DRAFT

Best Management Practices Monitoring Guidance Document

For Stream Systems

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DEFINITIONS

Accuracy: the closeness of an observed value or test response to the true or acceptable reference value specified in a reference method. Accuracy is influenced by both random error (precision) and systematic error (bias) (EPA, 2007).

Base flow: stream discharge that is not a result of direct runoff from precipitation or melting snow, and it is usually sustained by groundwater.

Baseline reference site: when using a comparison to a reference site for the site you are monitoring, this site is the second site in a similar watershed.

Best Management Practices (BMPs): conservation and land management practices that reduce or prevent movement of pollutants to surface and groundwater. Some examples of BMPs may include safe management of animal waste, control of pests and nutrients, contour farming, crop rotation, and vegetative buffers near streams.

Biological indices: indicators of biological integrity that directly measure the aquatic community.

Detection limit: the lowest concentration of a chemical that can dependably be distinguished from a concentration of zero (EPA, 2006).

Direct monitoring: collecting samples to measure physical, biological, and chemical variables.

Dissolved pollutant: a pollutant that will disintegrate in solution.

Embeddedness: the amount of substrate material (sand, clay, and silt) covering river rock.

Ephemeral stream: a stream channel that carries water only during and immediately after periods of rainfall or snowmelt.

Grab samples: samples collected at a particular location and time that represents the composition of the water, air, or soil only at that location and time (EPA, 2006).

Integrated samples: samples collected at particular time and different locations (e.g. different sections of the same river) that represent the composition of the water, air, or soil as a less variable sample over a period of time.

Intermittent stream: a stream that carries water only during wet periods of the year (30-90% of the time).

Metadata: “data about data,” i.e., the understanding, documentation use, and management of data.

National Pollution Discharge Elimination System (NPDES) Permit: a permit program to control water pollution by regulating point sources that discharge pollutants into waters of the United States. The NPDES permit program is administered at a state level (EPA, 2007).

Nutrient pollution: contamination of water resources by excessive amount of nutrients, specifically nitrogen and phosphorus.

Parameter (statistical): a statistical quantity, usually unknown, such as a mean or a standard deviation, which characterizes a population or defines a system (EPA, 2007).

Particulate pollutant: a pollutant that will not dissolve in solution, but remains in distinct particles.

Perennial stream: a stream channel that has continuous flow throughout the year.

Pollutants of concern: substances introduced into the environment that adversely affect the use of a resource or the health of humans, animals, or ecosystems, in the watershed or water body the where the effectiveness the BMP will be assessed (EPA, 2007).

Precision: A measure of mutual agreement between two or more individual measurements of the same property, obtained under similar conditions.

Probes: onsite instruments used to collect chemical water data. This data can be stored in a data logger and projected as real-time data, or collected as a grab sample.

Protocols: a series of formal steps for conducting a test, service, or procedure (EPA, 2006).

Quality Assurance and Quality Control (QA/QC): actions performed to ensure the quality of a product, service, or process.

Quality Assurance Project Plan (QAPP): a written document that outlines the procedures a monitoring project will use to ensure samples collected and analyzed, the management of the data, and the consequent reports are of high enough quality to meet the projects needs (EPA, 2006).

Sample and Analysis Plan (SAP): a document detailing procedural and analytical requirements for sampling events performed to collect samples.

Sampling frequency: the time between successive sampling events.

Standard Operating Procedure (SOP): written documents that describe, in great detail, the routine procedures to be followed for a specific operation, analysis, or action.

Stressors: physical, chemical, or biological entities that can induce adverse effects on ecosystems or human health.

Surrogate monitoring: monitoring one variable that correlates to the actions of another variable (i.e. the pollutant of concern) that may not be easily measured.

Total Maximum Daily Load (TMDL): is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources (EPA, 2007).

Total Phosphorus (TP): a measure of the concentration of phosphorus including soluble phosphorus and the phosphorus in the organic material suspended in wastewater, effluent, or water bodies.

Total Suspended Solids (TSS): a measure of the suspended non-filtered solids (e.g. sediment or organic matter) in wastewater, effluent, or water bodies (EPA, 2006).

Turbidity: a cloudy condition in water due to suspended solids (EPA, 2006).

