Key Topic #4: Strategies to Evaluate NPS Sources, Issues, and Solutions

Learning Objectives

1. **Identify** tools and techniques used to assess non-point source pollution, including watershed mapping, stormwater flow tracing, and visual assessment methods.
2. **Explain** how monitoring data (e.g., water quality indicators such as turbidity, E. coli, nutrients) can be used to evaluate the presence and severity of NPS pollution.
3. **Describe** the challenges in monitoring, quantifying, and managing NPS pollution compared to point source pollution.
4. **Apply** simple field protocols to evaluate land use and physical features (e.g., slope, impervious cover, vegetative buffers) that influence runoff and pollutant transport.
5. **Interpret** basic maps, aerial imagery, or field data to locate potential sources of NPS pollution in a given watershed.
6. **Recommend** appropriate solutions based on identified issues in a mock or real-world NPS pollution scenario, drawing on field evidence or data interpretation.

Nonpoint Source Monitoring

(https://www.epa.gov/nps/nonpoint-source-monitoring-technotes)
See original document above for embedded references.

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 TechNOTES is a series of publications that EPA published between 2005 and 2014 that describes this unique research and monitoring effort. TechNOTES offer:

- guidance on data collection,
- implementation of pollution control technologies and monitoring design,
- case studies that illustrate principles in action.

Designing Water Quality Monitoring Programs for Watershed Projects
Excerpts

Designing Water Quality Monitoring Programs for Watershed Projects

(https://www.epa.gov/polluted-runononpoint-source-monitoring-technical-notes) See original document above for embedded references.

Define Goals

Monitoring is carried out to support watershed projects for a number of reasons, including the following (USEPA, 1997a):

- To identify water quality problems, use impairments, causes, and pollutant sources
- To assess permit compliance
- To assist program development and management
- To respond to emergencies
- To validate or calibrate models
- To conduct research
- To develop TMDLs and load/wasteload allocation
- To assess use support status
- To track trends
- To track management measure implementation
- To assess the effectiveness of watershed projects

Relevant monitoring goals are to track management measure implementation, look for trends, and assess watershed project effectiveness. Land treatment monitoring goals might include the following:

- To find out when and where management measures are implemented and operational
- To determine whether management measures are working as planned
- To determine the degree of pollution control achieved by the management measures
- To measure the pollutant contributions from areas where management measures are not implemented
- To discover unplanned activities that could affect project success

Trend analysis and watershed effectiveness monitoring goals might include the following:

- To document pre-implementation water quality conditions
- To measure changes in water quality due to implementation of management measures
- To develop information to guide changes in the implementation plan if water quality goals are not achieved
- To measure the pollutant removal efficiencies of specific management measures
- To measure water quality changes in subwatersheds
- To document changes in pollutant load at the watershed outlet

Review Available Information and Monitoring Efforts

A good watershed monitoring program must be based on a thorough understanding of the system(s) being monitored. Collecting and evaluating all available information and data from other monitoring efforts lays an important foundation for such an understanding. Currently available information should be reviewed before new data are collected to assess its potential use in characterizing the watershed and achieving monitoring goals.

Existing data can also be helpful in designing the management measure implementation plan. For example, stream data for relatively homogenous watersheds might be helpful in assessing pollutant delivery coefficients for current land uses. Comparing these coefficients with literature values might provide a crude indication of the extent to which management improvements could reduce pollutant delivery.

When reviewing historical data, it is important to explore any relationships that might exist between water quality data and land use or land management data. Abrupt changes in water quality parameter values could be related to the addition of or improvement to a point source discharge such as a wastewater treatment plant, changes in impervious surface percentage, increases or decreases in livestock herd sizes, changes in agricultural crop production or livestock types, hydromodification or bridge construction, urbanization, or other land use or land management changes.

Design the Monitoring Program

The specifics of a successful monitoring program depend on the monitoring goals, the availability of existing data and monitoring efforts, the time frame for yielding results, the variability of the system monitored, the types of variables tracked, funding, and the priorities of program managers.

A no-frills monitoring program that meets established goals should be the base, to which enhanced capabilities are added as resources and management allow. Even with generous budgets, no monitoring should be conducted without carefully considering the use of the data to be collected.

Statistical Design

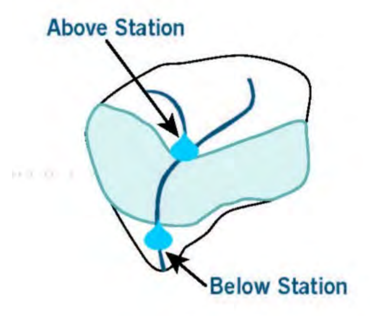
The statistical design must be chosen before other monitoring details (e.g., scale, number of sampling sites, monitoring station type, sampling frequency) can be determined. search sampling can be used to characterize a watershed and locate major pollutant sources; and probability sampling should be used to evaluate watershed projects. Types of probability sampling include simple random sampling, stratified random sampling, two-stage sampling, cluster sampling, systematic sampling, and double sampling

When evaluating the effectiveness of watershed projects, the emphasis should be on testing a hypothesis rather than estimating parameters. For example, the null hypothesis might be that phosphorus loads to the lake will not change between pre-implementation and post-implementation conditions. The goal for the monitoring design would be to test the null hypothesis and, if the null hypothesis is rejected, to conclude with some level of confidence that a change occurred.

The types of monitoring designs are as follows:

- Single-watershed before/after (not recommended)
- Above/below watersheds
- Side-by-side watersheds (not recommended)
- Paired watersheds (very good, but expensive)
- Trend monitoring (>10 years monitoring)

Above/Below Watersheds



In this design monitoring stations are placed above and below the area in which management measures are implemented. Also known as a nested design, this can be treated as a paired-watershed approach if monitoring is done before and after management measures are implemented (USDA, 1996). This design is not as vulnerable to year-to-year climate variations as is single watershed monitoring; it is fairly easy to find a situation where treatment can be implemented between stations; and it is possible to attribute changes in water quality to specific causes, as long as management measures and other land use variables are monitored in both watersheds.

One disadvantage is that the water quality at the above station and that at the below station are not independent because upstream concentrations usually affect downstream concentrations. This might confound statistical analysis of the data. If both pre-implementation and post-implementation monitoring are used, some of these problems can be addressed by a paired-watershed analysis. A paired t-test of the differences between paired above and below samples is appropriate for this design (USDA, 1996).

Watershed-level monitoring is the primary mechanism for evaluating the effectiveness of a watershed project because the projects are implemented at this scale. Watersheds can range in size from a few acres to several thousand acres depending on the project goals and setting. As a general rule, larger watersheds are slower to respond to treatment because of the pollutant transport mechanisms involved. This, however, might not be the case where biological monitoring is conducted, particularly in watersheds where habitat restoration is a key component of the implementation plan.

Variables

The basic monitoring program to assess watershed project effectiveness must focus on the pollutant sources identified in the watershed, the key pollutants from these sources, the water resources affected by these sources and pollutants, measures of designated use support in the affected water resources, and any biological and habitat issues of concern.

Logistical factors, including site access and conditions, personnel availability, and travel times, also influence the selection of water quality variables to monitor. Some water quality constituents, such as soluble reactive phosphorus, have short (24-hour) holding times and require refrigeration while waiting for pickup. In contrast, samples for total phosphorus analysis can be held for as long as 7 days under proper conditions. Samples for bacteria analysis can rarely be collected by automated sampling equipment because of sterility issues and have even shorter allowable holding times (6 hours) between collection and analysis. Trade-offs between the expense and personnel effort to accommodate such constraints and the value of the resulting information must be considered when selecting variables to monitor.

