Nonpoint Source Watershed Project Resources

October 26, 2016

Steve Dressing, Tetra Tech, Inc.

Discussion Topics

- NEW Nonpoint Source Monitoring Guidance
- Tech Notes
- Technical Memorandums
- BMP Tracking Guides

Monitoring and Evaluating Nonpoint Source Watershed Projects

Monitoring and Evaluating Nonpoint Source Watershed Projects

May 2016

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Office of Water
Nonpoint Source Control Branch
Washington, DC 20460
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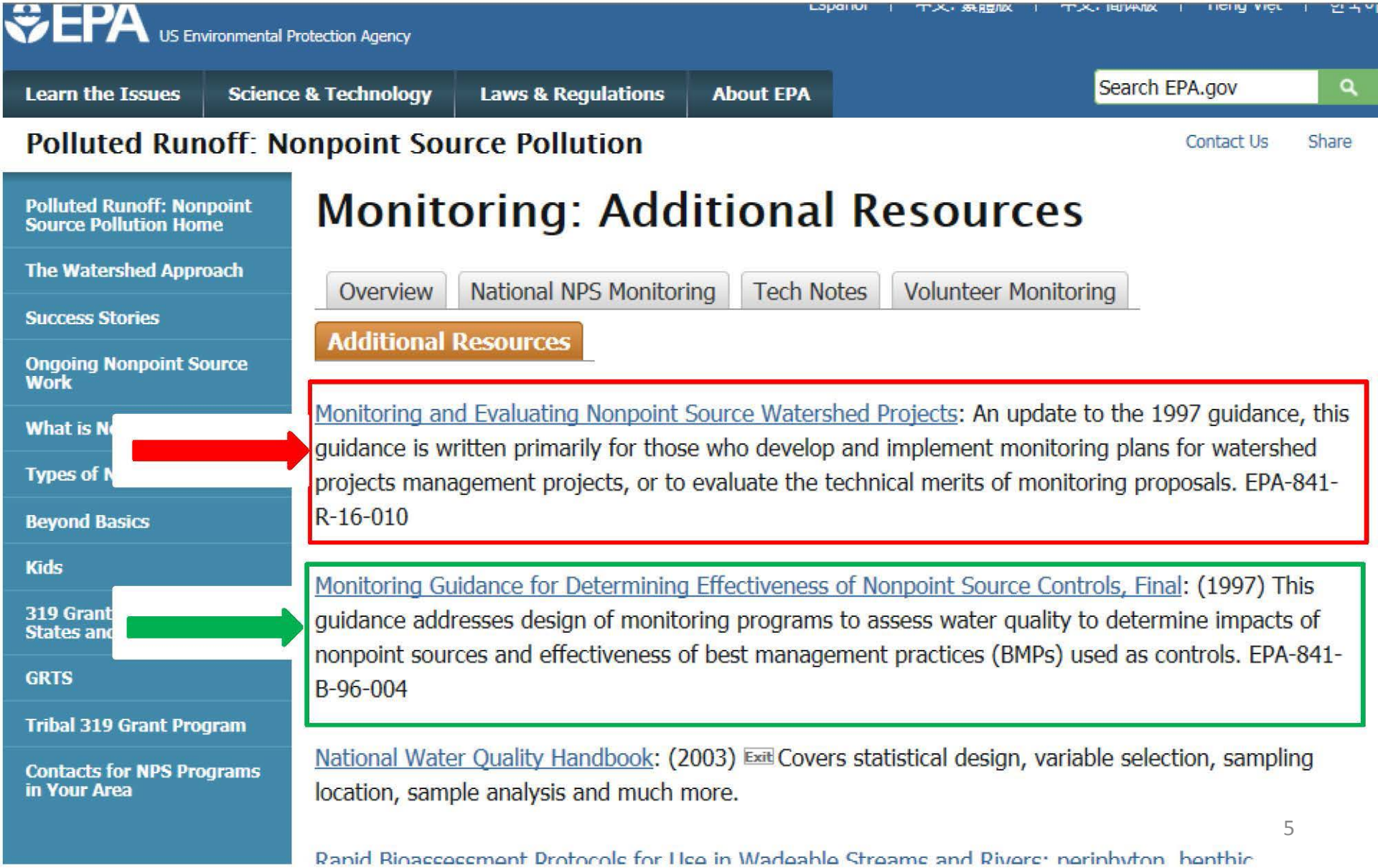
May 2016

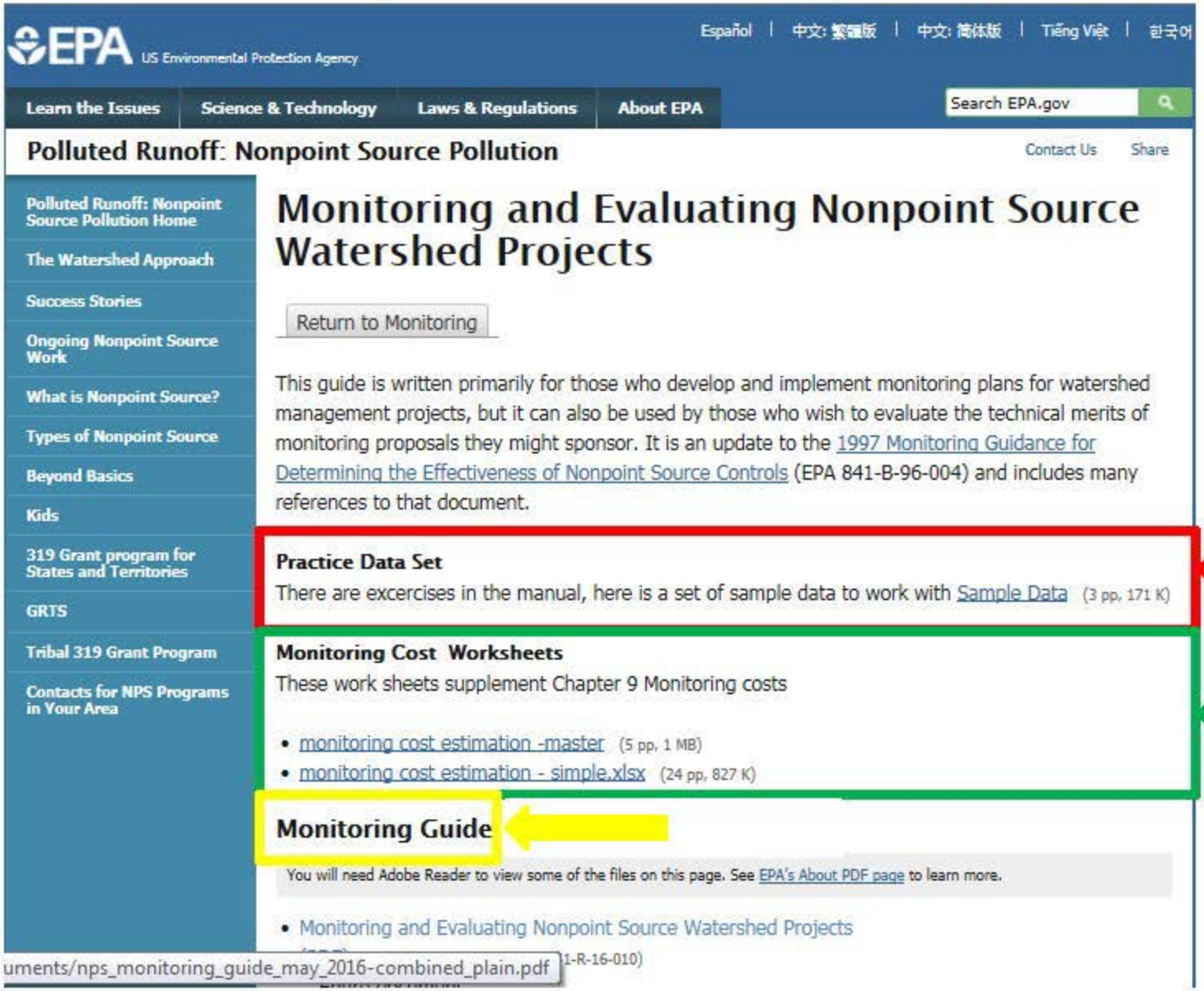
This document is available at: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-monitoring

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-additional-resources



https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed



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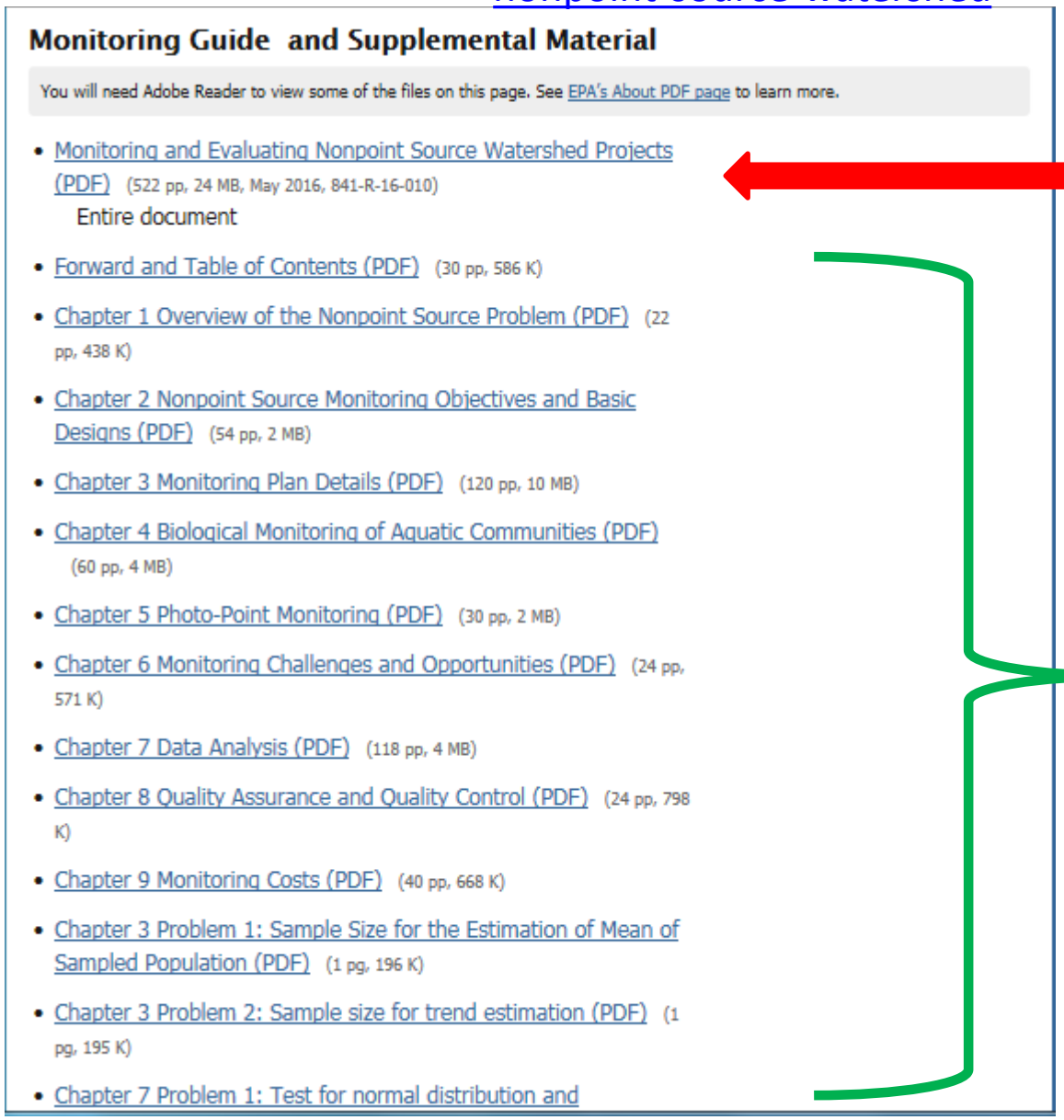

Monitoring Guide and Supplemental Material

You will need Adobe Reader to view some of the files on this page. See EPA's About PDF page to learn more.