INTRODUCTION

This monitoring guidance document is designed to help watershed managers identify appropriate and effective monitoring strategies to meet specific project objectives. In particular, this guide will help identify and monitor the water quality impacts of Best Management Practices (BMPs) implemented to address known impairments in a watershed. These practices may range from site-specific installations, such as a manure bunker, to large-scale efforts such as improved grazing management over thousands of acres of rangeland.

Monitoring plans that are not well designed may fail to collect the necessary data, resulting in an inability to identify or quantify project impacts. In addition to the lost financial resources that result from a poorly designed monitoring plan, the opportunity to collect baseline data may also be irretrievably lost. The most common mistakes in developing a monitoring program include the following:

- *Failure to carefully consider the project objectives*. If the monitoring was not planned carefully to match the project objectives, you may find yourself at the end your project without a good way to demonstrate the impact of the project.

- *Failure to modify project objectives*: Monitoring project objectives may change over time. A monitoring project to determine baseline data or to assess impairment will have different objectives than a project to assess a BMP.

- *Failure to understand the dynamics and transport processes of the pollutant of concern in your particular watershed.* Attention to the details and issues addressed in this guidance document before the project begins will ultimately save money and time by avoiding common mistakes such as inappropriate site selection, inappropriate timing of sample collection, or even measuring the wrong parameters altogether.

- *Failure to consider alternate methods for demonstrating impact.* Increasingly, models of varying complexity are used to assess water quality issues and demonstrate the impacts of BMPs. For a model to be applicable to a specific site or project, typically some environmental data need to be assembled or collected. Therefore, the models to be used and the data that may be needed for these models must also be carefully considered before the project begins.

The first 3 sections of this guidance document are intended to help you better characterize the objectives of your monitoring plan, carefully consider the scale of your project, and better understand how the pollutants of concern are processed within a watershed and are transported from the source to the receiving water. These are critical considerations when choosing the appropriate parameters to monitor, the best locations for monitoring, and the best timing of sample collection. These and other monitoring issues are addressed in Sections 4 through 8. The final sections of the guide discuss data integrity, storage, and analysis.

In addition to a complete set of references at the end of this document, Appendix A provides details about specific protocols or models.

SECTION 1 – WHAT IS YOUR MONITORING OBJECTIVE?

Your monitoring program is determined by the objectives of your project, which must be clearly defined. All subsequent decisions about your monitoring plan follow from the monitoring objectives.

Note that often there are multiple monitoring objectives within a watershed. It is none-the-less important to design monitoring programs for individual objectives. A review and comparison of the different monitoring programs required to meet different objectives within a watershed may result in combining some field or analytical efforts for more efficiency, but the individual monitoring plans should remain distinct to assure that specific project monitoring objectives are met.

The table below demonstrates how your monitoring program may change depending on these objectives.

Table 1. Monitoring programs are dependent on project objectives.

Program Objective	**What to measure, how often and where to monitor, who should collect samples, and methods to use.**
Regulatory Compliance of an NPDES Permit	Typically most aspects of the monitoring program are established in the permit by a regulatory agency. This will often include how often samples must be collected, what methods must be used, and who can collect the samples.
TMDL / BMP Effectiveness	These consider all TMDL pollutant(s) of concern, watershed characteristics and types of BMPs to be implemented. You may have considerable room for creativity and flexibility, as long as you can justify the approach in a valid sampling plan for your project and have appropriate quality assurance and quality control (QAQC) at all steps of the process.
Educational Programming	Monitoring programs for educational purposes are typically determined by cost, ease of methods, age appropriateness, and interest of volunteers

A clearly defined monitoring objective should be in the form of answering the question: “What is the concentration of this pollutant going to be after these implementations are complete?” Monitoring objectives that are a statement and not a question such as: “The monitoring objective is to prove the water has improved and can be removed from the state’s 303(d) list” tend to demonstrate the sampler is entering the monitoring program with a preconceived bias and the monitoring effort may not be conducted or interpreted in an objective manner.

SECTION 2 – UNDERSTANDING YOUR POLLUTANT AND YOUR NATURAL SYSTEM

Understanding how your pollutants of concern behave in a natural system is extremely important. Equally important is an understanding of how these pollutants might respond to specific best management practices. Many of the pollutants we deal with, such as sediment and nutrients, are found naturally and only become problems when high concentrations impair the beneficial uses of your waterways. To develop an effective monitoring plan, you must understand how these materials are detected, transported, transformed, and otherwise processed as they move from their source into the ground or surface water.