In the end, monitoring data will be used to make statements about the effectiveness of the watershed project. Precipitation, air temperature, and other weather variables are also typically tracked to aid in data analysis and interpretation.

Number of Samples

For many urban streams
it might be desirable to sample every storm event, whereas weekly sampling might be sufficient for rural streams. Storm event samples are often composited into weekly samples for laboratory analysis. Monthly or quarterly sampling could be adequate for some lakes, whereas reservoirs with short hydraulic residence times might require weekly sampling.

Monitoring of management measure effectiveness requires a greater sampling frequency than does trend monitoring. Trend monitoring, however, is typically carried out over a far longer period, bringing total sample counts near to those for effectiveness monitoring.

Trend Analysis

to support trend analysis, a sufficient number of samples must be collected to adequately represent seasonality or other sources of variability evident in the data. In general, a monthly sampling frequency (or taking more frequent samples that can be aggregated to monthly median values, for example) is generally the minimum frequency for sampling streams or rivers in nonpoint source situations. Sampling programs to support trend analysis should operate continuously for the entire project period, using consistent methods, locations, and schedules.

Timing

The sampling time chosen depends on the monitoring goals, the target population, and the anticipated relationship between management measure implementation and measured water quality. If seasonal impacts are expected, sampling should occur during the identified season(s). To determine the general conditions of the water resource, sampling should occur throughout the year, perhaps by weekly sampling.

For nonpoint source load estimation, sampling must occur during high-flow events because that is typically when the greatest pollutant loads occur. Some variables such as dissolved oxygen and temperature display diurnal patterns, and sampling time should be based on the portion of the pattern that is of interest. Biological monitoring is often done quarterly or on some other seasonal basis. In some climates summer sampling is impossible because there is no flow, while winter sampling might be precluded by freezing of the water resource.

Specific types of monitoring include:

- **Load Estimation**
- **Biological Monitoring**
- **Land Treatment**

Handling Noise in the Data

To cut through the noise to find the meaning or signal, a monitoring program to measure the effectiveness of a watershed project must be designed to include recognition of the variability described here. A number of obstacles and constraints must be overcome in most watershed monitoring programs, including the following:

- Lack of control over activities that affect water quality
- Hydrologic variation across seasons and between years
- Incremental change brought on by a land treatment program
- Lag time in the response of natural systems to change
- Surprises, disasters, and other unusual events

Keeping these issues in mind during the design and operation of a monitoring program will increase the probability of success.

Quality Assurance and Quality Control Plan

Quality assurance and quality control practices should be an integral part of the development, design, and implementation of a watershed evaluation project to minimize or eliminate problems associated with the methodologies, data quality, and coordination of sampling and analysis efforts (USEPA, 1997a).

Data Management, Analysis, and Reporting

While conducting a watershed evaluation project, it is important to document all data collected and used. All collected data should be validated with error checking, stored in a logically based and safe filing system with backups, and analyzed using proven approaches. Both hard and computerized copies of data should be maintained because each type of storage is susceptible to damage or loss. Both hard and computer copies should be housed separately from originals, and data should be backed up daily as long as new data are being acquired.

Exploring Your Data, The First Step

(https://www.epa.gov/polluted-runoffnonpoint-source-monitoring-technical-notes)
See original document above for embedded references.

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 (QAPP) you developed as a guide.

After you accept the dataset, you will still be faced with a challenge: What do I do with all these numbers? What do they mean? How do I start to make sense of them? The first step in answering such questions lies in exploratory data analysis (EDA). The purpose of EDA is to get the "feel" of your data, to begin to develop some ideas about what they can tell you and how you can draw some conclusions about them. Think of EDA as detective work—your job is to sift through all the facts, look for clues, and put the pieces together to find suggestions of meaning in the data.

Your specific objectives for data exploration might include the following:

- to describe the behavior of one or more variables
- to find extreme values and anomalies
- to test distribution and assumptions of independence and constant variance
- to see cycles and trends
- to find clusters or groupings
- to compare two or more locations or time periods and
- to examine relationships between variables

Data exploration is a necessary first step in analyzing monitoring data; unless initial exploration reveals indications of patterns and relationships, it is unlikely there there will be something for further analysis to confirm.

Decisions

If you are monitoring an erosion problem, you may want to see if there is a relationship between streamflow and suspended solids concentrations or look at how that relationship changed following land treatment. In most cases, you will want to look at the distribution of the data to determine whether the data satisfy statistical assumptions or whether a transformation is needed before further analysis.

There are two general approaches to EDA—quantitative (numerical) techniques and graphical approaches. The following sections identify some specific techniques for exploring your data.

Quantitative (Numerical) Techniques

Because these quantitative techniques are readily calculated by most spreadsheet programs and statistical software, this publication will not go into detail on the calculation of these statistics.

Evaluation of One Variable

Measures of Central Tendency

- The mean is computed as the sum of all values divided by the sample size.
- The median, or 50th percentile, is the central value of the distribution when the data are ranked in numerical order.

Measures of Spread

- The sample variance and its square root, the standard deviation, are the most common measures of the spread (dispersion) of a set of data.
- The coefficient of variation (CV), defined as the standard deviation divided by the mean, is a relative measure of the variability (spread) of the data.
- The interquartile range (IQR) is defined as the 75th percentile minus the 25th percentile

Evaluation of Two Variables

- In EDA, the simplest technique is correlation, which measures the strength of an association between two variables. The most common measure of correlation is Pearson's r, also called the linear correlation coefficient. If the data lie exactly on a straight line with positive slope, r.will equal 1; if the data are entirely random, r.will equal 0.

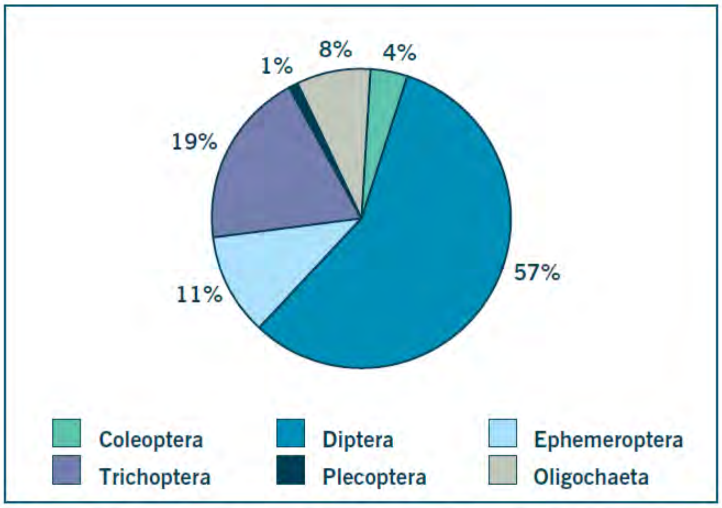
Graphical Approaches

Because graphs summarize data in ways that describe essential information more quickly and completely than do tables of numbers, graphics are important diagnostic tools for exploring your data. With the computers and software available today, there is simply no excuse for not graphing your data as part of EDA.

Graphical Evaluation of One Variable

Categorical Data

For categorical data such as the watershed area in different land uses or the number of aquatic macroinvertebrates in certain taxonomic groups, showing the data as frequencies in histograms or pie charts can effectively summarize data.



Pie Chart: Percent composition of the orders of macroinvertebrates, Godin Brook, 2000.