- Monitoring and Evaluating Nonpoint Source Watershed Projects (PDF) (522 pp, 24 MB, May 2016, 841-R-16-010)
  Entire document
- Forward and Table of Contents (PDF) (30 pp, 586 K)
- Chapter 1 Overview of the Nonpoint Source Problem (PDF) (22 pp, 438 K)
- Chapter 2 Nonpoint Source Monitoring Objectives and Basic Designs (PDF) (54 pp, 2 MB)
- Chapter 3 Monitoring Plan Details (PDF) (120 pp, 10 MB)
- Chapter 4 Biological Monitoring of Aquatic Communities (PDF) (60 pp, 4 MB)
- Chapter 5 Photo-Point Monitoring (PDF) (30 pp, 2 MB)
- Chapter 6 Monitoring Challenges and Opportunities (PDF) (24 pp, 571 K)
- Chapter 7 Data Analysis (PDF) (118 pp, 4 MB)
- Chapter 8 Quality Assurance and Quality Control (PDF) (24 pp, 798 K)
- Chapter 9 Monitoring Costs (PDF) (40 pp, 668 K)
- Chapter 3 Problem 1: Sample Size for the Estimation of Mean of Sampled Population (PDF) (1 pg, 196 K)
- Chapter 3 Problem 2: Sample size for trend estimation (PDF) (1 pg, 195 K)
- Chapter 7 Problem 1: Test for normal distribution and

Whole Document

Individual Chapters

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed

- Chapter 7 Data Analysis (PDF) (118 pp, 4 MB)
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- Chapter 3 Problem 1: Sample Size for the Estimation of Mean of Sampled Population (PDF) (1 pg, 196 K)
- Chapter 3 Problem 2: Sample size for trend estimation (PDF) (1 pg, 195 K)
- Chapter 7 Problem 1: Test for normal distribution and transformation (PDF) (3 pp, 119 K)
- Chapter 7 Problem 2: Descriptive statistics (PDF) (1 pg, 26 K)
- Chapter 7 Problem 3: Compare two groups (PDF) (1 pg, 145 K)
- Chapter 7: Problem 4: Compare input and output from an individual BMP (PDF) (2 pp, 21 K)
- Chapter 7 Problem 5: Compare more than two groups (PDF) (2 pp, 93 K)
- Chapter 7 Problem 6: Correlation and regression (PDF) (3 pp, 108 K)
- Chapter 7 Problem 7: Test for treatment effect in a paired-watershed design (PDF) (2 pp, 332 K)
- Chapter 7: Problem 8: Minimum detectable change analysis (PDF) (3 pp, 615 K)
- Grabbow, 1999 (PDF) (5 pp, 3 MB)
- Suppnick 1999 (PDF) (41 pp, 21 MB)

Contact Us to ask a question, provide feedback, or report a problem.

Example Problems

- Grabbow, 1999 (PDF) (5 pp, 3 MB)
- Suppnick 1999 (PDF) (41 pp, 21 MB)

Monitoring and Evaluating Nonpoint Source Watershed Projects

Addresses the following gaps in the 1997 Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls (EPA 841-B-96-004)

- Details on monitoring designs
- Details on monitoring equipment
- Biological monitoring applications
- Pollutant load estimation methods
- Photopoint monitoring
- Cost analysis
- Real-world data analysis examples

Co-Authors

- Don Meals, Tetra Tech
  - 30+ years of NPS monitoring experience
- Jon Harcum, Tetra Tech
  - Statistics and data analysis
- Jean Spooner, North Carolina State University
  - NCSU Water Quality Group
  - Statistics and data analysis
- Sam Stribling, Tetra Tech
  - Rapid Bioassessment Protocols
- Pete Richards, Heidelberg University
  - Pollutant load estimation techniques

Plus the wisdom, guidance, expertise, and documented findings of hundreds of NPS monitoring experts over the past 35 years.

Chapter 1. Overview of NPS Problem

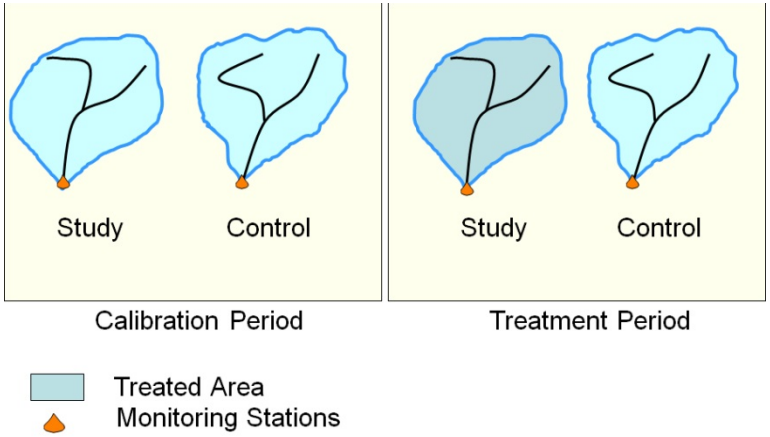
- Nonpoint source problems
  - Source categories
  - Pollutants
  - Use impairments
- Brief overview of programs to address NPS

Chapter 2. Monitoring Objectives and Basic Designs

- Basic design steps
- Fundamentals of good monitoring
  - Understanding the system
  - Monitoring source activities
  - Logistics
  - QA/QC
  - Data management
  - Feedback
  - Limitations of monitoring

Chapter 2. Monitoring Objectives and Basic Designs

- Monitoring scale
- Monitoring design
  - Reconnaissance/synoptic
  - Plot
  - Paired
  - Single station
  - Above/below
  - Multiple station
  - Input/output

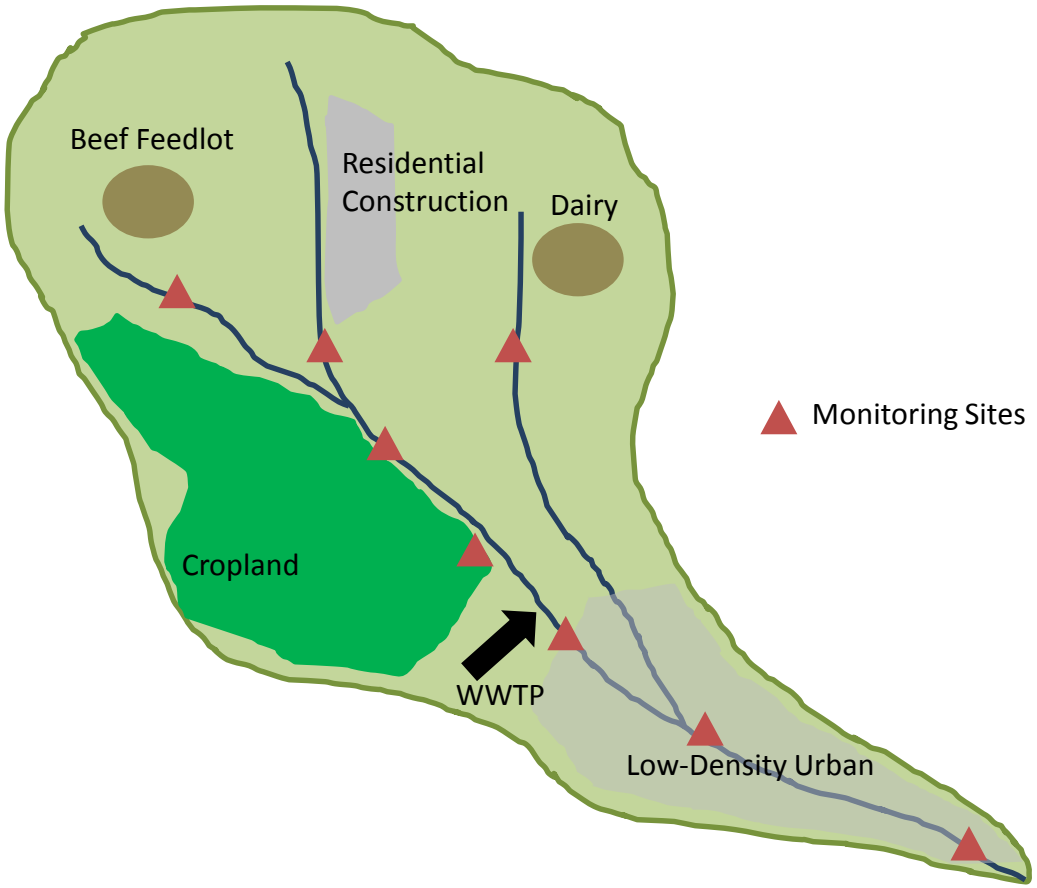


Chapter 3. Monitoring Plan Details

- Variable selection
  - General considerations
  - Selection factors (objectives, pollutant sources, impairments, cost, logistics, etc.)
  - Physical and chemical water quality constituents
    - Flow measurement
  - Biological data
  - Weather data
  - Watershed characteristics

Chapter 3. Monitoring Plan Details

- Sample type selection (grab, composite, integrated, continuous)
- Station location
- Sampling frequency and duration (minimum detectable change analysis)



Chapter 3. Monitoring Plan Details

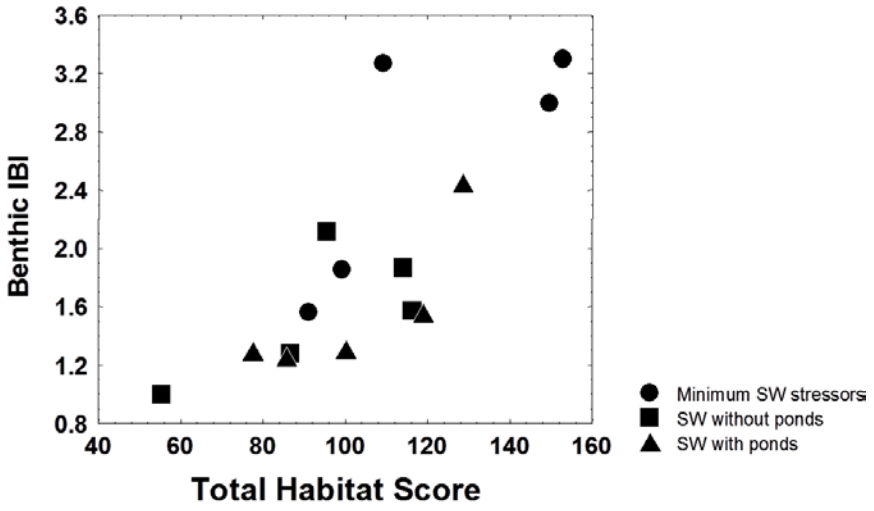
- Monitoring station construction and operation
- Sample collection and analysis methods
- Land use and land treatment monitoring
- Pollutant load estimation considerations
- Data management
- Data reporting and presentation

Chapter 4. Biological Monitoring

- Types of biological monitoring
  - Benthic macroinvertebrates
  - Fish
  - Periphyton
- Linkages to habitat
- Limitations of biological monitoring
- Reference sites and conditions
- 4 case studies

Chapter 4. Biological Monitoring

- Biomonitoring program design
- Biological assessment protocols
  - Field sampling
  - Sample processing/laboratory analysis
  - Data reduction/indicator calculation
  - Index scoring and site assessment
  - Reporting assessment results at multiple spatial scales