Before any successful monitoring or modeling takes place, you should understand the following factors:

1. Is the pollutant of concern physical, chemical, or biological?

2. How does the pollutant of concern move from the source to a water body? For example, is the pollutant in a dissolved, absorbed or a particulate form? If dissolved, does it move easily through groundwater or subsurface flows?

3. How is the pollutant processed and transformed in transit, and within a water body? For example, is it utilized by plants and transformed to a different form, or does it adsorb to soil particles?

4. Do you understand the degree of natural variability in flow and weather in addition to the natural changes in concentrations throughout a season? For example, during fall and winter, organic materials break down, releasing dissolved nutrients.

5. For long-term responses you need to consider other changes in the watershed that might mask or affect the response you are looking for, such as extended land use, changes in land use, periods of drought, etc.

You may not be familiar with many of these processes. If this is the case, you should work with someone who can help you better understand how your pollutant of concern is likely to behave in YOUR watershed or area. Agency resource specialists or Extension specialists at local Universities can help or can direct you to appropriate specialists.

Monitoring in a variable world:

Dramatic changes in concentrations often occur naturally, so it is important to understand this natural variability in your system. A common mistake in monitoring programs is to interpret these natural changes as having resulted from human impacts. Another common mistake is to interpret a short term naturally occurring reduction in concentrations as a response to a BMP.

In BMP effectiveness monitoring, your objective is typically to assess and/or demonstrate the impact of your BMP on addressing the water quality issue of concern. The ease with which this is done will depend on the magnitude of this impact relative to background conditions. The range of natural variability in your system must also be taken into consideration because this variability may mask any change resulting from your BMP implementation. As a general rule, you will need more frequent samples in a highly variable system, but by targeting your sampling timing you may be able to greatly improve your monitoring program.

Monitoring may not be necessary at all times of the year. It is particularly important to understand the hydrology of your waterbody, in order to predict when important changes in chemical and biological patterns are expected. Is your watershed/water system perennial, intermittent, or ephemeral? Is the pollutant of concern primarily transported during baseflow (when the system may be more dominated by groundwater) or during snow melt or storm events? At a minimum, you should consider the following:

<u>Predictable seasonal changes:</u>

Concentrations may vary dramatically during the year depending on your location and your stream system. For example, in mountainous regions with significant winter snow pack concentrations may vary during spring runoff compared to base flow conditions. You should consider whether the impacts of your BMP will be apparent during all conditions. Also consider whether you are only interested in those times of year when conditions have impacted the beneficial uses of your water body. For example, intensive monitoring of water temperature during the winter is not useful if the problem is high temperatures during summer low flow conditions. On the other hand, you may be interested in total loads of sediment, which are often delivered entirely during spring runoff and storm events. In this case, intensive monitoring during base flow may not be worth your time or money.

<u>Daily changes:</u>

Consider whether light or temperature conditions will affect what you are monitoring. For example, drifting of aquatic macroinvertebrates can be significantly different between night and day. Behaviors of fish and some zooplankton are also driven by light conditions. Plants respond significantly to night and day change. Photosynthesis by aquatic plants may increase pH during the day. Oxygen, on the other hand, may drop significantly at night because of plant respiration in the absence of photosynthesis. Flow may also change between night and day, responding to snowmelt during the day.

<u>Storm events:</u>

Many nonpoint source pollutants are transported into waterways primarily during storm events or snowmelt periods that generate surface runoff. Be aware of the importance of monitoring these events. See Section 7 (Protocols) for more information on monitoring approaches such as continuous monitoring or flow-triggered monitoring devices that can be used in situations such as these.

SECTION 3 – CONSIDER THE SCALE

Designing a monitoring program requires that you consider the spatial and temporal scale of the project. How big an area does the particular BMP affect? How soon after implementation do you expect to see an impact of your BMP? How long do you expect theBMP to remain effective?

The following figure shows some examples of the how both the scale of BMPs and the typical response time of BMPs can be quite different. For example, construction BMPs typically are effective immediately but do not remain in place for extended periods after the construction is completed. In contrast, you would not expect to see results from a willow planting project a month after the willows were planted, but this BMP should continue to be effective for years.
As another example, manure management BMPs at a single site such as improved winter storage might only directly affect a small reach of a river, in contrast to changes in upland grazing management, which might affect an entire watershed.

Consider these scale issues when planning a monitoring program for your particular BMP.