Other graphical methods include: histograms, quantile plots, box plots, time series, and autocorrelation.

Graphical Evaluation of Multiple Variables

Comparison of two or more variables is where EDA gets really interesting. This can mean comparing different datasets, such as stream nitrogen concentrations above and below a feedlot or phosphorus concentrations from a control and a treatment watershed, or comparing data from the same site over two different time periods, such as phosphorus loads from control versus treatment periods.

Graphical methods for multiple variables include: boxplots and scatterplots.

Next Steps

The results of your data exploration—knowledge of how your data are distributed, their characteristics, and their relationships—will help you formulate hypotheses that can be tested with more advanced statistical techniques. Procedures like the Student's t-Test, analysis of variance (ANOVA), analysis of covariance (ANCOVA), and regression can be used to draw conclusions about your data and its meaning (USEPA 1997).

Surface Water Flow Measurement for Water Quality Monitoring Projects

Excerpts

Surface Water Flow Measurement for Water Quality Monitoring Projects

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

See original document above for embedded references.

Measurement of surface water flow is an important component of most water quality monitoring projects. Flooding, stream geomorphology, and aquatic life support are all directly influenced by streamflow, and runoff and streamflow drive the generation, transport, and delivery of many nonpoint source (NPS) pollutants. Calculation of pollutant loads requires knowledge of water flow.

Surface Flow Fundamentals

Surface water flow is simply the continuous movement of water in runoff or open channels. This flow is often quantified as discharge, defined as the rate of flow or the volume of water that passes through a channel cross section in a specific period of time. Discharge can be reported as total volume (e.g., acre-ft or millions of gallons) or as a rate such as cubic feet per second (ft3/s or cfs) or cubic meters per second (m3/s) (USGS, 2007). The terms flow and discharge are often used interchangeably, but they will be used only as defined here. Discharge data are essential for the estimation of loads of sediment or chemical pollutants exported from a river or stream

The depth of flow (m or ft) is most commonly measured as stage, the elevation of the water surface relative to an arbitrary fixed point. Stage is important because peak stage may exceed the capacity of stream channels, culverts, or other structures, while both very low and very high stage may stress aquatic life.

Purposes of Flow Measurement

Flow data can be used for a variety of purposes, including problem assessment, watershed project planning, assessment of treatment needs, targeting source areas, design of management measures, and project evaluation. Nonpoint source management projects generally focus on reducing either flow, availability of pollutants, or both. It is often easier and less expensive to document changes in flow than in pollutant levels as a measure of project effectiveness.

Peak flows are important to the stability of the stream channel, the size and quantity of bed material, and sediment transport rates, while low flows are important with regard to stream water temperature and fish habitat. Water yield is important in western states dependent upon hydropower.

Fundamental Measurements

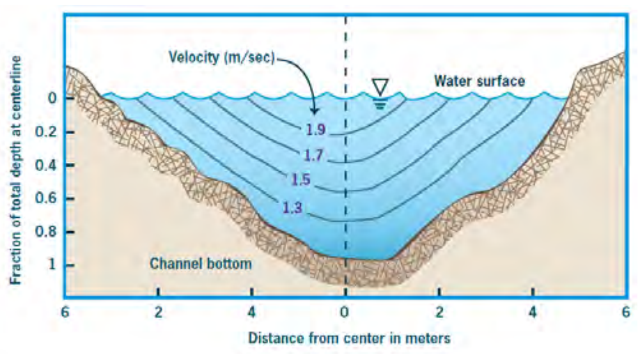
Basic Principles of Discharge Measurement

Discharge is typically calculated as the product of *velocity* and *cross-sectional area*. Surface water *velocity* is the direction and speed with which the water is moving, measured in feet per second (ft/s) or meters per second (m/s). The cross-sectional area of an open channel is the area (ft^2 or m^2) of a slice in the water column made perpendicular to the flow direction.

Determination of discharge (usually symbolized as Q) thus requires two measurements: the velocity of moving water (V, e.g., in m/s) and the cross-sectional area of the water in the channel (A, e.g, in m^2). The product of these two measurements gives discharge in volume per unit time:

$Q = V * A$ $\qquad$ $1.25\ m/s \times 36\ m^2 = 45\ m^3/s$

It is important to recognize that the velocity of moving water varies both across a stream channel and from the surface to the bottom of the stream because of friction and irregularities in cross-section and alignment. Friction caused by the rough channel surfaces slows the water near the bottom and sides of a channel so that the fastest water is usually near the center of the channel and near the surface. On a river bend, the water on the outside of the bend moves faster than the water on the inside of the bend, as it has to cover more distance in the same time. The figure below shows a generalized schematic of the pattern of water velocity in a cross-section of a stream.



Water velocities in a typical stream cross-section

Source: L. L. Sanders. *A Manual of Field Hydrogeology*. Prentice Hall, Upper Saddle River, NJ, 1998. ISBN 0-13-227927-4.

For more details, refer to USGS "How Streamflow is Measured".

Lag Time in Water Quality Response to Land Treatment
Excerpt

Lag Time in Water Quality Response to Land Treatment
(https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_4_dec2013_lag.pdf)
See original document above for embedded references.

An important reason watershed projects may fail to meet our water quality expectations is *lag time*. Lag time is an inherent characteristic of the natural systems under study that may be generally defined as the amount of time between an action and the response to that action. In this case, we define lag time as the time elapsed between installation or adoption of land treatment at a level projected to reduce nonpoint source pollution and the first measurable improvement in water quality in the target water body. Installation refers to the completion of the construction phase for structural practices; some vegetative practices will still need to mature over time. Adoption refers to the full use of an installed physical practice or management practice such as nutrient management. Land treatment-water quality monitoring projects—even those designed to be "longterm"— may not show definitive results if the lag time exceeds the monitoring period.

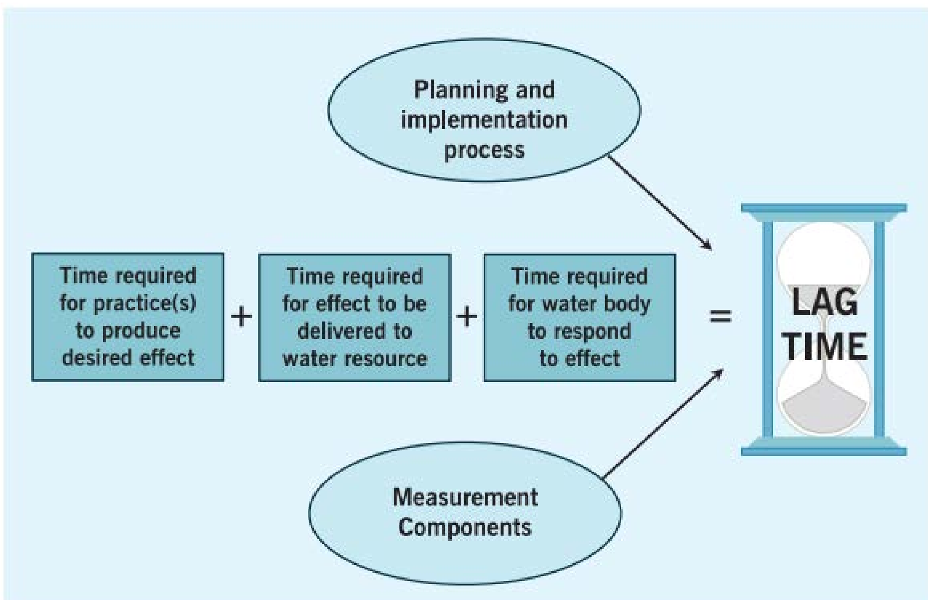


Figure 1. Components of lag time experienced in land treatment—water quality projects.

