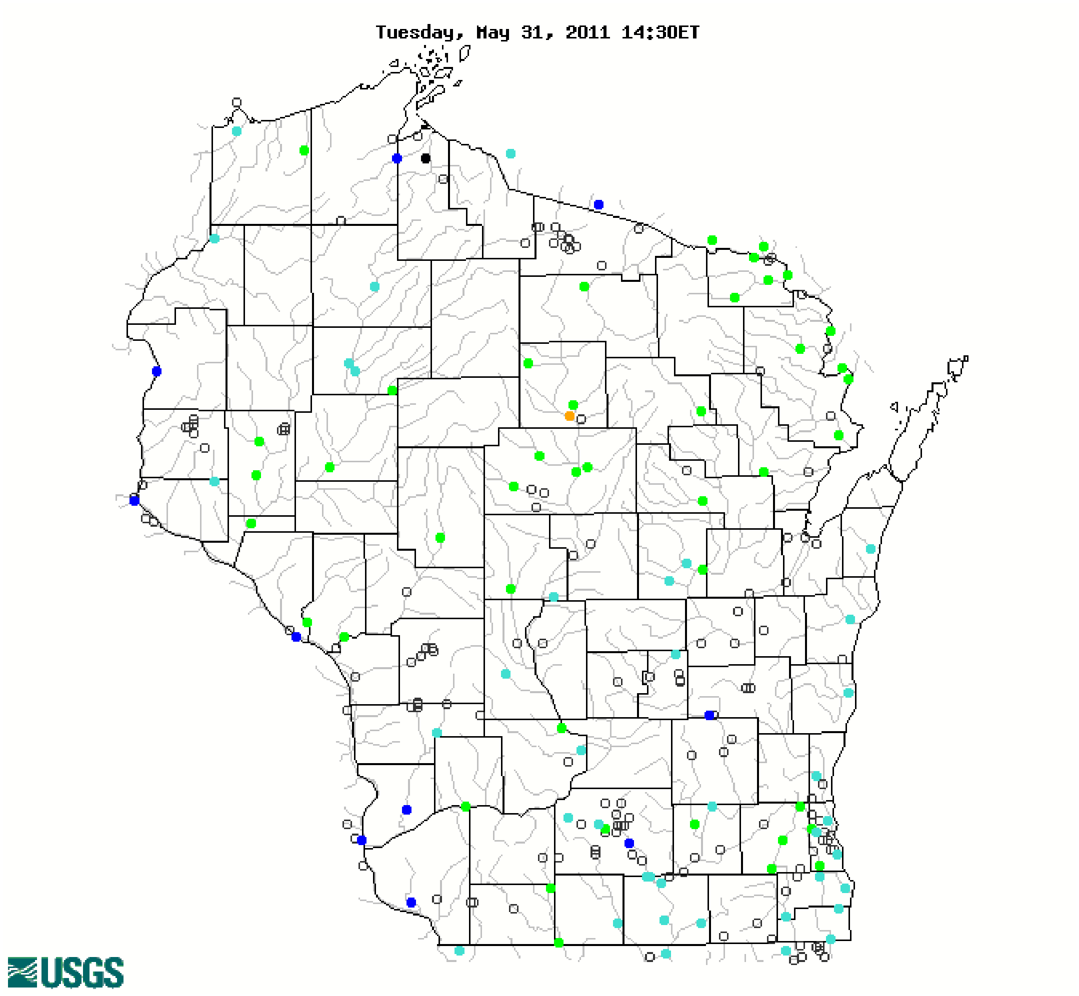
USGS Streamflow Stations in Missouri

http://il.water.usgs.gov/

USGS Streamflow Stations in Kansas

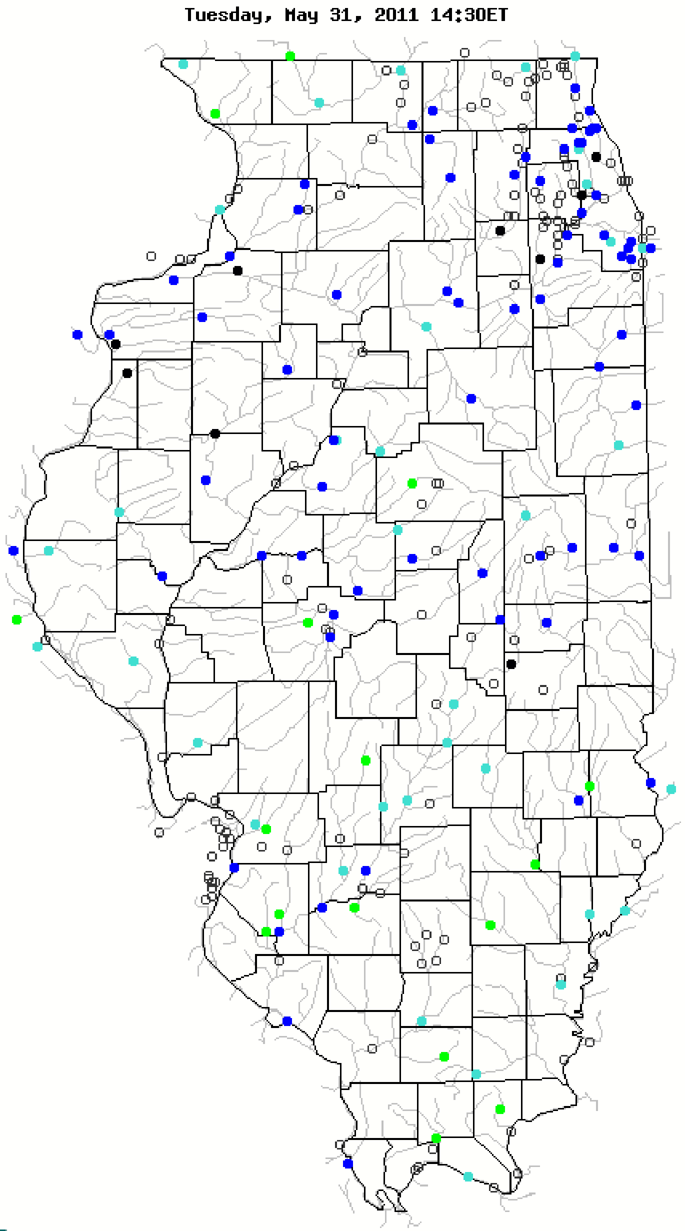


http://il.water.usgs.gov/



USGS Streamflow Stations in Wisconsin

http://il.water.usgs.gov/



USGS Streamflow Stations in Illinois