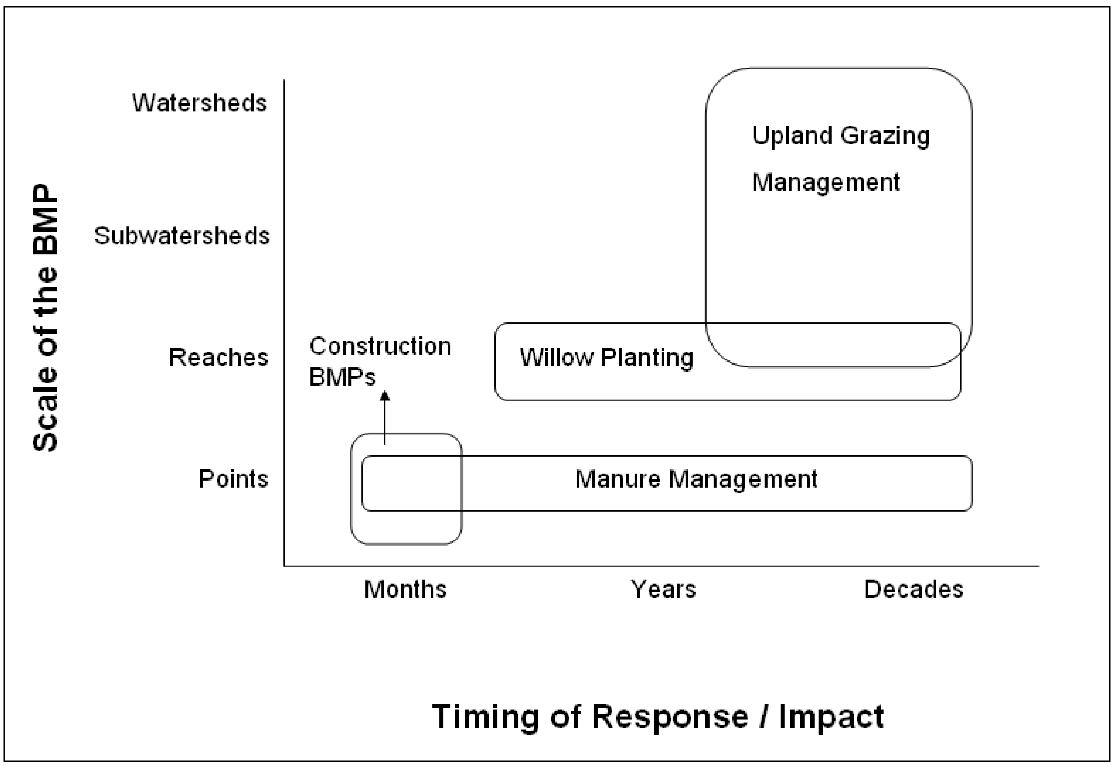

Figure 1. The scale of common BMPs and their typical response times.

SECTION 4 –MONITORING VERSUS MODELING: DIFFERENT APPROACHES TO DETECTING IMPACTS

Attempts to quantify impacts from BMPs often focus on the pollutant of concern. Other approaches, however, may be equally or more effective. These alternative approaches include monitoring a "surrogate" variable that is tightly correlated with your pollutant of concern, monitoring a "response" variable, or modeling the pollutants of concern or response variables. Remember also that a part of demonstrating the impact of a BMP is assuring that the BMP itself was implemented correctly and remains intact over time.

You should be aware of all methods of detecting change and choose the approach or approaches that work best in your situation. Refer to Table 2 for a list of common monitored pollutants and approaches for monitoring and modeling these pollutants.

Monitoring the pollutant of concern to detect a response to a BMP:

This approach is appropriate when you have clearly identified the pollutant or pollutants that are resulting in the loss of a beneficial use and you can anticipate a reduction in this pollutant as a direct response to a BMP implementation.

> Example of pollutant monitoring includes analyzing water samples for nutrient concentrations or measuring the amount of fine sediment filling spaces between cobble in a stream bottom.

If you chose this approach, make sure you also monitor related parameters that may be critical in interpreting your results. Examples include flow, which is often necessary to help interpret water concentrations, or water temperature and pH, which must be known to determine ammonia toxicity.