The time required to produce effects will vary depending upon the degree of impairment and the practices selected, as well as the nature of the effects themselves.

Figure 2. Fencing immediately excludes livestock from a stream (left, VT NNPSMP project), while a forested riparian buffer may take years to develop (right, PA NNPSMP project)

Time Required for Effect to Be Delivered to Water Resource

Practice effects initially occur at or near the practice location, yet usually watershed managers and stakeholders want and expect these effects to appear promptly in the water resource of interest in the watershed. The time required to deliver an effect to a water resource depends on a number of factors, including:

- The route for delivering the effect
    a. Directly in (e.g., streambed restoration) or adjacent to (e.g., shade) the water resource
    b. Overland flow (e.g., particulate pollutants)
    c. Overland and subsurface flow (e.g., dissolved pollutants)
    d. Infiltration to ground water (e.g., nitrate)
- The path distance
- The path travel rate
    a. Fast (e.g., ditches and artificial drainage outlets to surface waters)
    b. Moderate (e.g., overland and subsurface flow in porous soils)
    c. Slow (e.g., groundwater infiltration in absence of macropores)
    d. Very slow (e.g., transport in a regional aquifer)
- Precipitation patterns during the study period
    a. Wet periods generally increase volume and rate of transport
    b. Dry periods generally decrease volume and rate of transport

Time Required for Water Body to Respond to Effect

Another key factor is the speed with which the water resource responds to the effect produced by and delivered from the practice. For example, it may take a few years for algae production in a lake to decrease in response to reduced nutrient loading because of a lengthy flushing rate. If the response to be measured is fish populations rather than algae production, then even more time will be needed because fish need time to fill the newly improved habitat.

Example: Recent research in the **Chesapeake Bay Watershed** has confirmed that a substantial lag time between implementation of management practices and reductions in nitrogen loading to the Bay is very likely (Phillips and Lindsey 2003, STAC 2005). Ground water supplies a significant amount of water and nitrogen to streams in the watershed and about half of the nitrogen load in streams in the Bay watershed was transported through ground water. The age of ground water in shallow aquifers in the Chesapeake Bay watershed ranges from less than 1 year to more than 50 years.

The median age of all samples was 10 years, with 25 percent of the samples having an age of 7 years or less and 75 percent of the samples having an age of up to 13 years. Based on this age as representative of time of travel, scientists estimated that in a scenario of complete elimination of nitrogen applications in the watershed, a 50 percent reduction in base flow nitrate concentrations would take about five years, with equilibrium reached in about 2040.

Dealing with lag time *(summarized)*

- Adjust expectations
- Characterize the watershed
- Select and site BMPs
- Monitor small watersheds
- Select indicators carefully
- Design effective monitoring programs

Conclusions

Lag time between implementation of land treatment and water quality response is an unfortunate fact of life in many circumstances. Unless it is recognized and dealt with, the existence of lag time will frequently confound our ability to successfully document improved water quality resulting from treatment of nonpoint sources and may discourage vital restoration efforts. While ongoing and future research may provide us with better tools to predict and account for lag time, it is essential that watershed monitoring programs today recognize and grapple with this issue.

Using Biological and Habitat Monitoring Data to Plan Watershed Projects

Excerpts

Using Biological and Habitat Monitoring Data to Plan Watershed Projects

(https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_5_dec2013_biohab_planning.pdf)

See original document above for embedded references.

The status and condition of resident aquatic biota are important to water quality assessment programs and to the overall goals of protecting and restoring surface waters. This document is not intended to provide complete instruction in the process of biomonitoring but rather to provide a foundation for understanding the important roles that biological and habitat information can play in watershed planning and management.

2.0 Overview of Biological and Habitat Monitoring

The physical habitat represents the set of environmental conditions and constraints that supports or limits a biological community and includes such features as the geomorphology of the waterbody, the riparian zone, physical and chemical constituents dissolved or suspended in the water, and substrate and refugia for aquatic organisms. Measuring the components of the physical habitat is important to understanding and interpreting biological data because habitat is a major influence on what kind of organisms can inhabit the system.

Several questions can be addressed with comprehensive biological and physical habitat data:

1. What is the condition of the aquatic resource?
2. Is the resource impaired or degraded?
3. If there is a problem, what are the stressors?
4. What is the biological potential upon mitigation or restoration?

2.1 Relationship Among Biological, Physical, and Chemical Monitoring

The concept of ecological integrity embraces the combination of biological, physical, and chemical integrity. These three broad components of an ecosystem are inseparable in understanding the functioning of a healthy waterbody. The condition of the aquatic biological community reflects the exposure to, frequency, and duration of single or cumulative stressors in the ecosystem. In watershed planning, ecological attributes of the biological community can be considered response indicators of the multitude of stressors.

2.2 Elements of Survey Design for Bioassessment

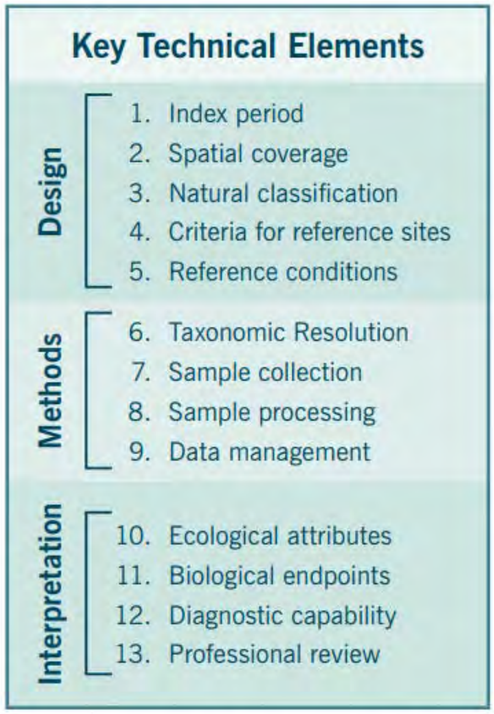


Figure 2. Critical elements of a bioassessment program.

3.0 Opportunities to Use Biological and Habitat Data in Watershed Project Planning

Biological and habitat data can be used effectively to build partnerships because they allow individuals to visualize problems better than can be done in many cases using chemical and physical data alone. While people may find it difficult to appreciate the significance of high nutrient levels, depressed dissolved oxygen concentrations, or elevated water temperatures, they can easily understand declining fishing success, depletion of prized fish species, fish advisories caused by mercury contamination, or outright fish kills.

3.2 Characterizing Watersheds

Use of biological indicators to understand resource condition.

The interpretation of biological data is grounded in the understanding of the condition of the resource that is expected under unperturbed or minimally disturbed scenarios—a condition termed as *reference condition*. Once a reference condition is established, a *best attainable condition* can be described. This condition reflects the balance between a regional reference condition that may be outside of a watershed of interest and the best attainable condition given the level and intensity of land use modification and effectiveness of implemented or proposed BMPs to offset the influence of stressors.

Use of biological and habitat measures to identify causes and sources of problems in the watershed.

Biosurvey techniques are best used for detecting aquatic life impairments and for assessing their relative severity.