http://il.water.usgs.gov/

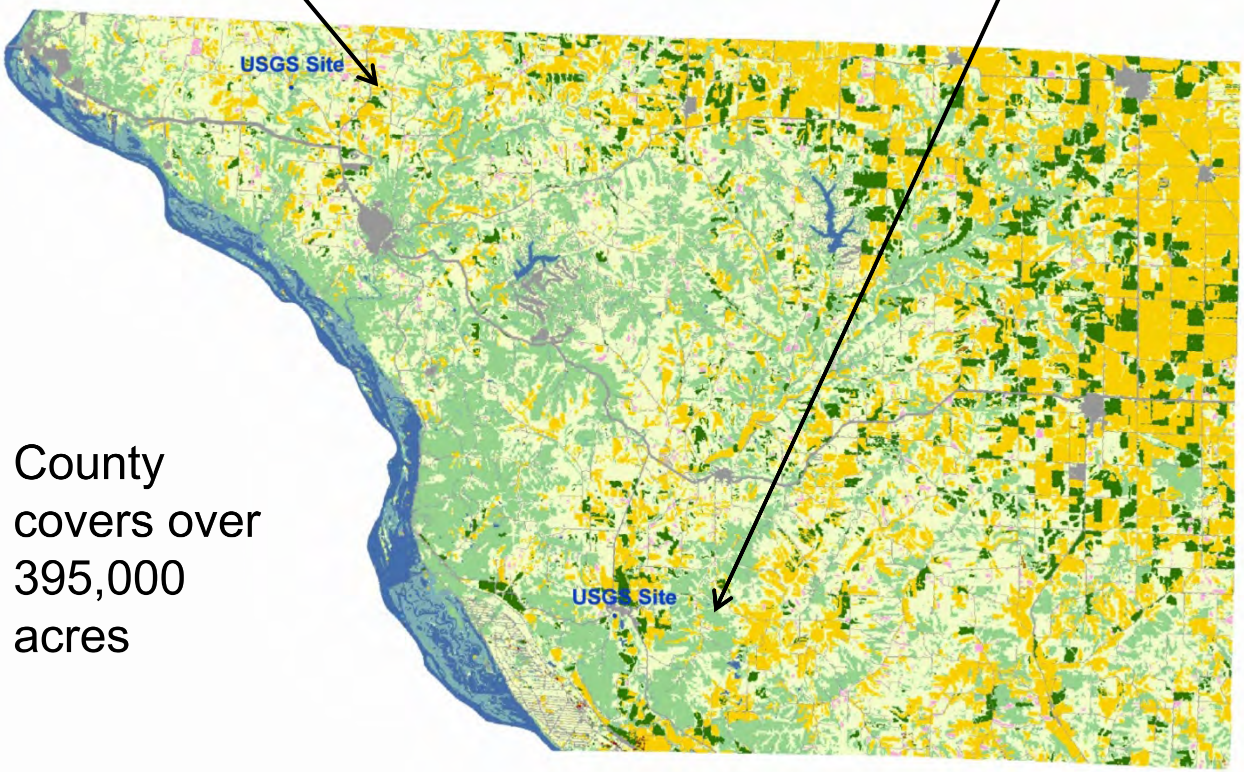
USGS Stations

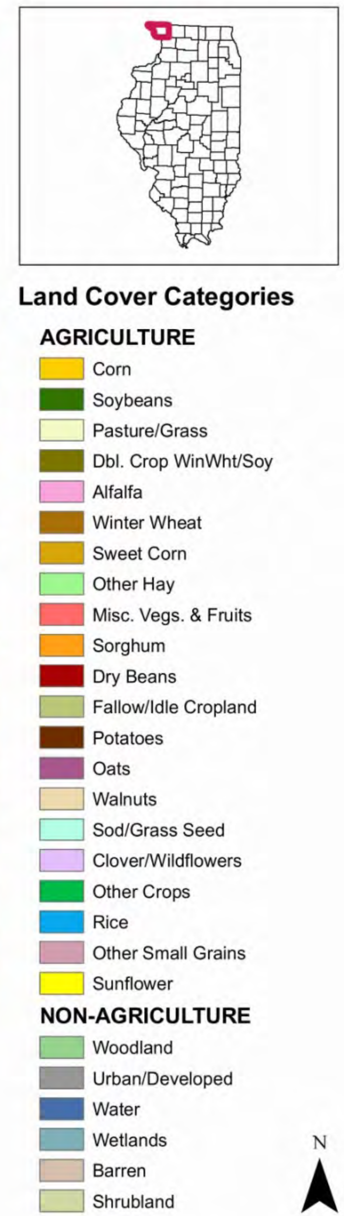
- Great flow data
- Long periods of record
- Looks like good coverage…except

2010 Jo Daviess County, Illinois

Site 05414820

Site 05419000