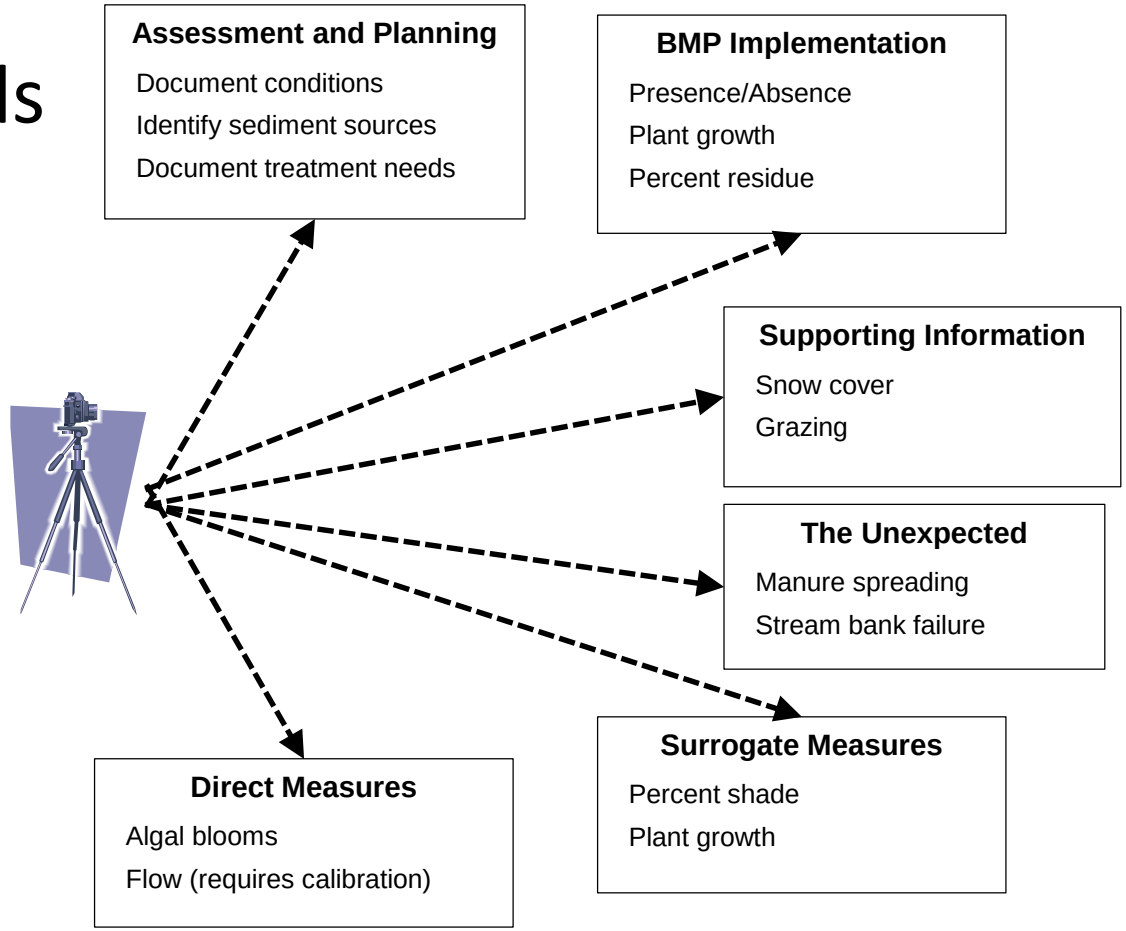
Chapter 5. Photo-Point Monitoring

- Procedure (Frederick Hall, USDA-FS)
- Objectives
- Methods
- Areas to monitor
- Photo points and camera points

- Identifying sites and recording data
- Data analysis plans

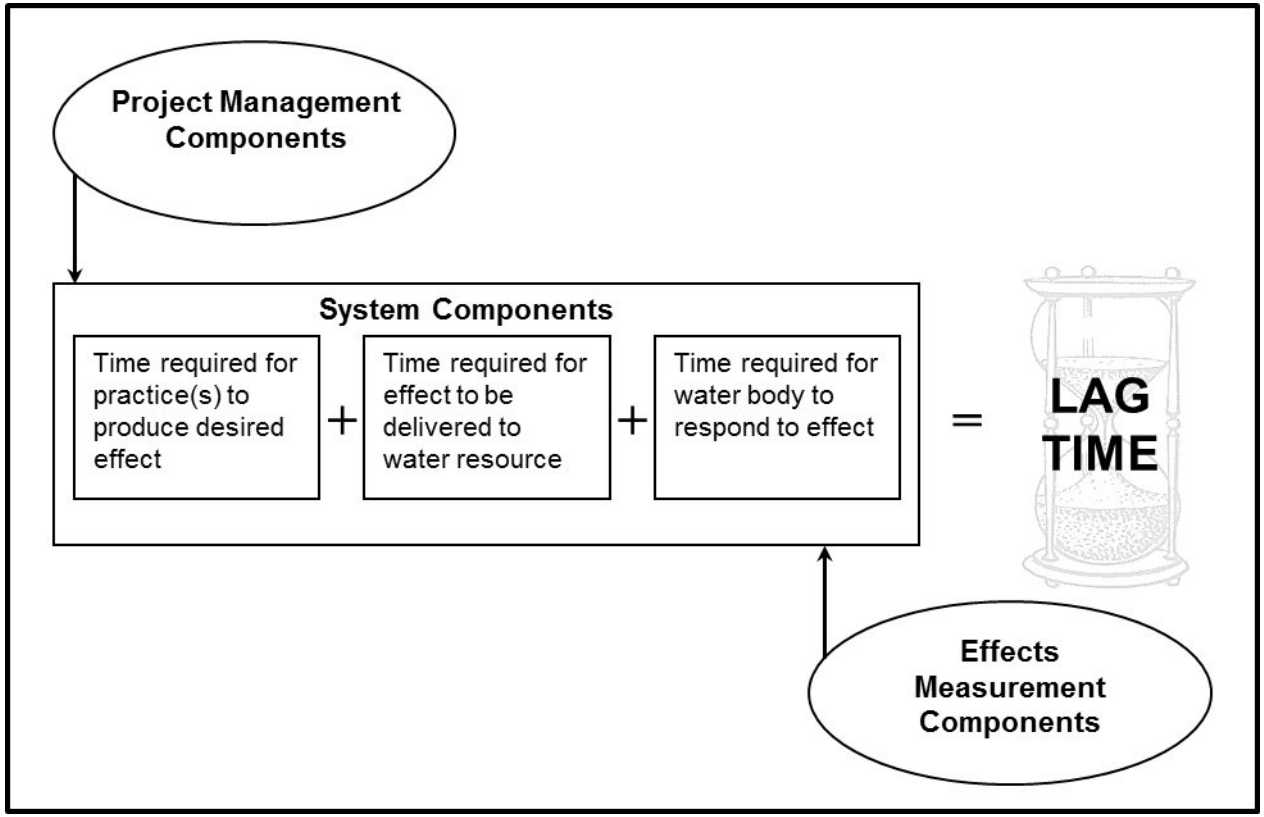
Chapter 5. Photo-Point Monitoring

- Equipment needs
- Applications of photo-point monitoring
- Advantages, limitations, and opportunities



Chapter 6. Monitoring Challenges and Opportunities

- Monitoring pitfalls
  - Design flaws
  - Procedural problems
- Lag time issues
- Integrating monitoring and modeling
- Supporting BMP and other databases



Chapter 7. Data Analysis

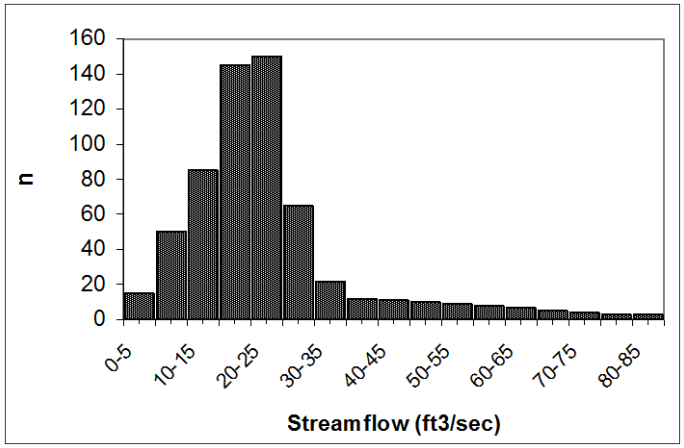
- Overview of statistical methods
  - Exploratory data analysis and data transformations
  - Dealing with censored data
  - Data analysis for water quality problem assessment
  - Project planning data analysis
  - BMP and project effectiveness data analysis

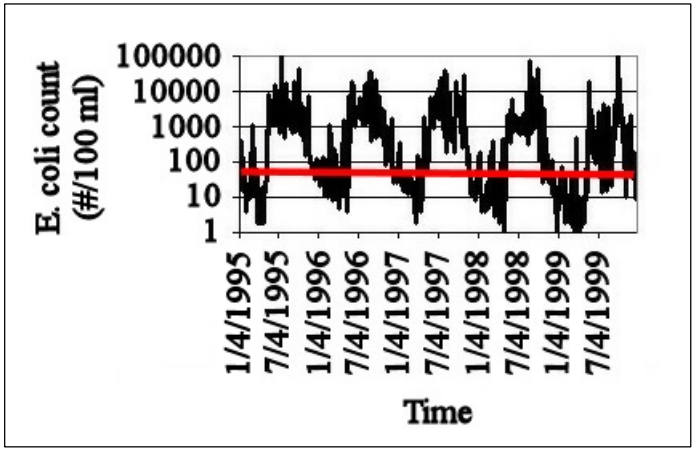
Chapter 7. Data Analysis

Analytical Objective	Monitoring Design Used	Recommended Method	Method Type*	Data Requirements	Major Cautions and Concerns
Watershed project effectiveness	Above/below-Before/after	t-Test of input vs. output EMCs or loads, ANCOVA, Wilcoxon Rank Sum, Mann-Whitney	P, N	Data must meet assumptions for parametric statistics to apply; otherwise use nonparametric test	Change in pollutant concentration or load measured at the below station may be difficult to detect if concentrations or loads at the above station are high.

Chapter 7. Exploratory Data Analysis and Data Transformations

- Steps in data exploration
- Key variable characteristics (e.g., variability)
- Transformations for non-normal data
- Examination for:
- Extreme, outlier, missing, or anomalous values
- Frequencies
- Seasonality or other cycles
- Autocorrelation
- Relationships between two or more time periods or locations
- Relationships between two variables



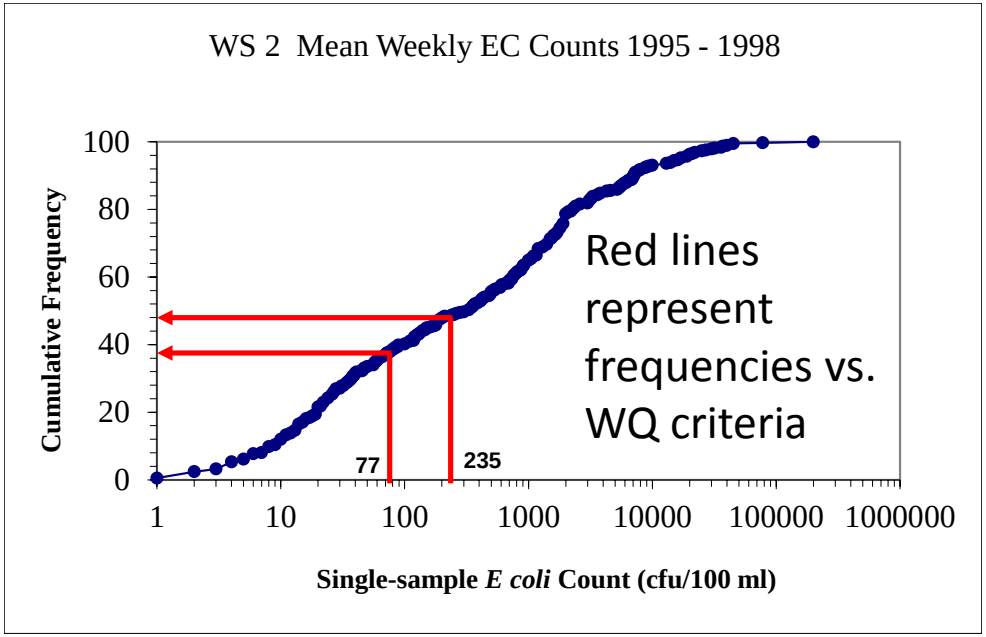


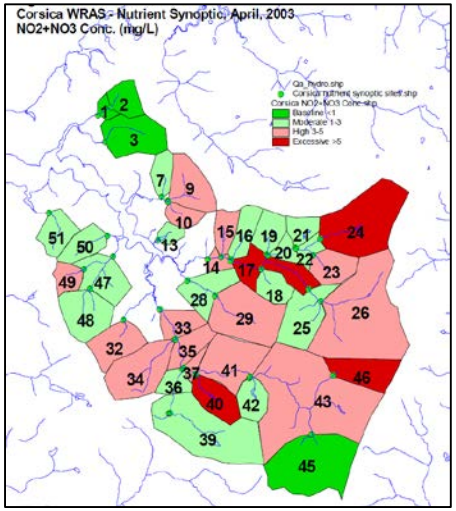
Chapter 7. Dealing with Censored Data

- Types of censoring
  - Left censored (e.g., less than detection limit)
  - Right censored (e.g., too numerous to count)
- Methods for handling censored data
  - Maximum likelihood estimation (MLE)
  - Regression on order statistics (ROS)
  - Helsel, D.R. 2012. *Statistics for Censored Environmental Data Using Minitab and R. 2nd ed.* Wiley and Sons, New York.