4.0 What to Consider When Selecting and Implementing Biological/Habitat Data Collection

- Understand waterbody classification/types and take advantage of classification systems developed in your area (where available).
- Take advantage of reference condition work developed for your area.
- Make use of state-specific or eco-regionally refined indices whenever possible.
- Fully understand what the biological indicators you are using mean and what they do not mean, and, therefore, what they can and cannot do.
- Select and use methods that are appropriate to the biological indices you have chosen.
- Be sure to collect a core set of physical, chemical, and habitat data to complement your biological data.

Example 2: … habitat and biological data by themselves may not be enough to guide successful restoration if other factors play a role in causing the problem. The Waukegan River (Illinois) NNPSMP project documented biological impairment with fish, macroinvertebrate, and habitat surveys, as well as visual observations of eroding streambanks and high storm flows. The project sought to restore the fishery through a combination of biotechnical streambank stabilization measures and in-stream structures such as lunkers and improved pool and riffle sequences. Although habitat improvements were clearly documented and some small early improvements in fish numbers and several biological indices were noted, the project did not achieve the hoped-for improvements in the fish community (White et al. 2003). Project staff attributed this shortfall to a failure to address extremes in flow regime from the highly urbanized watershed or to other pollutants such as toxics that were not revealed in habitat and biological surveys. The project would have benefited from a more complete stressor identification process. This outcome illustrates the importance of combining both habitat/biological and physical/chemical data to develop a full understanding of the problem as the basis for designing a successful treatment plan.

Pollutant Load Estimation for Water Quality Monitoring Projects

Excerpts

Pollutant Load Estimation for Water Quality Monitoring Projects

(https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_8_dec_2013_load.pdf)

See original document above for embedded references.

Determination of pollutant load is a key objective for many nonpoint source (NPS) monitoring projects. The mass of nutrients delivered to a lake or estuary drives the productivity of the waterbody. The annual suspended sediment load transported by a river is usually a more meaningful indicator of soil loss in the watershed than is a suspended sediment concentration. The foundation of water resource management embodied in the TMDL (total maximum daily load) concept lies in assessment of the maximum pollutant load a waterbody can accept before becoming impaired and in the measurement of changes in pollutant loads in response to implementation of management measures.

Estimation of pollutant load through monitoring is a complex task that requires accurate measurement of both pollutant concentration and water flow and careful calculation, often based on a statistical approach. It is imperative that a NPS monitoring program be designed for good load estimation at the start.

Basic Terms

Flux – instantaneous loading rate (e.g., kg/sec)

Flow rate – instantaneous rate of water passage (e.g., L/sec)

Discharge – quantity of water passing a specified point (e.g., m^3)

Load – mass of substance passing a specified point (e.g., metric tons)

Issues of Variability

Both flow and concentration vary considerably over time, especially in NPS situations. Accurate load estimation becomes an exercise in both how many samples to take and when to take them to account for this variability.

The key point here is that many samples are typically needed to accurately and reliably capture the true load pattern. Quarterly observations are generally inadequate, monthly observations will probably not yield reliable load estimates, and even weekly observations may not be satisfactory, especially if very accurate load estimates are required to achieve project objectives.

Practical Load Estimation

Ideally, the most accurate approach to estimating pollutant load would be to sample very frequently and capture all the variability. Concentration is expensive to measure and in most cases impossible to measure continuously. It is therefore critically important to choose a sampling interval that will yield a suitable characterization of concentration.

There are three important considerations involved in sampling for good load estimation: sample type, sampling frequency, and sample distribution in time.

Planning Monitoring Programs for Effective Load Estimation

This leaves three basic choices for practical load estimation:

1. Find a way to estimate un-measured concentrations to go with the flows observed at times when chemical samples were not taken;
2. Throw out most of the flow data and calculate the load using the concentration data and just those flows observed at the same time the samples were taken;
3. Do something in between — find some way to use the more detailed knowledge of flow to adjust the load estimated from matched pairs of concentration and flow.

The second approach is usually unsatisfactory because the frequency of chemical observations is likely to be inadequate to give a reliable load estimate when simple summation is used. Thus almost all effective load estimation approaches are variants of approaches 1 or 3.

Summary and Recommendations

Estimation of pollutant load through monitoring is a complex task that requires accurate measurement of both pollutant concentration and water flow, as well as careful calculation, often based on a statistical approach. A NPS monitoring program must be designed for good load estimation at the start. In planning a watershed project, determine whether the project goals require knowledge of load, or if goals can be met using concentration data alone. In many cases, especially when trend detection is the goal, concentration data may be easier to work with and be more accurate than crudely estimated load data.

Good load estimates are usually derived from continuous flow data and intermittent data on pollutant concentration.

Land Use and BMP Tracking for NPS Watershed Projects
Excerpts

Land Use and BMP Tracking for NPS Watershed Projects
(https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_11_aug28_bmptrack.pdf)
See original document above for embedded references.

Nonpoint source (NPS) pollution is driven mainly by land use and land management activities, including best management practices (BMPs) that are implemented to reduce, prevent or treat such pollution. Accurate information about land use, land management, and the implementation and operation of BMPs is therefore of great interest to those who attempt to assess or solve NPS water quality problems. In a typical NPS watershed project, BMPs are implemented or adopted at various locations in the watershed to reduce the generation and delivery of NPS pollutants, while water quality monitoring is conducted to document the effects of implemented BMPs. Linking water quality response to land treatment requires monitoring of both water quality and land management.

General Considerations
Watershed projects often lack an up-front plan for collecting and using land use/BMP data to determine watershed condition, progress in BMP implementation, or whether implemented BMPs have improved water quality. These plans should be developed as part of the overall project planning process to ensure a clear understanding of the data needed to meet project objectives and how the data are to be obtained and used. Monitoring at the watershed scale can continue for multiple years or decades, so cost must be considered when making decisions about the scope, level of detail, and the frequency of land use/treatment monitoring that will be done. Knowing what is needed should help focus project efforts on ways to obtain the best dataset possible within cost constraints.

Project Objectives
BMPs are tracked for a variety of reasons, including:

- To determine whether the requirements of cost-sharing contracts or regulatory controls have been met
- To measure the impact of efforts designed to encourage voluntary adoption of BMPs
- To assess current or baseline watershed conditions
- To demonstrate progress in solving NPS pollution problems
- To determine the effectiveness of individual BMPs at reducing NPS pollution levels or impacts
- To assess the relationships between water quality monitoring data and pollution control status at a watershed or basin scale

Nonpoint source watershed projects often include an objective to relate indicators of water quality condition to indicators of land condition or management, either statistically or less rigorously. This relationship is captured conceptually with the following simplified equation:

Water Quality = ƒ (Pollutant Source Management)

The strength of the relationship in this equation is influenced by climate, type of water resource, local soils and topography, and other factors that are usually beyond the control of watershed projects. Water quality conditions on the left side of the equation are often represented by fairly well-recognized measures such as beneficial use support status, pollutant concentrations or loads, or biological/habitat condition. Pollutant source management, however, is often represented on the right side of the equation by basic land use variables (e.g., agriculture, mixed-use urban, forest) or broad indicators of land management (e.g., acres under conservation tillage or nutrient management, forest harvest acreage, nutrient application rates, BMPs applied) that are less well established or proven for this purpose.

Spatial Scale

Land use/treatment monitoring should address the entire area contributing to flow at the water quality sampling point(s). As a general rule, all land use and management activities that influence the generation and transport of pollutants in this area should be tracked or accounted for through experimental design.

Monitoring Design

The best way to isolate the impact of BMPs and land treatment programs on water quality conditions is to use a paired-watershed design or above/below-before/after (nested-pair) design.