County covers over 395,000 acres

Site	Drainage (Ac)	Distance from Mouth (mi)
05414820	25,344	7
05419000	158,080	13.9

USGS 05414820 SINSINAWA RIVER NEAR MENOMINEE, IL

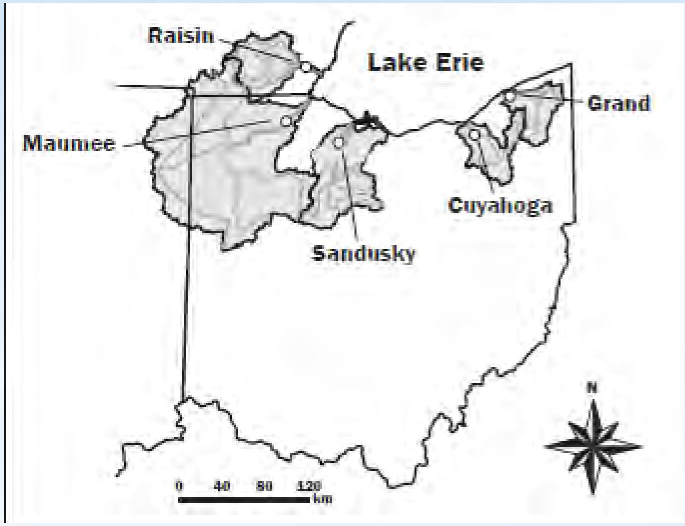
- Period of record: 1967-today
- Daily discharge (nearly 16,000 data points)
- No water quality since 1983