Chapter 7. Data Analysis for Water Quality Problem Assessment

- Summarize existing conditions
- Assess compliance with water quality standards





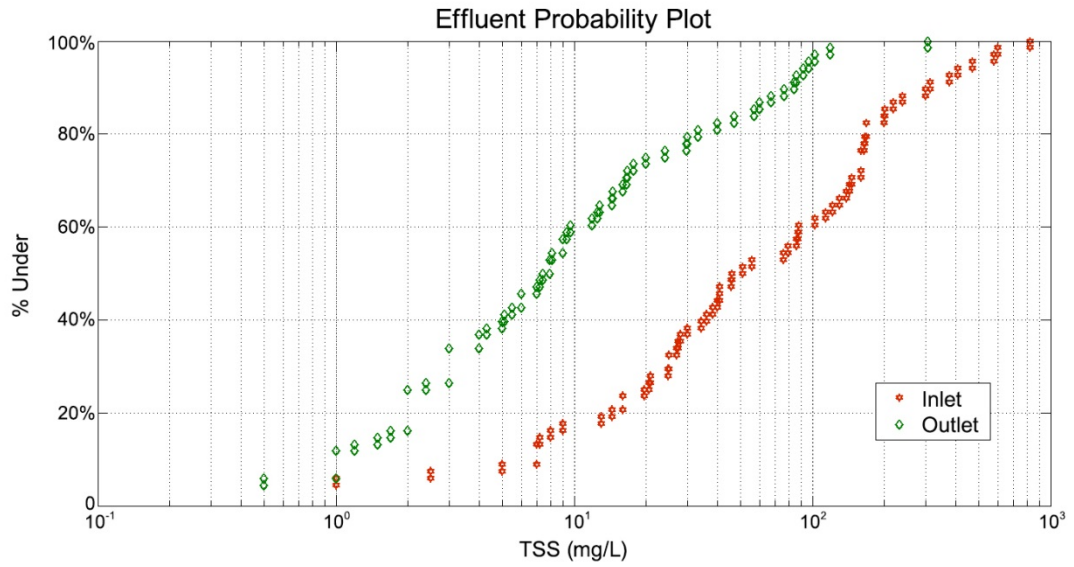
- Identify major pollutant sources
- Define critical areas

Chapter 7. Data Analysis for Project Planning

- Estimation and formulating hypotheses for testing
- Estimating pollutant reductions needed (e.g., mass balance, load duration curve)
- Estimating land treatment needs
- Estimating minimum detectable change
- Locating monitoring stations

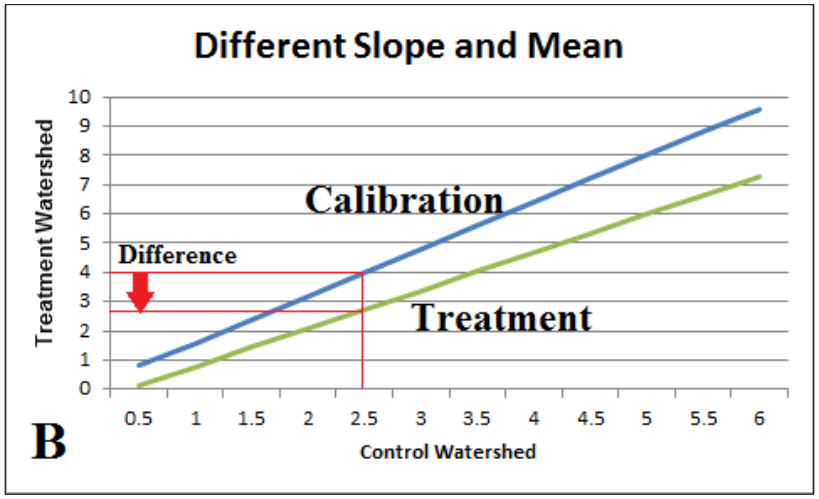
Chapter 7. Data Analysis for BMP Effectiveness

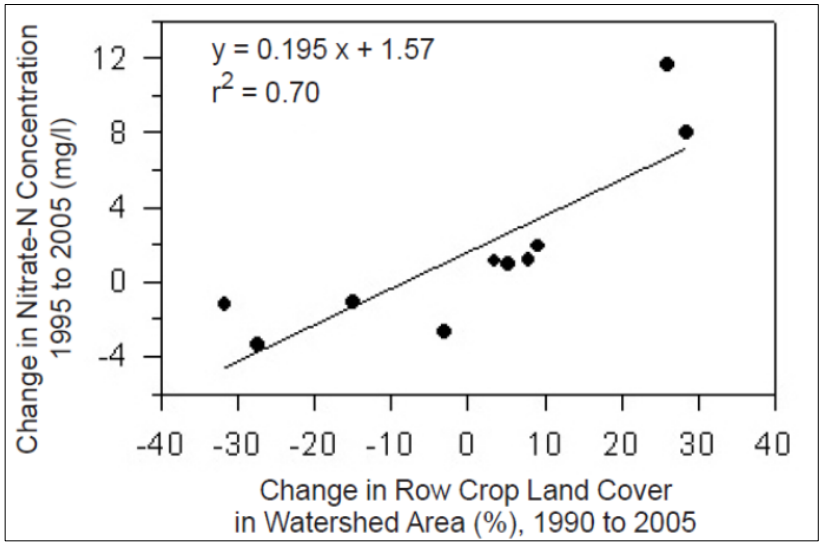
- Analysis of plot study data
- Analysis of BMP input/output data
- Analysis of BMP above/below data
- Analysis of BMP paired-watershed data



Chapter 7. Data Analysis for Project Effectiveness

- Paired-watershed data analysis
- Above/below-before/after data analysis
- Nested watershed data analysis
- Single watershed trend station data analysis
- Multiple watershed data analysis
- Linking water quality trends to land treatment

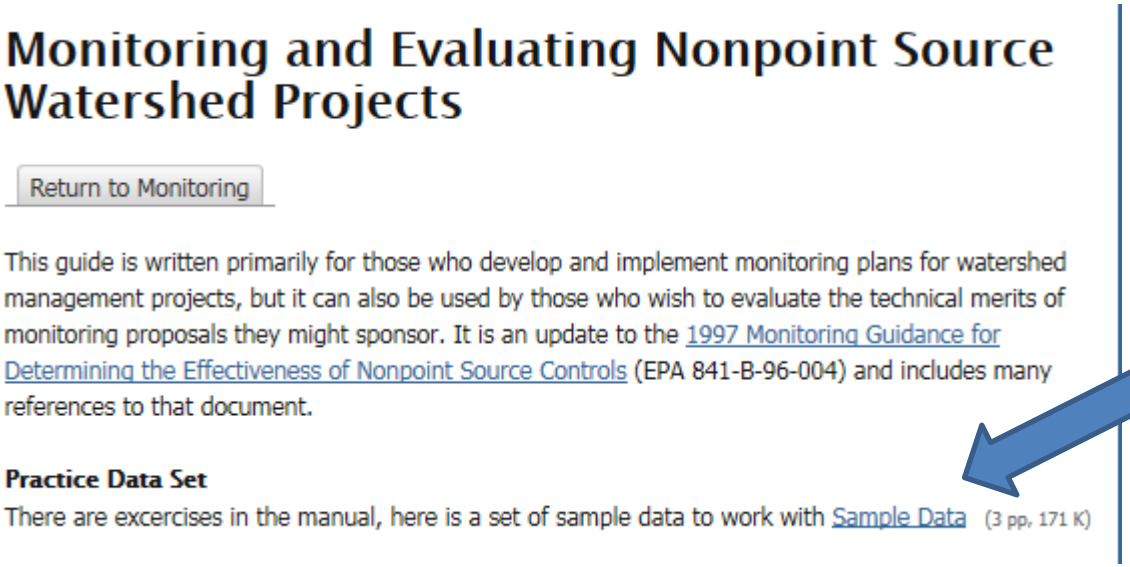




Chapter 7. Load Estimation

- Pete Richards, Heidelberg University
- General considerations
- Approaches to load estimation
  - Numeric integration
  - Regression
  - Ratio estimators
- Load duration curves

Example Datasets



Monitoring and Evaluating Nonpoint Source Watershed Projects

Return to Monitoring

This guide is written primarily for those who develop and implement monitoring plans for watershed management projects, but it can also be used by those who wish to evaluate the technical merits of monitoring proposals they might sponsor. It is an update to the 1997 Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls (EPA 841-B-96-004) and includes many references to that document.

Practice Data Set

There are excercises in the manual, here is a set of sample data to work with Sample Data (3 pp, 171 K)

Three datasets in a simple spreadsheet file

Used in ten problems to test your understanding of concepts and analytical approaches

- Chapter 3 Problem 1: Sample Size for the Estimation of Mean of Sampled Population (PDF) (1 pg, 196 K)
- Chapter 3 Problem 2: Sample size for trend estimation (PDF) (1 pg, 195 K)
- Chapter 7 Problem 1: Test for normal distribution and