Basic BMP Tracking Information

What – pollutant sources and source areas, and existence and/or operation of structural and management practices in place to reduce or prevent pollutant generation or delivery

Where – complete coverage or targeted locations within geographic area of interest

When – at important points of time during the project or during the lifespan of the BMP

How – using a variety of direct (e.g., visual observation) and indirect (e.g., third-party reports) approaches

Table 1. Selected pollutants and watershed source characteristics and activities to monitor.

Pollutant Type	Potential Source Characteristics and Activities to Monitor
Suspended sediment (upland erosion)	Cropland tillage, planting, harvesting, construction, logging, erosion control BMPs, precipitation
Suspended sediment (instream erosion)	Streamflow, stream morphometry, riparian zone management, precipitation
Phosphorus (P)	Manure applications, livestock populations, manure and fertilizer management, soil test P, wastewater treatment plant discharge
Nitrogen (N)	Fertilizer applications, legume cropping, manure and fertilizer management, groundwater movement, wastewater treatment plant discharge
Herbicides	Herbicide application rates and timing, precipitation
E. coli (rural)	Livestock populations, grazing practices, riparian zone management, pasture fencing, wildlife populations and seasonal patterns
E. coli (urban)	Pet populations, wildlife/waterfowl activity, septic system maintenance/failure, sewer maintenance, illicit discharge/connections, combined sewer overflow, wastewater treatment plant discharge
Heavy metals	Vehicle traffic, highway infrastructure, street sweeping, stormwater management structures and activities, wastewater treatment plant and industrial discharge
Stormwater flow	Impervious cover, stormwater management facilities, precipitation, combined sewer overflow discharge

Table 2. Relationship of water quality and land use/land treatment variables. "Weekly" and "Annual" variables represent different metrics to be assessed on different time scale.

Water Quality Monitoring Variable	Primary Source	~Weekly Land Use/Treatment Monitoring Variables	~Annual Land Use/Treatment Monitoring Variables
Suspended sediment	Cropland erosion	• Date of tillage operations • Form of tillage (e.g., no-till, mulch-till, reduced-till, and conventional tillage) • Crop canopy development (percentage of soil surface covered by plant foliage) • Cover crop density	• Acreage (and percentage) of land under reduced tillage • Acreage (and percentage) served by terrace systems • Acreage (and percentage) of land converted to permanent cover • Linear feet (and percentage of linear feet) of watercourse protected with riparian buffers (specify buffer width)
Total N	Agricultural cropland	• Manure and fertilizer application rates • Manure and fertilizer forms • Date of manure and/or fertilizer application • Manure and fertilizer application methods	• Number (and percentage) and acreage (and percentage) of farms implementing comprehensive nutrient management plans (CNMP) • Annual fertilizer and manure N applications per acre • Legume acreage • Crop N needs and basis
Stream flow	Urban	• Operation and maintenance of stormwater system • Functioning of stormwater diversions or treatment devices	• Percentage impervious cover • Acreage (and percentage) served by stormwater runoff collection system • Number and area of rain gardens or other infiltration practices • Annual inspection results

How: Data Collection Methods

Definitions

Tracking is following the course or trail of something, typically in order to find it or to note its location at various points in time.

Monitoring is observing and checking the progress or quality of something over a period of time.

Verification is proving that the information obtained by tracking or monitoring is true, accurate, or justified.

Validation is ensuring that the information obtained by tracking or monitoring will achieve the stated goals.

Specific methods

Direct observation

Personal observations may be the best way to track BMPs and land use for plot and field studies. At this smaller scale, sites are visited frequently to service monitoring equipment and collect samples, so a good record of source activities can be obtained. Today's mobile technology makes it possible to collect, transfer, and store information with multiple devices at virtually any location. Smartphones and smart GPS units are two of the options for performing these tasks.

Other types of direct observation include quantitative windshield surveys (systematic observations made from a moving vehicle). Photography can be an important tool in some situations. For example, an automated digital camera can be installed at an edge-of-field monitoring station to take periodic photographs looking up into the drainage area to record crop growth, agrichemical applications, or other visible information.

Landowner information

Land use and BMP information can often be collected directly from those owning or managing the source area and implementing the practices. This approach may be the only way to obtain good information on management activities such as manure or fertilizer application rates. Log books can be given to land owners and site managers to record activities relevant to the monitoring study. An advantage of this method is that the same individual who conducts the activity does the reporting. However, it is difficult to guarantee compliance or consistent reporting among different individuals.

Landowner self-assessment

Some jurisdictions require or provide incentives to induce landowners to conduct regular self-assessments of some or all of their installed/adopted BMPs. For those self-surveys to be useful, landowners must have a clear understanding of what each BMP is so that reporting is accurate and consistent across a watershed.

On-site assessment
The existence and condition of BMPs can be assessed by on-site inspections conducted by state or local personnel. It is essential that personnel performing the assessments be trained and certified appropriately so that information is collected in a consistent, reliable, and repeatable fashion.

Agency reporting
There are many state, county, and municipal programs that track, spot-check, and report BMP implementation, but the resolution, relevance, and availability of data from these programs is variable.

Surveys and statistical sampling
To conduct BMP verification in large, diverse watersheds, it may be appropriate to collect information on a sample of the total BMP population using surveys or statistical sampling procedures.

Remote sensing
Remote sensing can be used to track practices over large geographic areas, but it is only suited for recording information that can be detected visually (e.g., structural or land cover BMPs) rather than BMPs like nutrient management. Ground-truthing is needed to establish the relationship between the images and what is on the ground.

Remote sensing data may be collected on two basic platforms: aerial and space-based. Aerial imagery includes images and data collected from relatively low altitude and involves placing a sensor or camera on an aircraft. Space-based imagery includes images and data collected from satellites that orbit the earth. For large watershed projects, it may be feasible to fund a custom aerial photography effort or even engage in informal data collection by hiring a plane and pilot for a few hours and taking handheld photographs.

Hybrid approaches
Some BMPs can be detected and verified by some methods, but not by others.

Challenges
In many respects, collecting good data through land use/BMP tracking is more challenging than it is through water quality monitoring where procedures and practices are well-developed and based on decades of experience. Gaining access to suitable locations may be the biggest hurdle for water quality monitoring efforts, requiring permission from landowners. Sample collection for water quality monitoring, however, is generally unfettered once sites have been reached. On the other hand, efforts to collect suitable land use/BMP information can be much more complicated as illustrated by the challenges described below.

Confidentiality
A principal reason for the often haphazard nature of BMP data collection by watershed projects is the fact that privacy laws and policies often restrict the type and amount of information available to those involved in a watershed project, most notably information about agricultural enterprises.

Relating Land Use/Land Treatment Data to Water Quality Data
For a range of reasons, including budgets and programmatic constraints, watershed project monitoring efforts are almost never designed to establish true cause and effect relationships between land treatment and water quality. Rather, project effectiveness monitoring designs are generally intended to measure improvement in water quality and, ideally, relate the improvement to BMPs implemented in the watershed. A plausible argument that land treatment led to improved water quality is often the best that can be hoped for, and even that is usually not a simple task at the watershed level.