USGS 05419000 APPLE RIVER NEAR HANOVER, IL

- Period of record: 1934-today
- Daily discharge (nearly 28,000 data points)
- Suspended sediment through 1997

Lake Erie Example

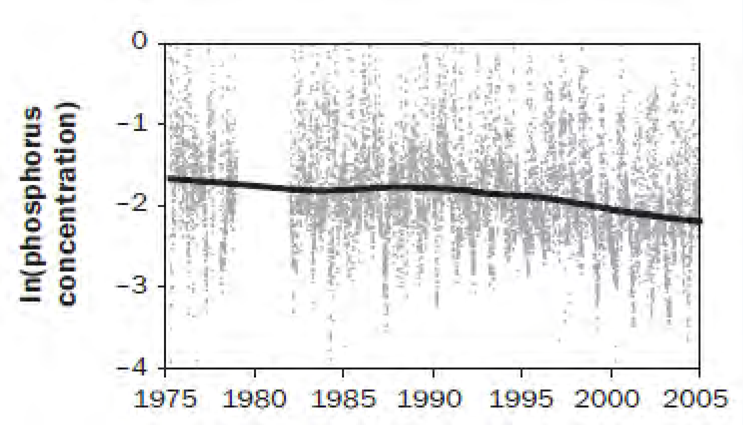
- ► Maumee and Sandusky Rivers
  - Maumee: 6,330 square miles, 74% row crop
  - Sandusky: 1,251 square miles, 78% row crop
- ► 30 years of daily data (1975-2004)
- ► USGS gaging stations for flow
- ► No sample compositing
- ► About 12,000 samples per station



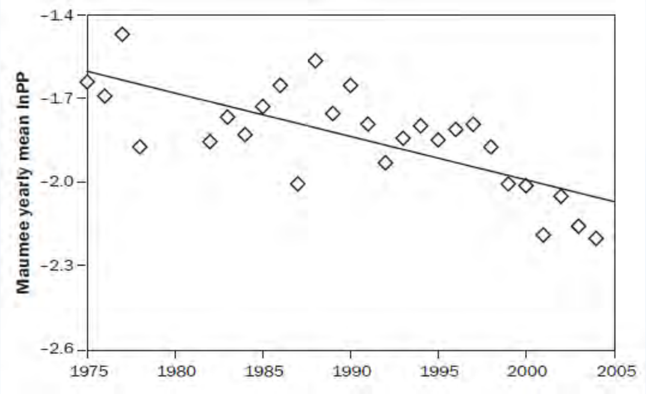
Richards, R.P., D.B. Baker, and J.P. Crumrine. 2009. Improved water quality in Ohio tributaries to Lake Erie: a consequence of conservation practices, Journal of Soil and Water Conservation, 64(3):200-211.

Lake Erie Example

- ► Statistically significant decreases in concentrations of TSS and particulate P (10-18% per decade)
- ► Flow ↑ but not significant
- ► TSS and particulate P loads ↓ 6-12% per decade (not sig.)
- ► Greatest improvements in low-flow and summer and fall
- ► Generally attributed concentration decreases to conservation tillage and CRP



Maumee River



Modeling Details

- ▶ Which model(s) to use?
  - http://it.tetratech-ffx.com/steplweb/STEPLmain_files/LoadReductionModels.pdf
- ▶ Where to use the model(s).
  - Location
  - Scale

Model Selection Factors

- Type
  - Landscape only: only simulates land-based processes
  - Comprehensive: include land and stream and conveyance routing (all described here)
- Level of Complexity
- Time Step
- Hydrology
- Water Quality
- Types of BMPs

Need to select a model that is appropriate for addressing the modeling objectives you have identified.