Example Datasets

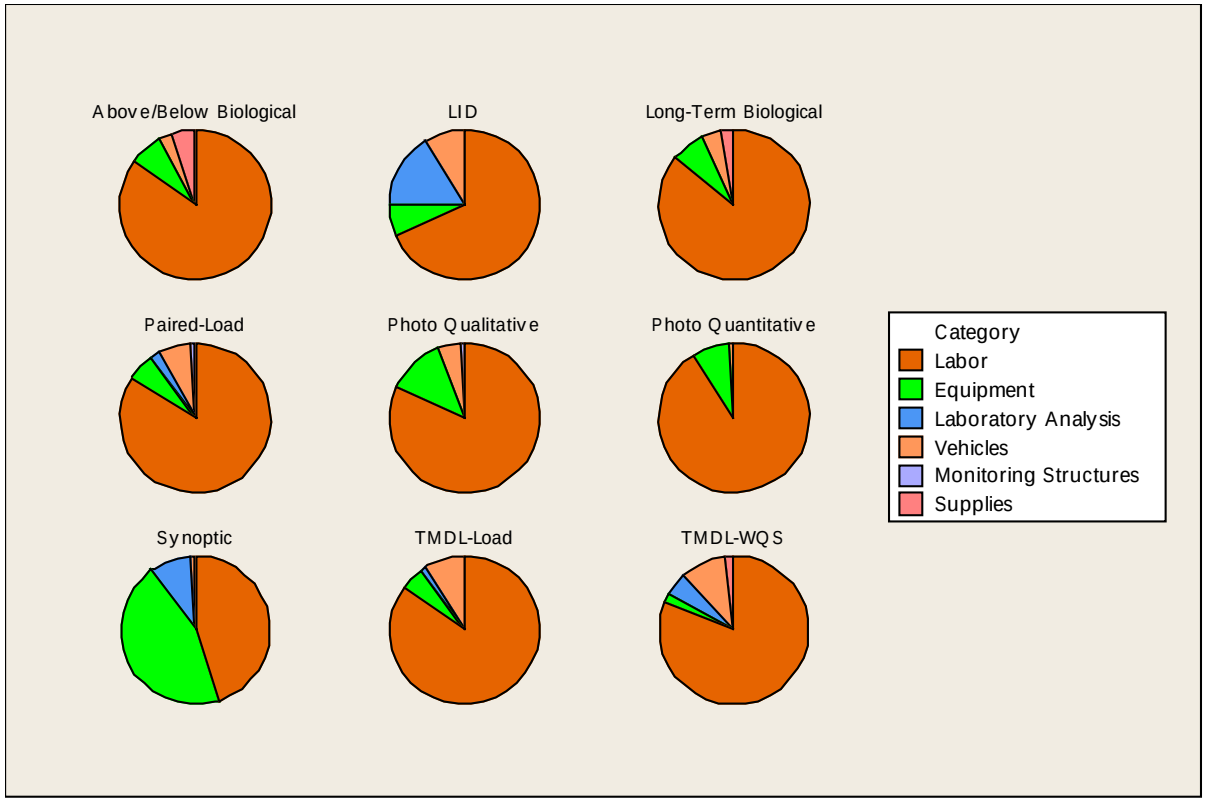
Problem Number	Objective	Test	Dataset	Problem and Answer File
1	Test for conformance to normal distribution	Graphical, skewness, kurtosis, Shapiro-Wilk, Kolmogorov	1	normality.pdf
3	Compare two groups	t-Test	1	2groups.pdf
		Wilcoxon/Kruskal-Wallace		
4	Compare input/output for a BMP	Paired t-Test	2	pairedtests.pdf
7	Assess change due to treatment in paired-watershed design	ANCOVA	1	pairedancova.pdf

Chapter 8. Quality Assurance and Quality Control

- Background and EPA policies
- Data quality objectives
- Elements of a Quality Assurance Project Plan
- Field operations
- Laboratory operations
- Data and reports
- Geospatial data

Chapter 9. Monitoring Costs

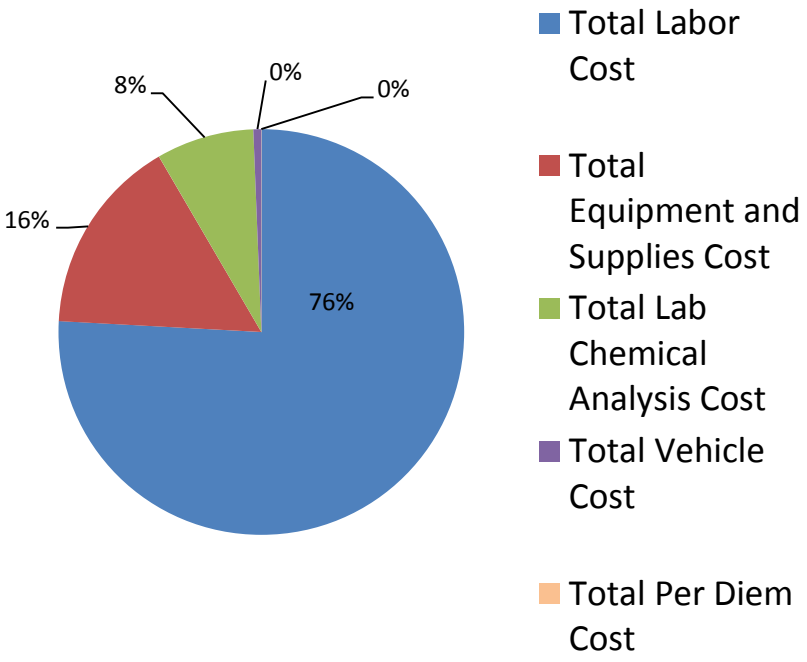
- Overview of cost items
- Cost estimation examples
- Using MDC to guide monitoring decisions
  - MDC and cost vs. number of sites, frequency, duration, variables



Monitoring Cost Spreadsheets

- Two cost estimation sheets (master & simple)
- Simple Version
  - 3 Designs: Above/Below, Paired-Watershed, Trend
  - 4 Sample Types: Biological/Habitat, Grab Samples, Sondes, Loads
  - 2 Variable Sets: Nutrients & Turbidity or Nutrients, Turbidity & Metals
  - Enter 18 bits of info and get total and annual costs
  - Users can change many default values

Monitoring Cost Spreadsheets



Cost Category	
Labor	$66,947
Equipment and Supplies	$13,891
Sampling Analysis	$6,864
Vehicles	$557
Per Diem	$0
TOTAL COST	$88,259
Average Annual Cost	$17,652
Total Cost with Inflation	$88,894
Average Annual Cost with Inflation	$17,779

TOTAL COST:	$88,259

Above/Below, 5 years, 26x/yr, Sondes, Nutrients & Turbidity

Tech Notes
2005-2014

TechNOTES 1

National Nonpoint Source Monitoring Program

July 2005

Through the National Nonpoint Source Monitoring Program (NNPSMP), states monitor and evaluate a subset of watershed projects funded by the Clean Water Act Section 319 Nonpoint Source Control Program.

The program has two major objectives:

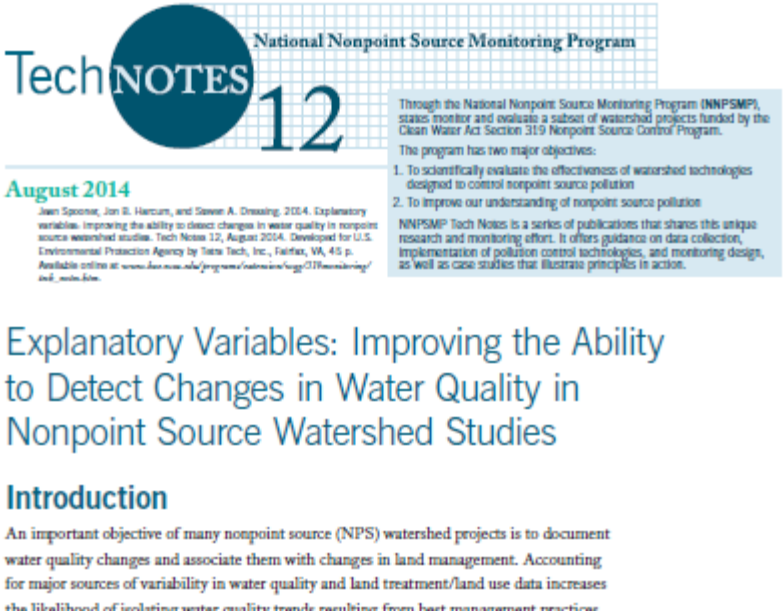
1. To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution
2. To improve our understanding of nonpoint source pollution

NNPSMP Tech Notes is a series of publications that shares this unique research and monitoring effort. It offers guidance on data collection, implementation of pollution control technologies, and m
as well as case studies that illustrate principles in actio

Monitoring Data

Exploring Your Data, The First Step

Now that your monitoring program is up and running, it is time to evaluate the data. If you designed your monitoring program carefully (Tech Note #2), you will have the right kinds of data collected at appropriate times and locations to achieve your objectives. At the start, you should check your data for conformity with original plans and quality assurance/quality control (QA/QC) procedures. Use the Quality Assurance Project Plan



TechNOTES 12

National Nonpoint Source Monitoring Program

August 2014

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NNPSMP Tech Notes is a series of publications that shares this unique research and monitoring effort. It offers guidance on data collection, implementation of pollution control technologies, and monitoring design, as well as case studies that illustrate principles in action.

Explanatory Variables: Improving the Ability to Detect Changes in Water Quality in Nonpoint Source Watershed Studies

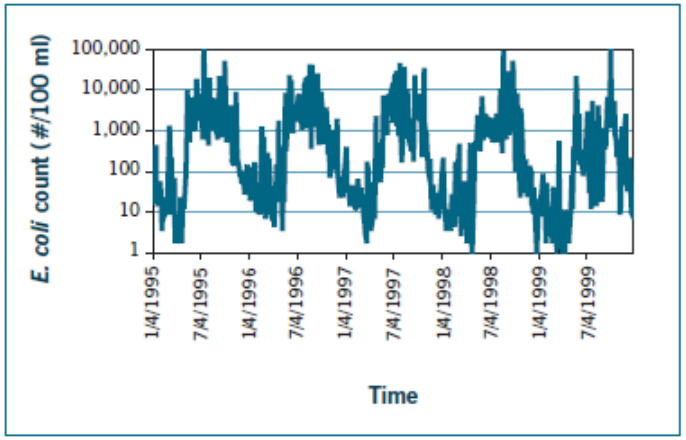
Introduction

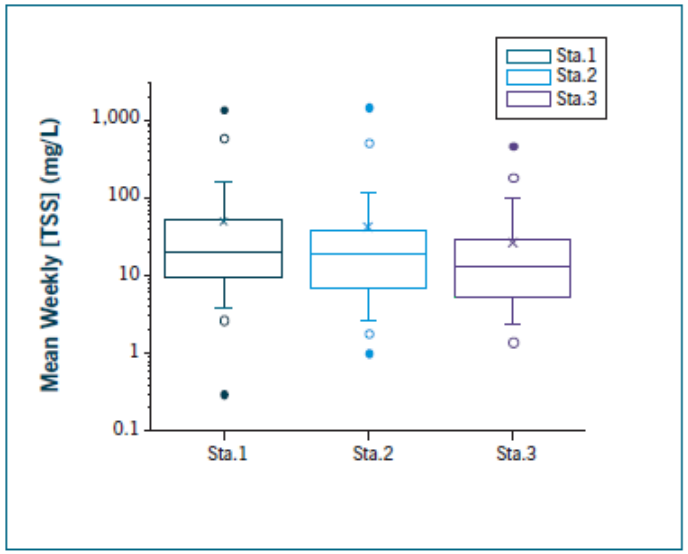
An important objective of many nonpoint source (NPS) watershed projects is to document water quality changes and associate them with changes in land management. Accounting for major sources of variability in water quality and land treatment/land use data increases

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-monitoring-technical-notes

1. Monitoring Data - Exploring Your Data, The First Step

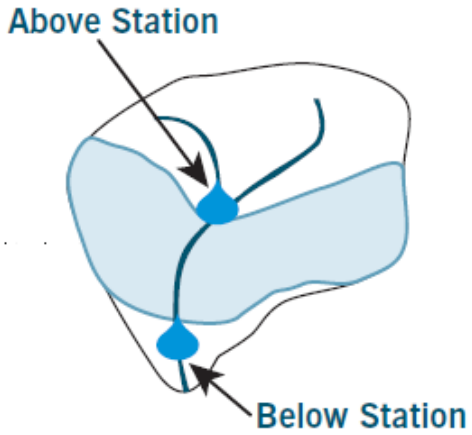
- Steps in exploratory data analysis (EDA)
- Quantitative techniques
- Graphical approaches
- Single variables
- Multiple variables





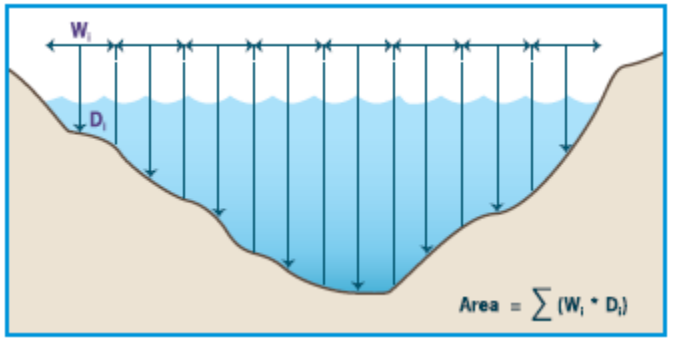
2. Designing Water Quality Monitoring Programs for Watershed Projects