Monitoring Surrogates or Response Variables:

In some cases, monitoring the pollutant of concern is expensive or difficult, while monitoring a closely related parameter is relatively straightforward. The challenge in these cases is always to demonstrate that you are measuring something that will respond in a predictable way to a change in the pollutant of concern. If you chose this approach, consider the following:

> An example of surrogate monitoring is to measure turbidity, which is relatively straightforward, and can be correlated to suspended sediment or total phosphorus.
>
> An example of monitoring a response variable is to measure the amount of chlorophyll (or plant biomass) in a lake rather than measure nutrient concentrations directly.

- How sure are you of the linkage between the stressor and the surrogate?
- Note that the relationship between a surrogate or response variable and the pollutant of concern may be different in different watersheds, at different locations within a watershed or even at different times of the year. Do you need to do additional monitoring to establish the relationship between your pollutant and the surrogate in your system or is the relationship well described in the literature for your environment?

- Are there problems of compounding variability in measuring the surrogate, and the relationship between the surrogate and pollutant?

Modeling the pollutant of concern or a response variable:

Models often provide an excellent approach to better understand how your pollutant may behave under a range of conditions that you cannot directly measure. Some models result in numeric predictions, such as expected concentrations under different flows in a stream. Other models are not good at predicting specific concentrations but may help you understand how your pollutant may vary or may respond to a change in management. It is critical that you understand the strengths and limitations of any model that you use. If you wish to use a model, consider the following:

- What type of model should you use? Your monitoring objectives and the pollutant of concern will determine this.
- What is the application scale of the model? Does it match your project scale e.g. plot, field, watershed, or basin?
- Is your model process-based (attempts to mimic the natural processes in a system)? If so, do you understand the important processes for your pollutant well enough so that your model will provide useful results?
- Is your model based on statistical relationships of previously collected data? If so, are you careful to not extend your model predictions beyond the limits of these data?
- Is your model an event or a long-term simulation model?

For any modeling effort, you must understand the following:

- What is the accuracy and precision of the model?
- Do you have the data that are needed to go into the model?
- Is the model calibrated and verified for local conditions?
- How good are the numbers that go into the model?
- Consider issues such as cost, complexity, and time in development of the model?
- Do you understand the sensitivity of the model's results to different inputs into the model? Will you be able to evaluate which elements of the model are most important to achieving useful results for your purposes? Which elements are less important?

Models can also be helpful in prioritizing or designing BMP implementations. For example, a landowner wishes to move a corral off of a creek. The landowner's preferred location is 25 feet off of the creek. A model may suggest this location will result in a 75% reduction of nutrients to the creek. A similar project that would result in a projected 95% reduction may receive a higher funding priority, benefiting the landowner. The use of the model to inform the landowner that moving the corral 40 feet from the creek may result in a projected 95% reduction in nutrients might be sufficient information to allow the landowner to change their plans for the final corral location.

Because modeling may require unique skills, you may need to subcontract this work. It is critical, however, that those involved in other aspects of managing and implementing the BMP understand modeling sufficiently to make informed decisions about the modeling process, including an understanding of the strengths and limitations of a particular modeling approach. Refer to Appendix A for some specific models to consider.

Table 2. Common pollutants and approaches for directly monitoring, monitoring surrogates, response variables, and commonly used models. This table is far from complete, but should help you understand some of the issues to consider when decide which approach or approaches will best meet your monitoring objectives.

Pollutant	**Direct Monitoring**	**Surrogate Monitoring**	**Other important variables ***	**Response variables**	**Models**
Temperature	Probes, launched monitors (e.g. hobo), and direct measurements	Light / shading, ground water signal (stable isotope variables)	Air temperature	Algae, macros, and fish	CEQual WASP(7) SNTEMP (USGS)
Dissolved Oxygen (DO)	Probes and direct measurements	Temperature, redox, and Flow/temperature/algal biomass	Temperature will affect percent saturation	Macros and fish	Streeter Phelps
Nutrients (phosphorus and nitrogen)	Grab samples and integrated samples In some cases use probes, or streamside auto-analyzers to collect surrogate samples	Turbidity or sediment	pH, temperature, and DO might affect the solubility of phosphorus	Algae, macros, and fish	UAFRI SWAT QUAL2K
Sediment	Grab samples and integrated samples	Turbidity		Physical characteristics, embeddedness, macros, and algae	PSIAC AgNPS SWAT KINEROS2 SELOAD
Salts / TDS	Probes and grab samples	Riparian vegetation		Macros and fish	QUAL2K
Pathogens	Grab samples and integrated samples	Fecal Coliform Bacteria, *E.coli*	Turbidity, nutrients		
Metals	Grab samples	Bioaccumulation in living organisms	DO might affect total hardness	Bacteria in the sediments	MINTEQAQ
Organics	Grab samples	Bioaccumulation in living organisms		Bacteria in the sediments	WINPST

** These are variables that often must also be measured in order to correctly interpret your monitoring results.*

Existing Data:

Once you decide what you want to monitor or model, you need to find out what information is already available. Determine what data are available and what you may need to collect.