Models for Load Estimation

Land Use	Sources/Concerns	Pollutants	Models
Agricultural	Grazing	Nutrients and sediment	GWLF AGNPS SWAT
Agricultural	Livestock and wildlife sources	Nutrients	Spreadsheet estimation STEPL SWAT HSPF
Agricultural	Cropland management Conservation tillage	Nutrients and pathogens	AGNPS SWAT
Mixed Use	Stormwater management Agriculture Residential	Sediment and nutrients	SWMM HSPF
Urban	Stormwater management Land use conversion Redevelopment	Sediment, nutrients, and metals	SWMM HSPF

Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

Models – Major Features

Model	Level of Complexity			Time Step	BMP Support Level	
	Export Coefficients	Loading Functions	Physically Based		Nutrient Control	Irrigation and Tile Drains
AnnAGNPS			X	Daily	High	Low
GWLF		X		Monthly	Low	No
HSPF			X	Sub-Daily	High	No
SPARROW	Hybrid Statistical/Mechanistic			Annual	No	No
STEPL		X		Annual	Low	No
SWAT			X	Daily	High	High

Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

Models – Considerations for Use

Model	Experience Needed	Time Needed for Application	Data Needs	Support Available	Software Tools	Cost
AnnAGNPS	Limited	>1 month	Medium	Medium	Medium	Free
GWLF	Little/No	<1 month	Low	Low	High	Free
HSPF	Much	>6 months	High	High	High	Free
STEPL	Little/No	<1 month	Low	High?	High	Free
SWAT	Moderate	>1 month	Medium	Medium	High	Free

Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

Models – Data Needs

CN=Curve Number, USLE= Universal Soil Loss Equation

Model	Number of Watersheds	Land Use and Soil Parameters	Stream Channel	Nutrient Applications	Management Practices
AnnAGNPS	>1	CN/USLE	N/A	Rate	Location and type associated with land use
GWLF	1	CN/USLE	N/A	Manure and nutrients, date	General / agricultural
HSPF	>1	HSPF-specific	Flow/discharge relationships, length	Rate	Location and type
STEPL	1	CN/USLE	Dimensions of stream, recession rate	N/A	General type
SWAT	>1	CN/USLE	Dimensions of stream channel	Rate	Location and type associated with land use

Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

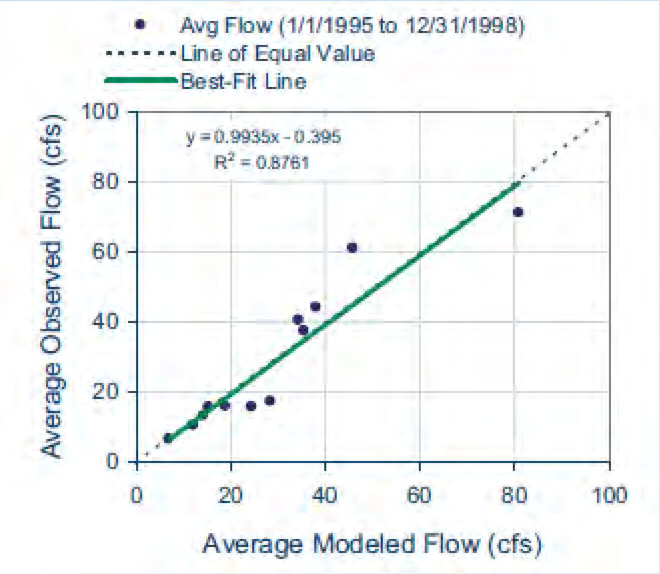
Model Testing

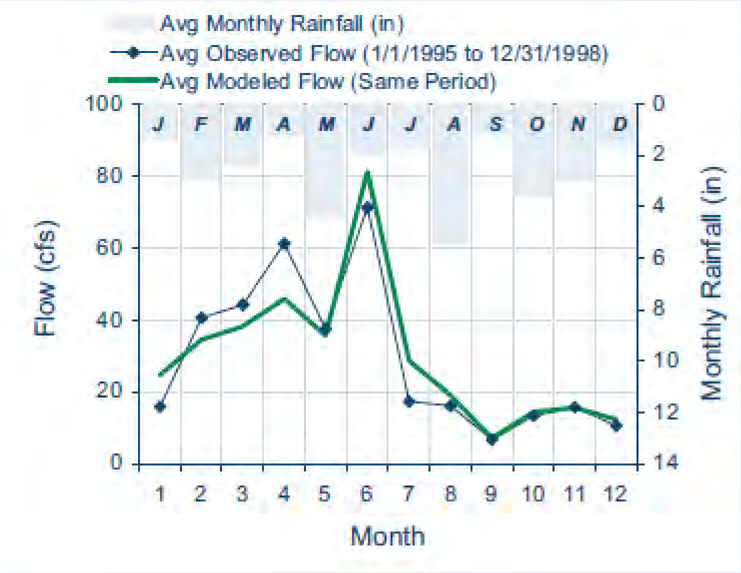
- Compare modeling results with observed data
- ***Best where flow and water quality data are available***
- Two periods: Calibration and Validation
  - Typical time periods/range of conditions
  - Adjust with calibration dataset
  - Validate with separate dataset
- Curve-number based models offer limited calibration because look-up tables are used

Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

Model Testing

- Typical factors in evaluating model performance
  - Water balance
  - Observed versus modeled flow
  - Observed versus modeled load (annual, seasonal, source)
  - Observed versus modeled pollutant concentrations





Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

Models – Calibration Options

Model	Flow Calibration	Pollutant Calibration
AnnAGNPS	Limited/ CN	Nutrient concentrations in water and sediment
GWLF	Ground water recession	Nutrient concentrations in water (runoff, ground water) and sediment
HSPF	Multiple, infiltration, soil storage, ground water	Pollutant buildup and wash-off, instream transport/decay
STEPL	Limited/CN	Loading rate
SWAT	Ground water	Nutrient concentrations in water and sediment

CN=Curve Number

Source: Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA, http://water.epa.gov/polwaste/nps/handbook_index.cfm

Candidate Models-AnnAGNPS

- Continuous-simulation (≤125,000 acres)
- Simulates quantities of surface water, sediment, nutrients, and pesticides leaving the land areas and their subsequent travel through the watershed.
- Runoff based on CN and sediment determined by RUSLE
- Handles feedlots, point sources (constant loading rates), concentrated sediment sources (gullies), and irrigation
- Output is expressed on an event basis for selected stream reaches and as source accounting (contribution to outlet) from land or reach components over the simulation period.
- Can evaluate the effect of agricultural practices, ponds, grassed waterways, irrigation, tile drainage, vegetative filter strips, and riparian buffers.
- Spatially variable rainfall is not allowed.
- Needs more validation
- Small user base and limited training (1x/yr)
- **www.ars.usda.gov/research/docs.htm?docid=5199**.

Candidate Models-STEPL

- Simplified spreadsheet tool for estimating the annual load reductions that result from implementing management practices.
- Easy to use.
- Computes the combined effectiveness of multiple BMPs implemented in serial or parallel configurations (or both) in a watershed.
- Management measures that affect hydrology or sediment can be estimated with empirical factors such as CN for estimating runoff and USLE C (vegetative cover) and P (practice) factors.
- Annual pollutant load reductions (N, P, BOD5, sediment) attributable to the management practices are estimated with reduction factors (or management practice effectiveness) applied to the pre-management practice loads from the various land uses.
- http://it.tetratech-ffx.com/steplweb/

Candidate Models-GWLF

- Generalized Watershed Loading Function
- Simulates runoff and sediment delivery using the SCS curve number equation (CNE) and the USLE, combined with average nutrient concentration based on land use
- Monthly outputs due to lack of detail in predictions and stream routing
- Easy to use; 15+ year history
- Low data and calibration requirements
- BMP tool (PRedICT) is simple way to estimate the impact of management practices.
- Limited to nutrient and sediment load prediction
- http://www.avgwlf.psu.edu/

Candidate Models-HSPF

- Hydrologic Simulation Program–Fortran
- Simulates watershed hydrology, land and soil contaminant runoff, and sediment-chemical interactions.
- Generates time series results
- Simulates land processes (lumped for each land use type at subwatershed level) and receiving water (well-mixed, one-directional flow) processes simultaneously.
- Time steps: subhourly, hourly, or daily.
- Requires extensive calibration and expertise
- http://www.epa.gov/ceampubl/swater/hspf/

Candidate Models-SWAT

- Soil and Water Assessment Tool
- Works best in agricultural areas; urban component newer
- Pesticides, nutrients, sediment based on agricultural inputs, and management practices
- Validated in many watersheds
- More comprehensive than GWLF and can better estimate the water quality impacts of some management changes
  - Worth the extra effort only in watersheds where high-resolution agricultural management analyses are warranted and where information on agricultural land use practices can be obtained.
- http://swatmodel.tamu.edu/

Using Models Together

- Integrating small-scale (e.g., SWAT) and larger-scale (e.g., HSPF) modeling
  - HSPF represents all major processes in the watershed;
  - HSPF is operating at a large spatial scale appropriate to regional decisions
  - Many of the key processes occur at the field and finer scale.
    - HSPF can only approximate these fine-scale processes in an aggregate way.
  - Therefore, the use of field- and small-watershed models (e.g., SWAT) is important to ensure that the larger-scale model provides an honest and physically realistic representation of field-scale processes.