- Goals
- Review of existing data and monitoring efforts
- Statistical designs (e.g., above/below)
- Scale, variables, sample type, number of samples, etc.
- Land treatment
- QA/QC



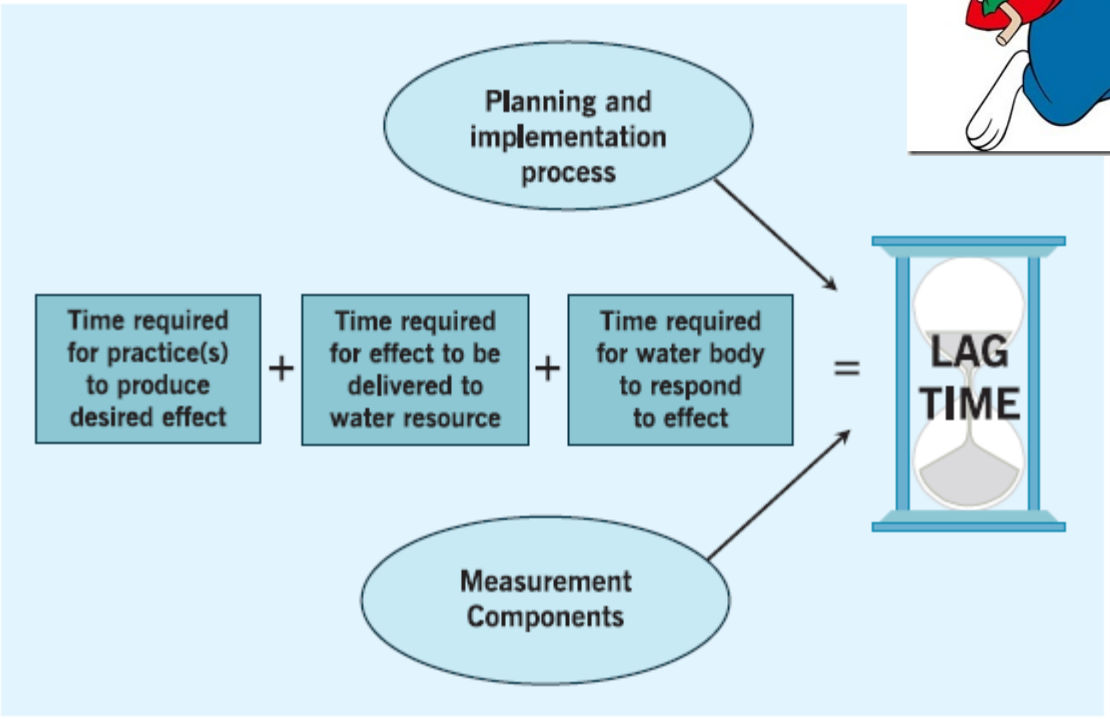
3. Surface Water Flow Measurement for Water Quality Monitoring Projects

- Basic principles of discharge measurement
- Stage measurements
- Stage-discharge curves
- Flow measurement methods
- Applications of flow data



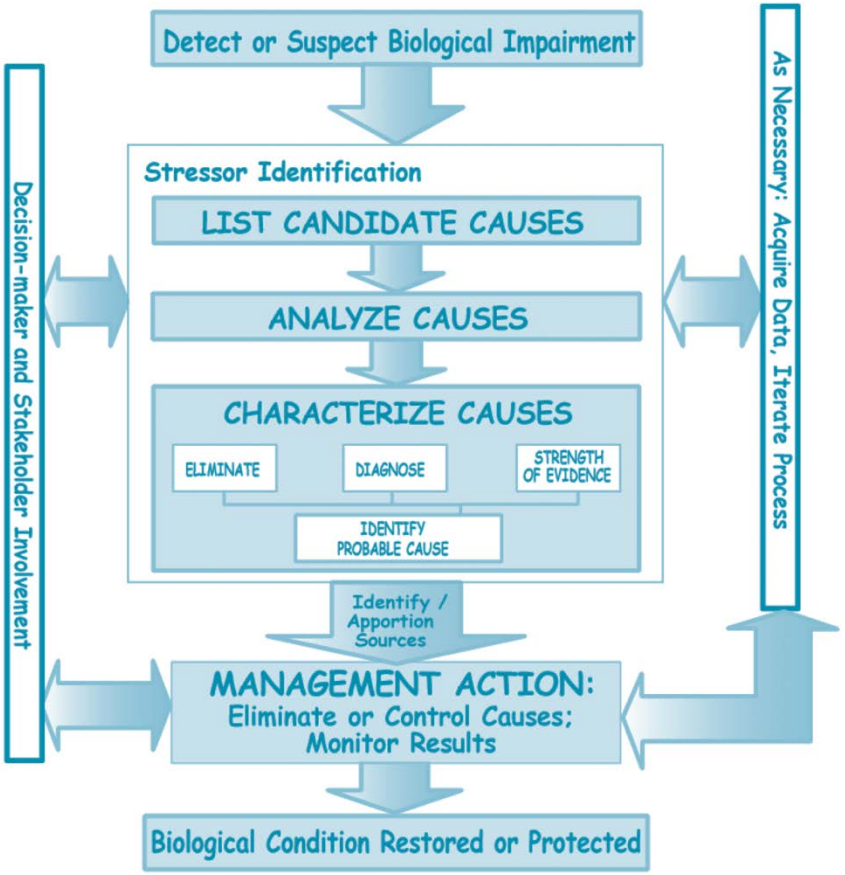
4. Lag Time in Water Quality Response to Land Treatment

- Components of lag time
- Dealing with lag time



5. Using Biological and Habitat Monitoring Data to Plan Watershed Projects

- Overview of biological and habitat monitoring
- Opportunities to use biological and habitat data in watershed project planning
  - Examples



6. Statistical Analysis for Monotonic Trends

- Presents and demonstrates the basic analysis of long-term water quality data for trends
- Data exploration, data reduction, flow adjustment
- Tests with and without covariates
- Seasonality

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(y_j - y_i)$$

$$Y_\tau = \beta_0 + \beta_1 \sin(2\pi t/n) + \beta_2 \cos(2\pi t/n) + \beta_3 t + \text{other terms} + \varepsilon_\tau$$

$$Y = \beta_0 + \beta_1 t + \beta_2 Q + \varepsilon$$

$$S_k = \sum_{i=1}^{m} S_i$$

$$Y = \beta_0 + \beta_1 t + \varepsilon$$

7. Minimum Detectable Change Analysis

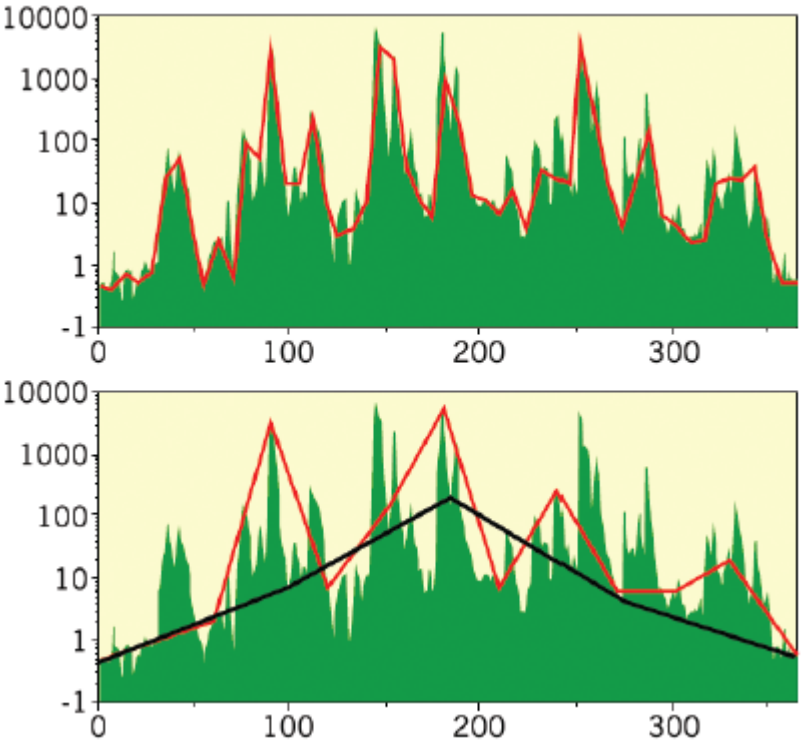
- Factors affecting magnitude of MDC
- Steps to calculate MDC
- Examples

$$MDC = (N) * t_{(n*N-2)df} * 365 * s_{b1}$$

$$MDC = t_{(n_{pre} + n_{post}-2)} \sqrt{\frac{MSE}{n_{pre}} + \frac{MSE}{n_{post}}}$$

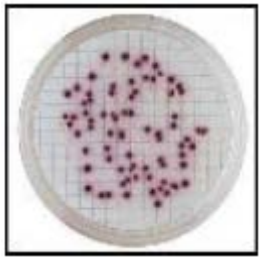
8. Pollutant Load Estimation for Water Quality Monitoring Projects

- General considerations
- Issues of variability
- Planning monitoring for load estimation
- Approaches to load estimation
  - Numeric integration
  - Regression
  - Ratio estimators
- Load duration curves



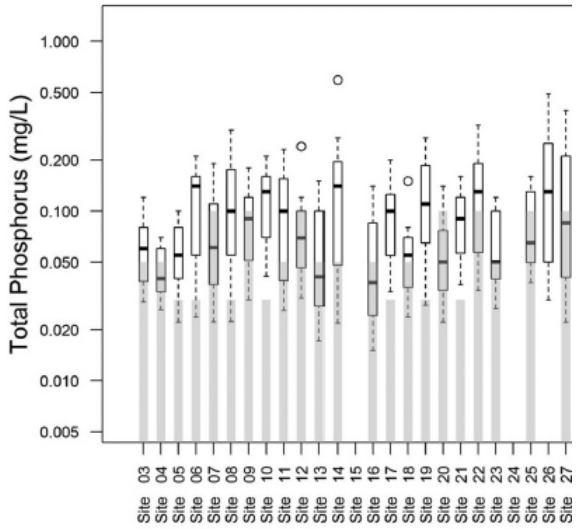
9. Monitoring for Microbial Pathogens and Indicators

- Bacteria
- Fecal indicator bacteria
- Protozoa
- Viruses
- Sources, fate, and transport
- Monitoring issues
- Microbial source tracking
- Case studies



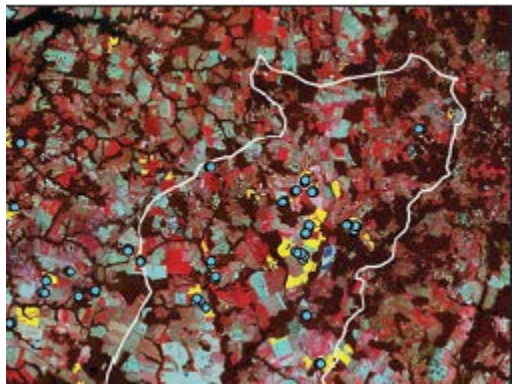
10. Baseline Assessment of Left-Censored Environmental Data Using R