Recommendations
- Incorporate management and analysis of land use/treatment tracking data into project planning, including development of a QAPP.
- Before implementing new data collection efforts, consult with agencies and others managing cost-share or regulatory programs to see if they collect useful BMP data that can be shared with the project. Address issues of confidentiality of landowner BMP and management information at the beginning of the project.
- Track land use and BMPs to document progress in solving NPS pollution problems, to determine the effectiveness of individual BMPs, and to assess the relationships between water quality monitoring data and pollution control status at a watershed scale. Be sure to track land use change for long-term projects.
- Choose monitoring methods that are appropriate for the BMPs to be tracked.
- Select variables to monitor that reflect the pollutant types and sources important to water quality impairments and pollution control efforts.
- Ensure that observation frequency is appropriate both for the BMPs being tracked and for matching with water quality monitoring data in future, planned analyses.
- Track all land use and management activities that influence the generation and transport of pollutants in a project watershed. For BMPs this includes both cost shared and non-cost-shared practices. Assess both point and nonpoint sources at the beginning of watershed projects.
- When monitoring the effectiveness of individual BMPs or a watershed land treatment program, it is important to document compliance with design specifications, the spatial distribution and interrelationships of components in a BMP system, details of maintenance and operation, and situations where the BMP operated under conditions outside of the design range.

- In a diverse land treatment program, use hybrid approaches to BMP data collection that include different means of detecting structural and management practices because they are more likely than a single approach to give complete and reliable results.

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

Excerpts

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

(https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_12_aug2014_explan_var.pdf)

See original document above for embedded references.

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 the likelihood of isolating water quality trends resulting from best management practices (BMPs). Correlation of water quality and land treatment changes alone is not sufficient to infer causal relationships. Factors not related to BMPs may be causing the water quality changes, such as changes in land use, climatic, or hydrologic conditions. These factors are often referred to as explanatory variables or covariates.

What are Explanatory Variables and Why are They Important in NPS Watershed Studies

Definition of Explanatory Variable

Categorical Variable: A variable that can take on one of a limited, and usually fixed, number of possible values (e.g., seasons).

Continuous Variable: A variable that can take on any value between its minimum and maximum value (e.g., flow rate).

Control: The absence of treatment with BMPs or other land treatment. Pertains to the control watershed in NPS monitoring studies.

Control Variable: A water quality variable (e.g., nitrate) measured in a control watershed at the same time it is also measured in the treatment watershed, resulting in a paired observation.

Covariate: Essentially equivalent to explanatory variable.

Dependent or Response Variable: The “Y” variable in an equation, typically the primary water quality variable of interest in NPS watershed studies.

Explanatory Variable: Variable that affects the relationship between the primary water quality variable of interest and the primary land treatment variable of interest (e.g., flow).

Factor: A variable that influences the value of the primary variable. Independent and explanatory variables are factors influencing the value of the primary water quality variable of interest in NPS watershed studies.

Independent Variable: Each “X” variable in an equation (e.g., trend variable, land treatment variable such as acres with cover crops, control watershed water quality variable, and other explanatory variables such as flow or season.

LS-Means: The mean values of Y for each time period that have been adjusted for explanatory variable values.

Primary Variable: The water quality variable of primary interest (e.g., total phosphorus).

Treatment: The application of BMPs or land treatment during a monitoring study. Occurs in the treatment watershed of a NPS monitoring study.

General Rules of Thumb

Both projects beginning with and without a rich dataset should apply some basic rules of thumb when selecting explanatory variables.

- The date should be associated with every variable value, thus allowing assignment of month or season to address seasonal considerations.
- The literature has many examples of relationships between flow measurements and pollutant concentrations and loads (Baker 1988, Foster 1980, Johnson et al. 1969, Lowrance and Leonard 1988, and Schilling and Spooner 2006), so flow or a flow surrogate (e.g., stage) should be measured whenever possible.
- Runoff begins with precipitation and a multitude of studies has shown the effects of rainfall intensity and amount on runoff quality and amount, so precipitation should be measured or weather data obtained from a nearby existing weather station.
- Information on land use and ground cover is essential to most projects, particularly given that BMPs are generally targeted on the basis of land use and management.
- Any sources that will be treated (e.g., cropland, streambanks, lawns) should be monitored using explanatory variables that relate to water quality and the BMPs being implemented (e.g., animal units with access to and excluded from streams, nutrient application rates and yield by crop type).
- Some variables of potential use are very inexpensive to track and can be dropped later if found to be useless. Examples include water and air temperature and salinity or conductivity.

Summary and Recommendations

The often extreme variability in NPS-related water quality data creates challenges in data interpretation that can only be met through sound design and execution of the monitoring plan coupled with defensible statistical analysis of the data. All NPS watershed projects designed to document water quality improvements and relate them to improved land management and treatment with BMPs should include explanatory variables in their monitoring programs. By collecting data on explanatory variables, projects strengthen their capabilities to detect true changes in water quality and isolate the likely causes of those changes.

How to Read a Topographic Map and Delineate a Watershed

USDA-NRCS Minnesota

Note: Websites and computer programs such as ArcGIS have tools that can be used to determine watershed boundaries and the area of the watershed. The procedure below is a manual method that teaches basic watershed determination skills and understanding.

Watersheds can be large (Mississippi River basin) or small (a portion of a roof or yard).

Interpreting Topographic Maps

In order to successfully delineate a watershed boundary, the evaluator will need to visualize the landscape as represented by a topographic map. This is not difficult once the following basic concepts of the topographic maps are understood.

Each contour line on a topographic map represents a ground elevation or vertical distance above a reference point such as sea level. A contour line is level with respect to the earth's surface just like the top of a building foundation. All points along any one contour line are at the same elevation.

The difference in elevation between two adjacent contours is called the contour interval. This is typically given in the map legend. It represents the vertical distance you would need to climb or descend from one contour elevation to the next.

The horizontal distance between contours, on the other hand, is determined by the steepness of the landscape and can vary greatly on a given map. On relatively flat ground, two 20 foot contours can be far apart horizontally.

On a steep cliff face two 20 foot contours might be directly above and below each other. In each case the vertical distance between the contour lines would still be twenty feet.

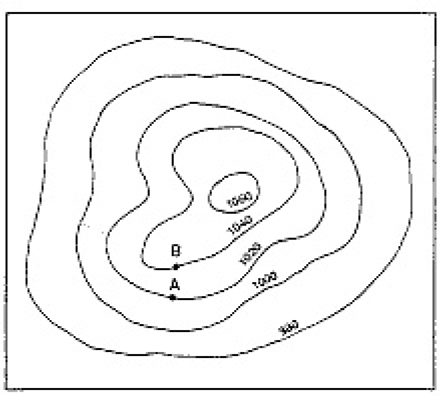


Figure E-1: Isolated Hill

One of the easiest landscapes to visualize on a topographic map is an isolated hill. If this hill is more or less circular the map will show it as a series of more or less concentric circles (Figure E-1). Imagine that a surveyor actually marks these contour lines onto the ground. If two people start walking in opposite directions on the same contour line, beginning at point A, they will eventually meet face to face.

If these same two people start out in opposite directions on different contours, beginning at points A and B respectively, they will pass each other somewhere on the hill and their vertical distance apart would remain 20 feet. Their horizontal distance apart could be great or small depending on the steepness of the hillside where they pass.

A rather more complicated situation is one where two hills are connected by a saddle (Figure E- 2). Here each hill is circled by contours but at some point toward the base of the hills, contours begin to circle both hills.

How do contours relate to water flow? A general rule of thumb is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. Water flows from the top of the saddle or ridge, down each side in the same way water flows down each side of a garden wall (See arrow on Figure E-2).