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.

Recommendations

Seven years ago….

A Science Strategy to Support Management Decisions Related to Hypoxia in the Northern Gulf of Mexico and Excess Nutrients in the Mississippi River Basin, Circular 1270, USGS, 2004

Prepared by the Monitoring, Modeling, and Research Workgroup, Mississippi River/Gulf of Mexico Watershed Nutrient Task Force

Recommendations

- **Be Realistic**
  - You cannot monitor or model everywhere
  - Your ability to track land use/management details/covariates is limited
  - Target both the monitoring and modeling activities in a coordinated manner to achieve overall evaluation objectives

Recommendations

- **Use the strengths of both monitoring and modeling**
  - 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.

Recommendations

- Monitor at smaller scale to measure loads in targeted watersheds of importance
- Monitor at smaller scale to calibrate/validate models used at smaller scale
- Model at smaller scale to expand coverage and provide load estimation for “all” smaller watersheds
- Model at smaller scale to provide input to larger-scale models
- Model at smaller and larger scale to help interpret monitoring data
- Monitor at larger scale to measure loads where affordable and to calibrate/validate models used in other larger-scale watersheds

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

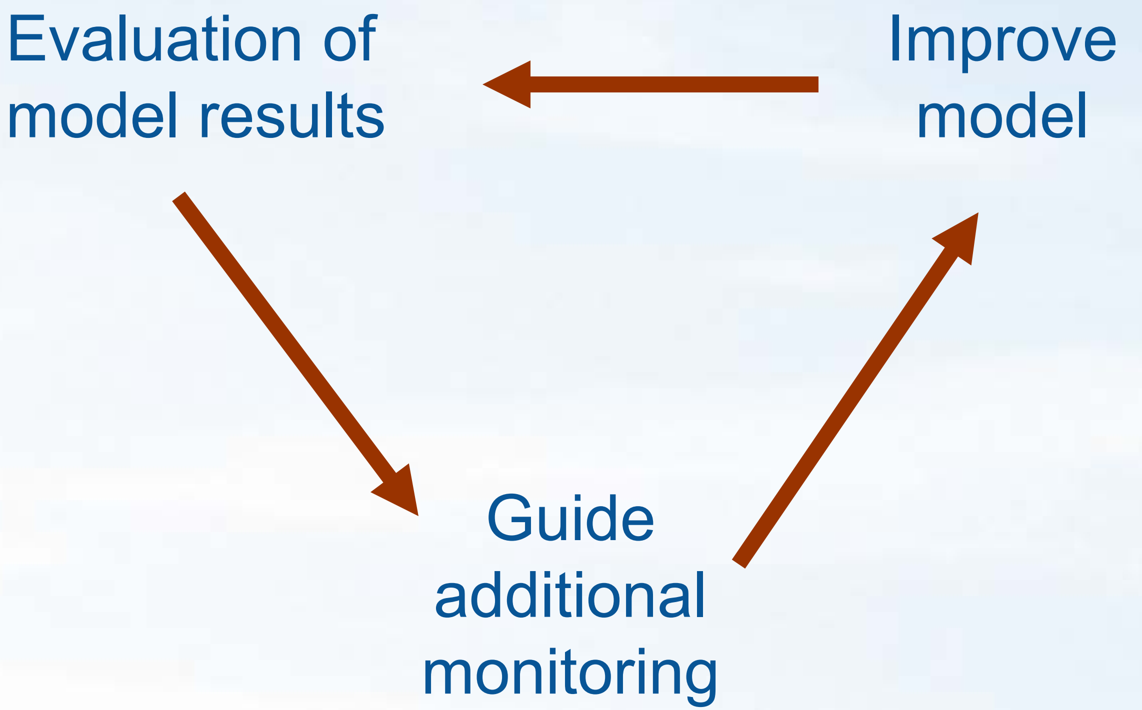
Fundamental knowledge about generation, fate, and transport of nonpoint source pollutants