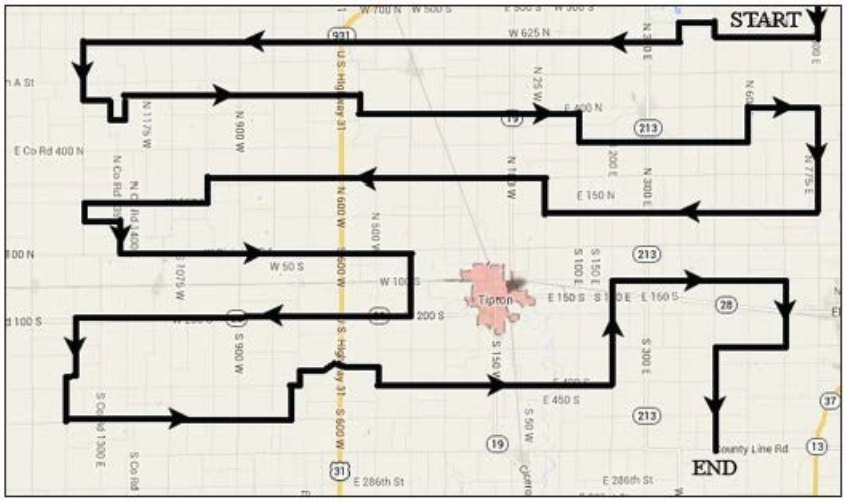
- Basic information on R
  - Installation of R and Rstudio
  - Starting up and using R
  - Importing data
- Censored data
  - Methods for estimating summary statistics (e.g., robust ROS)
- Detailed example-Little Calumet East Branch
- Data set and R script provided



11. Land Use and BMP Tracking for NPS Watershed Projects

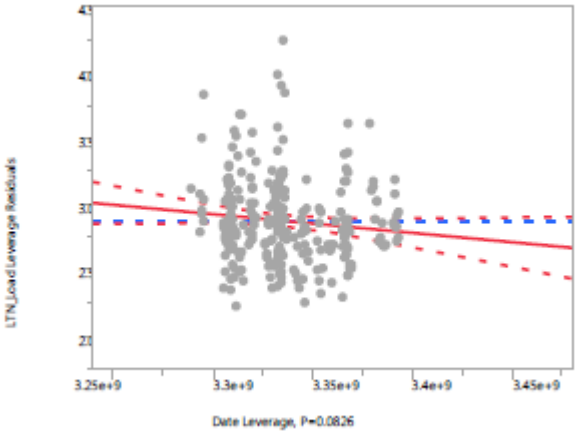
- Variable selection
- Geographic coverage
- Frequency, duration, timing
- Data collection methods
- Data management, QA/QC
- Challenges (e.g., confidentiality)
- Relating land use/land treatment data to water quality data

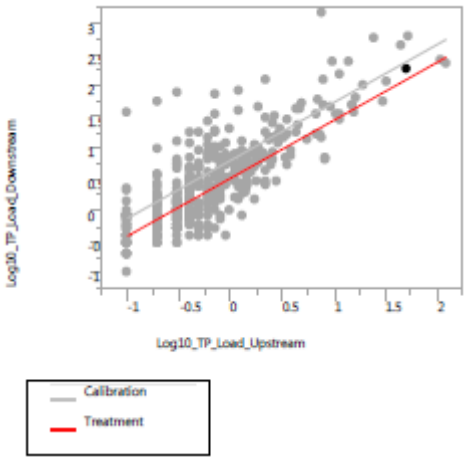




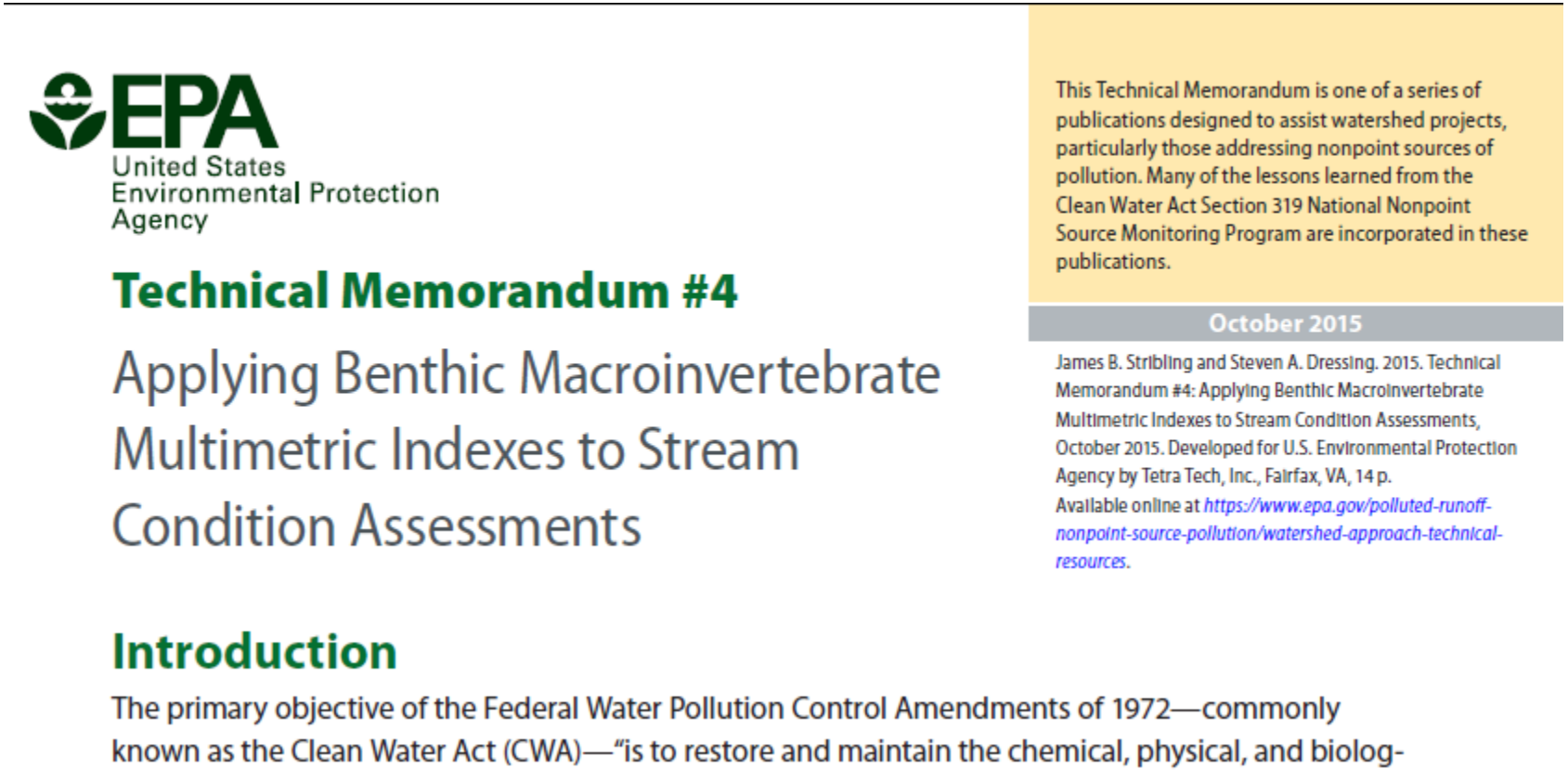
12. Explanatory Variables: Improving the Ability to Detect Changes in Water Quality in Nonpoint Source Watershed Studies

- Discussion of explanatory variables, importance, and their use
- How to determine most important explanatory variables to measure and use in trend analysis
- Incorporating explanatory variables in trend analyses
- Examples





Technical Memorandums 2015



EPA
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Technical Memorandum #4

Applying Benthic Macroinvertebrate Multimetric Indexes to Stream Condition Assessments

This Technical Memorandum is one of a series of publications designed to assist watershed projects, particularly those addressing nonpoint sources of pollution. Many of the lessons learned from the Clean Water Act Section 319 National Nonpoint Source Monitoring Program are incorporated in these publications.

October 2015

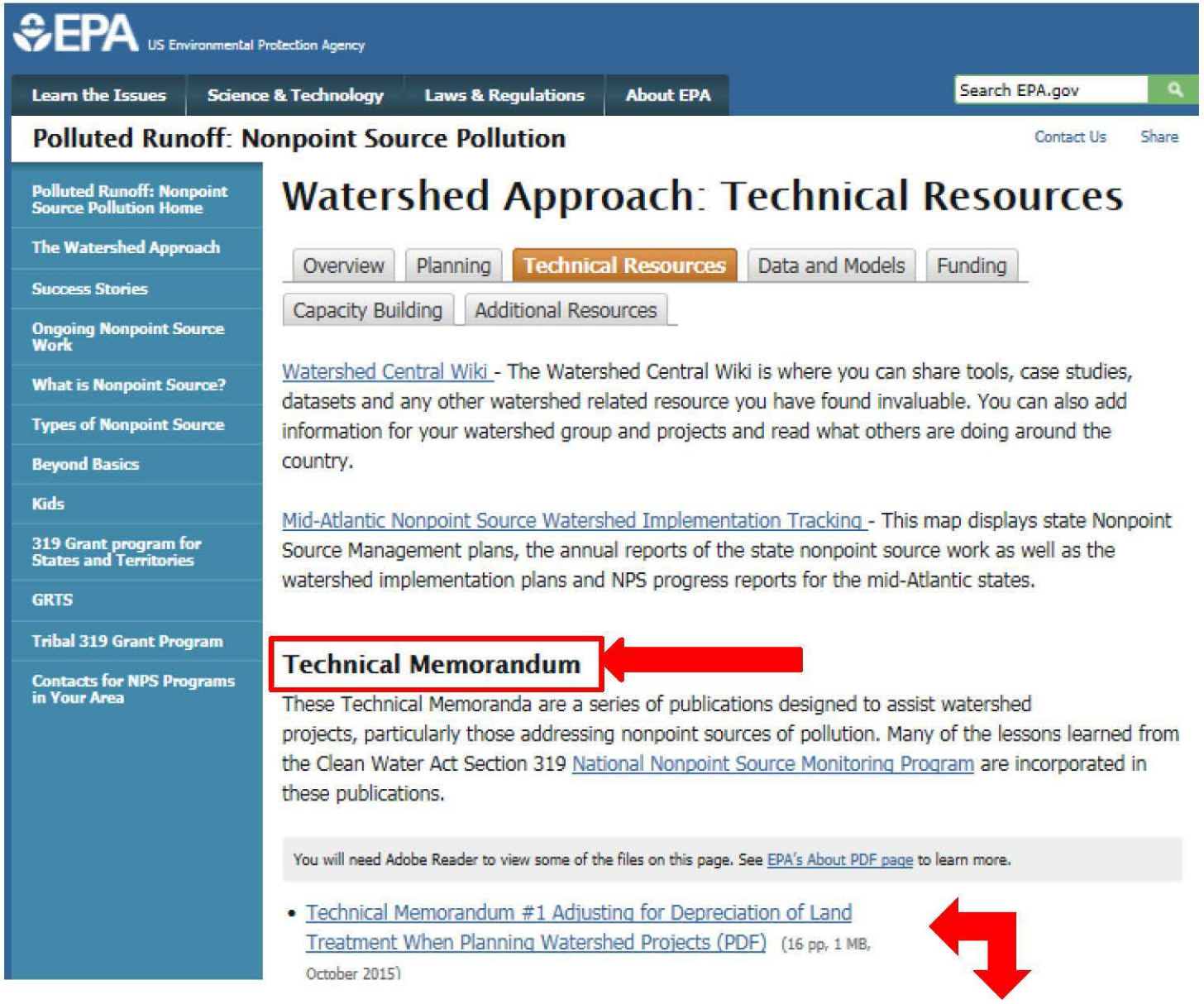
James B. Stribling and Steven A. Dressing. 2015. Technical Memorandum #4: Applying Benthic Macroinvertebrate Multimetric Indexes to Stream Condition Assessments, October 2015. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 14 p.
Available online at *https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/watershed-approach-technical-resources*.