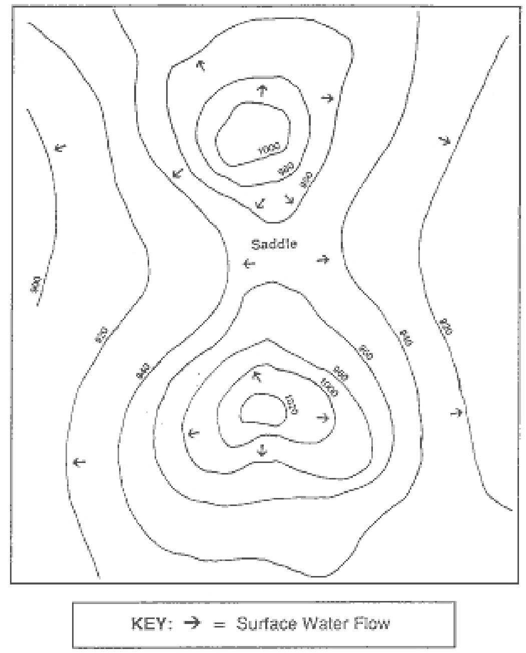


Figure E-2: Saddle

As the water continues downhill it flows into progressively larger watercourses and ultimately into the ocean. Any point on a watercourse can be used to define a watershed. That is, the entire drainage area of a major river like the Mississippi can be considered a watershed, but the drainage areas of each of its tributaries are also watersheds.

Each tributary in turn has tributaries, and each one of these tributaries has a watershed. This process of subdivision can continue until very small, local watersheds are defined which might only drain a few acres, and might not contain a defined watercourse.

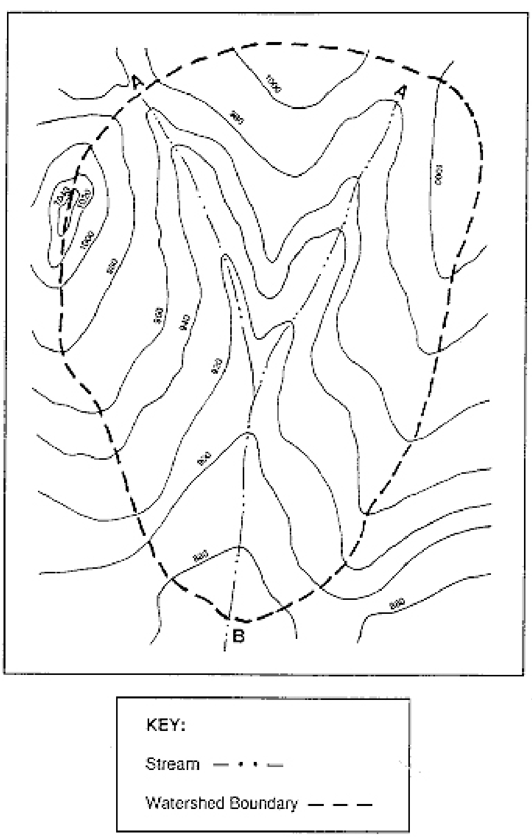


Figure E-3 shows an idealized watershed of a small stream. Water always flows downhill perpendicular to the contour lines. As one proceeds upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Like- wise the valley slopes upward on each side of the stream. A general rule of thumb is that topographic lines always point upstream. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape even when there is no stream depicted on the map. In Figure E-3, for example, the direction of streamflow is from point A to point B.

Ultimately, you must reach the highest point upstream. This is the head of the watershed, beyond which the land slopes away into another watershed. At each point on the stream the land slopes up on each side to some high point then down into another watershed. If you were to join all of these high points around the stream you would have the watershed boundary. (High points are generally hill tops, ridge lines, or saddles).

Delineating a Watershed

The following procedure and example will help you locate and connect all of the high points around a watershed on a topographic map shown in Figure F-4 below. Visualizing the landscape represented by the topographic map will make the process much easier than simply trying to follow a method by rote.

1. Draw a circle at the outlet or downstream point of the wetland in question (the wetland is the hatched area shown in Figure E-4 to the right)
2. Put small "X's" at the high points along both sides of the watercourse, working your way upstream towards the headwaters of the watershed.
3. Starting at the circle that was made in step one, draw a line connecting the "X's" along one side of the watercourse (Figure E-5, below left). This line should always cross the contours at right angles (i.e. it should be perpendicular to each contour line it crosses).
4. Continue the line until it passes around the head of the watershed and down the opposite side of the watercourse. Eventually it will connect with the circle from which you started.

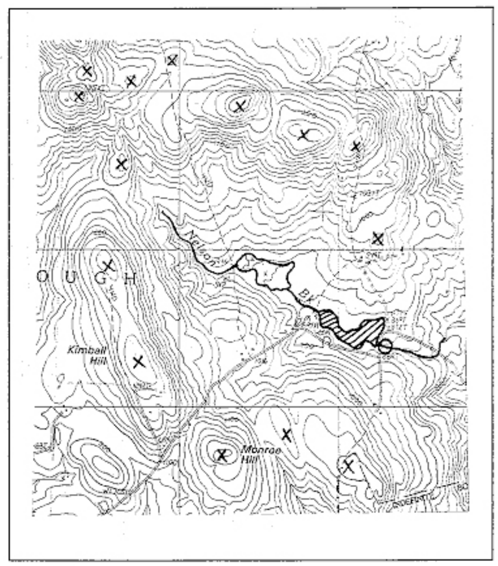


Figure E-4: Delineating a Watershed Boundary - Step 1

At this point you have delineated the watershed of the wetland being evaluated.

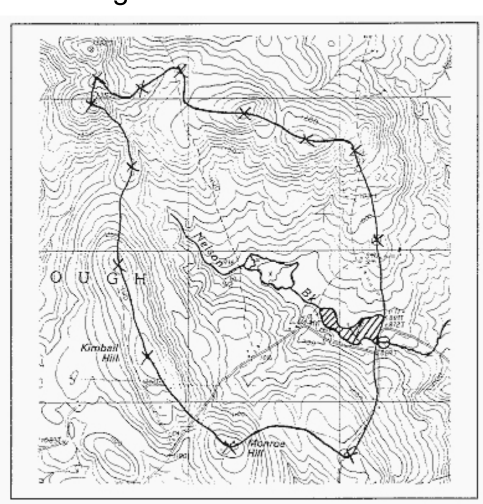


Figure E-5: Delineating a Watershed Boundary - Step 2

The delineation appears as a solid line around the watercourse. Generally, surface water runoff from rain falling anywhere in this area flows into and out of the wetland being evaluated. This means that the wetland has the potential to modify and attenuate sediment and nutrient loads from this watershed as well as to store runoff which might otherwise result in downstream flooding.

Measuring Watershed Areas

There are several available methods for measuring the area of a watershed:

a) Dot Grid Method,
b) Planimeter, and
c) Computer programs such as ArcGIS.

a) The dot grid method is a simple technique which does not require any expensive equipment. In this method the user places a sheet of acetate or mylar, which has a series of dots about the size of the period at the end of this sentence printed on it, over the map area to be measured. The user counts the dots which fall within the area to be measured and multiplies by a factor to determine the area. A hand held, mechanical counting device is available to speed up this procedure.

b) Another method involves using a planimeter, which is a small device having a hinged mechanical arm. One end of the arm is fixed to a weighted base while the other end has an attached magnifying lens with a cross hair or other pointer. The user spreads the map with the delineated area on a flat surface. After placing the base of the planimeter in a convenient location the user traces around the area to be measured with the pointer. A dial or other readout registers the area being measured.

c) Computer programs such as ArcGIS have measure tools that can be used to determine the area of the watershed.

For more information on Minnesota NRCS conservation planning and other technical references, visit https://www.nrcs.usda.gov/.