⟷

Modeling

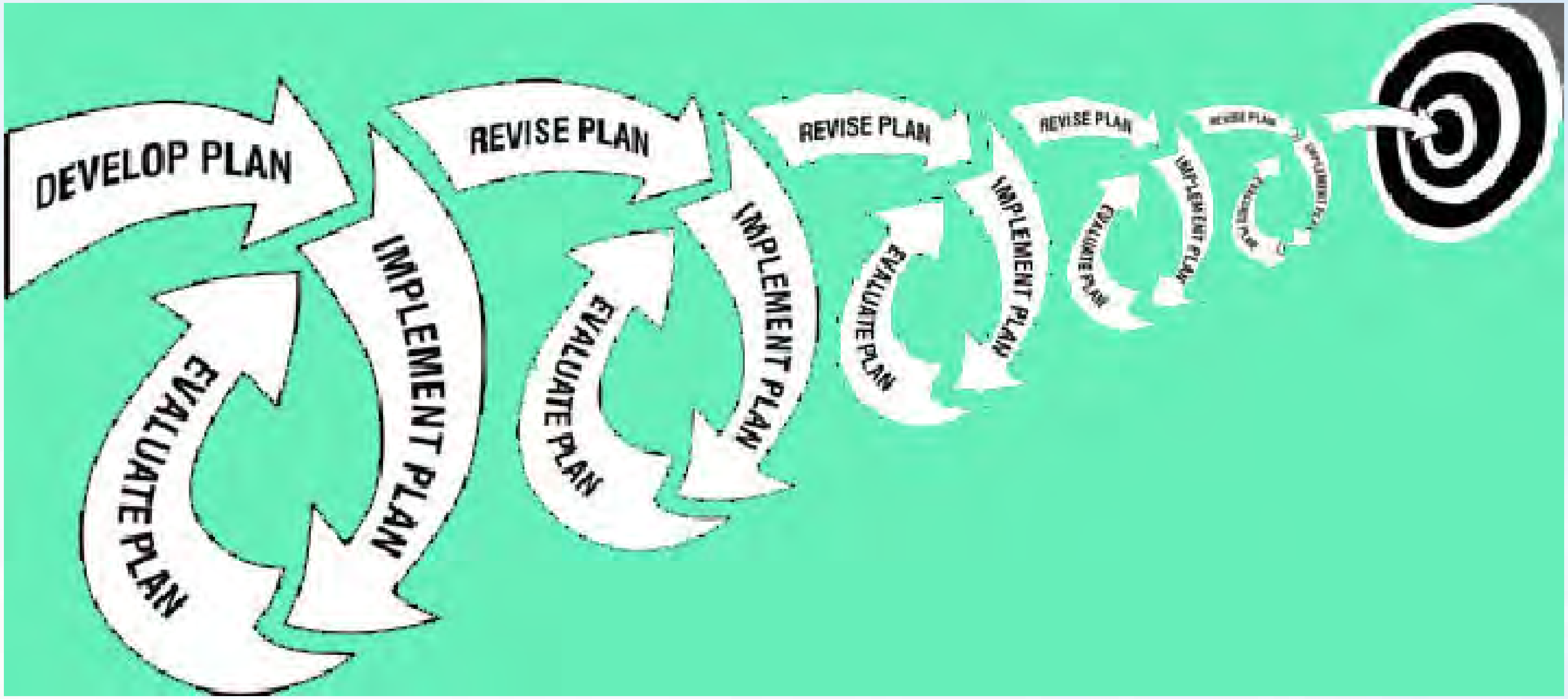
Means to assemble, express, and test current state of understanding

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

Discussion

TETRA TECH

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Selected References

Harmel, R.D., D.R. Smith, K.W. King, and R.M. Slade. 2009. Estimating storm discharge and water quality data uncertainty: A software tool for monitoring and modeling applications, Environmental Modelling & Software 24: 832–842.

Walker, W.W. 2001. Quantifying uncertainty in phosphorus TMDL's for lakes. New England Interstate Water Pollution Control Commission and U.S. Environmental Protection Agency Region 1, Lowell, MA.