Introduction

The primary objective of the Federal Water Pollution Control Amendments of 1972—commonly known as the Clean Water Act (CWA)—"is to restore and maintain the chemical, physical, and biolog-

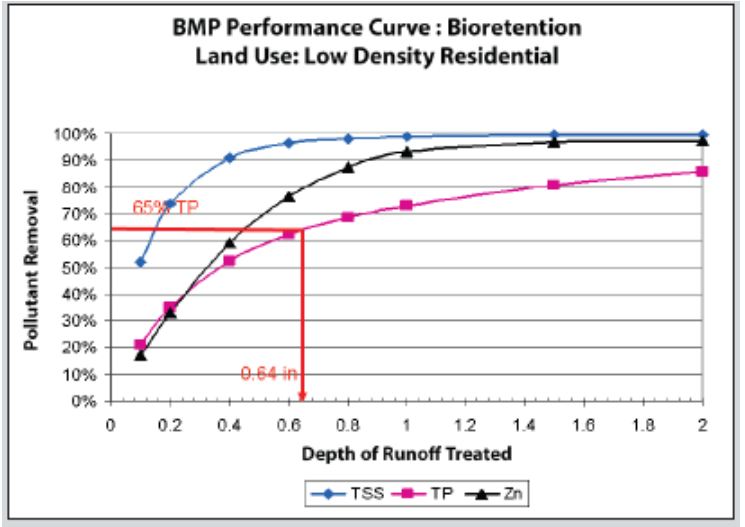
https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/watershed-approach

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/watershed-approach-technical-resources



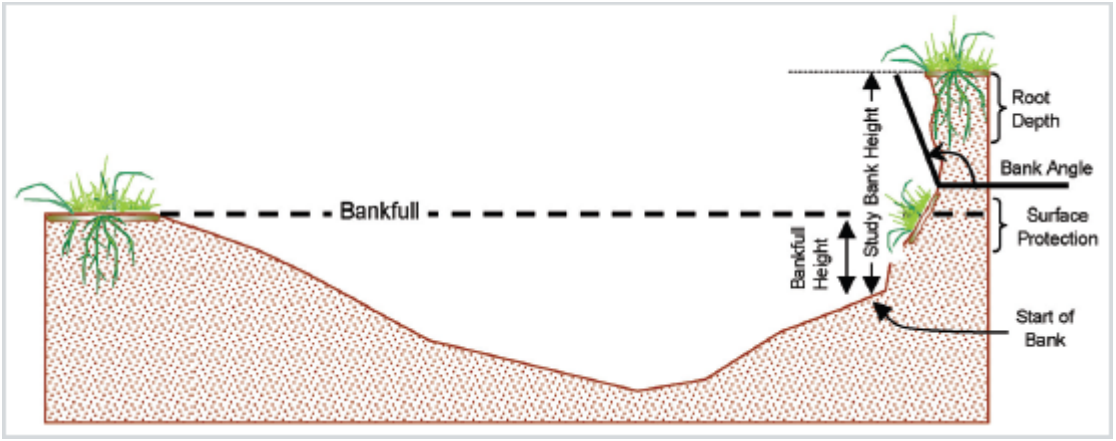
1. Adjusting for Depreciation of Land Treatment When Planning Watershed Projects

- Causes of depreciation
- Assessment of depreciation
  - BMP verification
  - Depreciation indicators
- Adjusting for depreciation
  - Assessing baseline conditions
  - Adaptive management
  - Etc.
- Recommendations



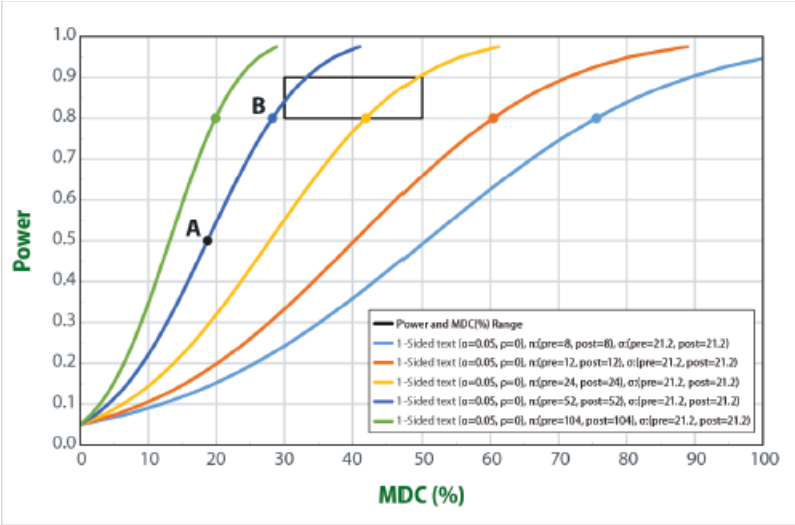
2. Relative Applicability of Particle Distribution Measures and Bank Slope Stability in Evaluating NPS Watershed Projects

- Measurements of bedded sediments and bank stability (e.g., surface particle size distribution)
- Application of bank and sediment measures (e.g., setting treatment priorities)



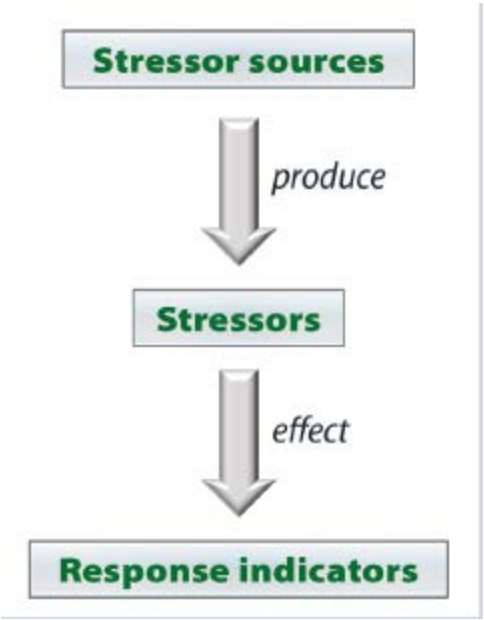
3. Minimum Detectable Change and Power Analysis

- Builds from Tech Notes #7 on MDC
- Tech Notes #7
  - Power = (1-β) = 0.5
  - B = Type II error rate (Accept H_o when H_o is False)
- This memorandum provides for MDC calculations at other power levels (e.g., 0.8)
  - Step-trend analysis
  - No explanatory variables



4. Applying Benthic Macroinvertebrate Multimetric Indexes to Stream Condition Assessments

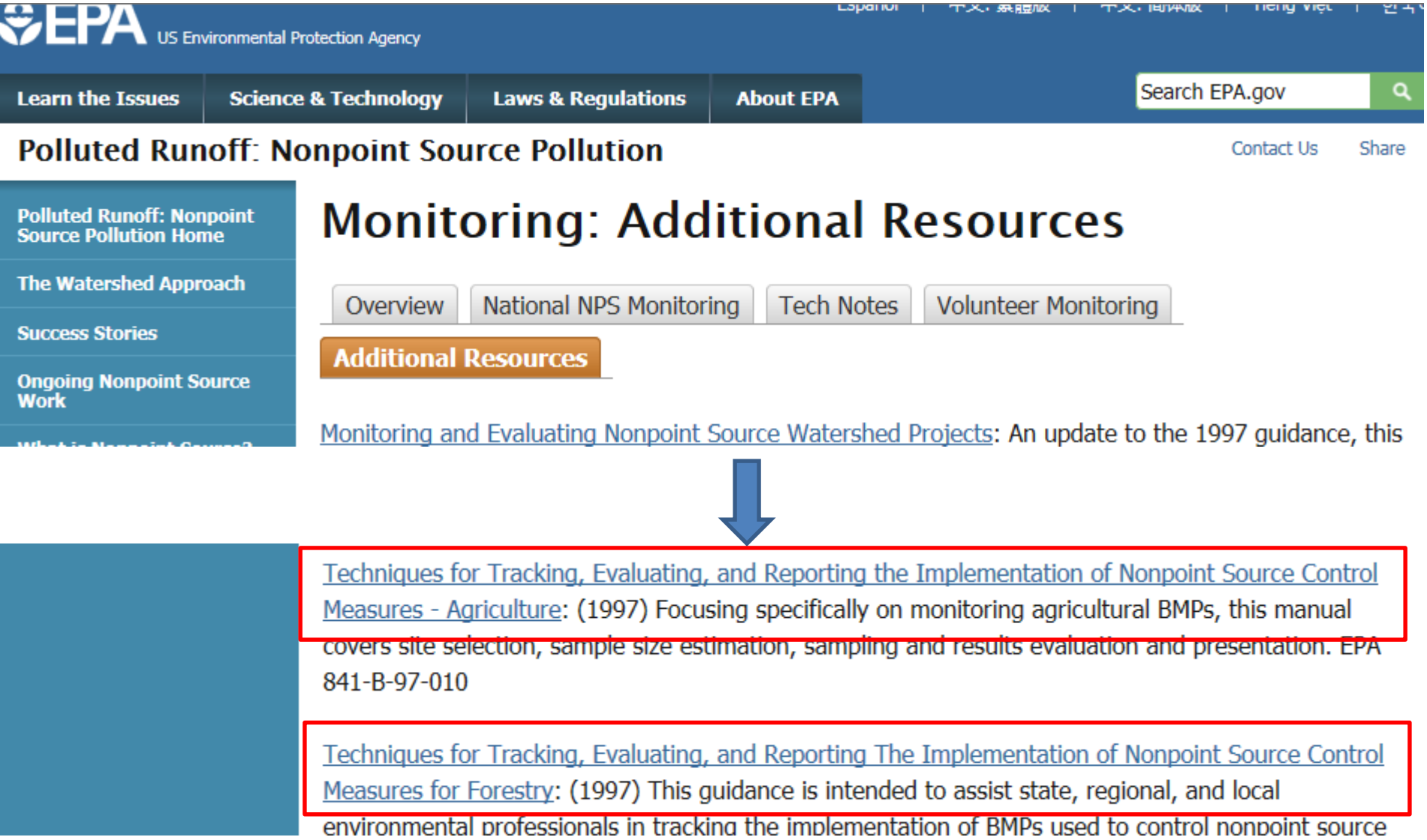
- Application of index of biological integrity to assessment of and reporting on aquatic ecological condition of a water body
  - Field sampling
  - Laboratory processing
  - IBI calculation
  - Site assessment



5. Data Reporting and Presentation

- Under Development – December 2016
- Water quality and land treatment data
- Accurate and complete reporting
- Statistical confidence and power

https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-additional-resources



BMP Tracking

- Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – **Agriculture** (1997)
- Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures for **Forestry** (1997)
- Techniques for Tracking, Evaluating and Reporting the Implementation of Nonpoint Source Control Measures **Urban** (2001)

BMP Tracking

- Sampling design
- Methods for evaluating data
- Conducting the evaluation
- Presentation of evaluation results
- Methods being applied to Chesapeake Bay BMP verification efforts

95% Confidence Level													
p		±d	Large N	100		200		600		1000		1,500	2,000
No Information	50%	5%	385	80%		66%		39%		28%		20%	16%
	50%	10%	97	50%		33%		14%		9%		6%	5%
	50%	15%	43	31%		18%		7%		4%		3%	2%
	50%	20%	25	20%		12%		4%		3%		2%	1%
	50%	25%	16	14%		8%		3%		2%		1%	1%
Good Maintenance	70%	5%	323	77%		62%		35%		25%		18%	14%
	70%	10%	81	45%		29%		12%		8%		5%	4%
	70%	15%	36	27%		16%		6%		4%		2%	2%
	70%	20%	21	18%		10%		4%		2%		1%	1%
	70%	25%	13	12%		7%		2%		1%		1%	1%
Excellent	85%	5%	196	67%		50%		25%		16%		12%	9%
	85%	10%	49	33%		20%		8%		5%		3%	2%
	85%	15%	22	19%		10%		4%		2%		1%	1%
	85%	20%	13	12%		7%		2%		1%		1%	1%
	85%	25%	8	8%		4%		1%		1%		1%	0.4%

Wrap-Up

- Much of what has been learned in NPS over the past 30+ years is documented and available at EPA's website
- Constant need for training
  - NPS staff turnover: Use website materials for NPS 101 training … and advanced classes
  - Review these materials BEFORE diving into a watershed project or monitoring effort
- More is out there:
  - USGS
  - USDA (Jack Clausen-National Water Quality Handbook) http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044775.pdf)
- Re-learning old lessons is a waste of resources – READ!

Discussion