1. Consider what is already known about the effectiveness of your BMP. Look for NRCS, consultant, Extension, or other reports and results that indicate how effective you EXPECT your project to be. This will provide essential information on what to monitor, how long to monitor, and when to monitor.

2. Look for existing data. A number of different agencies, universities, NGOs or private consulting firms may all have collected data that will help with your project. If relevant data to your project have already been collected, you may not need to conduct "pre-implementation" monitoring. Be careful, however, to consider the quality of the data collected by other entities.

   Spatial data such as land use, soils, ownership, and elevation are often available in different formats (photos, hard copy maps, or GIS layers). These can be particularly important in helping you interpret your monitoring results or helping to develop models.

3. See if anyone else is or has been collecting these data: Is there a similar project to yours that is already being monitored? Do not forget the value of "lessons learned" and apply these whenever possible. HOWEVER, unless conditions are very similar (climate, soils, scale, etc.) you should not assume that your project will achieve very similar results.

***Monitoring the status of the BMP*:**

Note that with BMP monitoring, it may also be important to track the BMP itself. This includes determining whether the BMP was properly installed or implemented, whether expected behavior changes have occurred, and whether the BMP has been properly operated and maintained over time.

SECTION 5 – CHOOSING THE BEST MONITORING DESIGN

The specific monitoring design (the choice of location and timing of sample collection) that best meets your project objectives will depend on the type and scale of your project and the degree to which you can control other variables when you monitor. Monitoring for BMP effectiveness is often more targeted than other types of monitoring, and to the extent possible should isolate your project from other influences that may complicate your results. Below are listed several different approaches to selecting monitoring sites. For each approach, you will find the assumptions inherent in that approach, as well advantages and disadvantages and additional tips on when a particular approach is the best choice.

***Upstream and downstream monitoring*:**

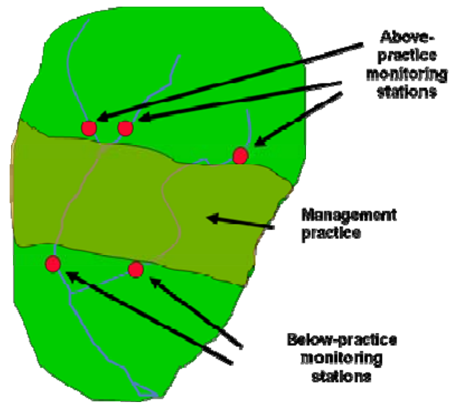

Figure 2. Upstream and downstream monitoring.

This approach refers to sampling above and below a BMP or set of BMPs.

Assumptions:

- Any changes you see are due to the implementation.

Advantages:

- This approach directly measures the change in the stream between two points.
- Typically it covers a relatively short reach of river so it may be easy to collect samples.
- If there are no changes in flow between your two sites, then you can compare concentration instead of load. This means you would not need a flow measurement, which is sometimes difficult to obtain. HOWEVER, the EPA and other agencies typically want to know how much of a pollutant has been removed, which is what a load measurement will tell you.

Disadvantages:

- This only works when water is actively moving through your BMP and into your water body. For example, an upstream and downstream plan will not pick up the improvement from a feeding operation during dry, base flow conditions.
- The best time to collect your samples is when it is raining or when snow melt is running off the land. Otherwise, the changes might be very subtle if seen at all.

When to use this approach:

- This approach works particularly well for an in-stream implementation, such as a sedimentation trap. This will also work for implementations that affect the stream's edge, such as willow plantings, but probably only when flows are enough to inundate the planting area.
- Timing is critical for this type of monitoring. If your BMP is capturing runoff from an off-stream site, you must sample during runoff events to identify the change.

Monitoring a reference site for comparison:

With this approach, you monitor a second site in a very similar watershed, which is your baseline reference site. Changes in your BMP site are compared to this baseline. The monitoring approach is greatly strengthened if you collect data at both sites before AND after BMP implementation (referred to as BACI or **B**efore **A**fter **C**ontrol **I**mplementation design).

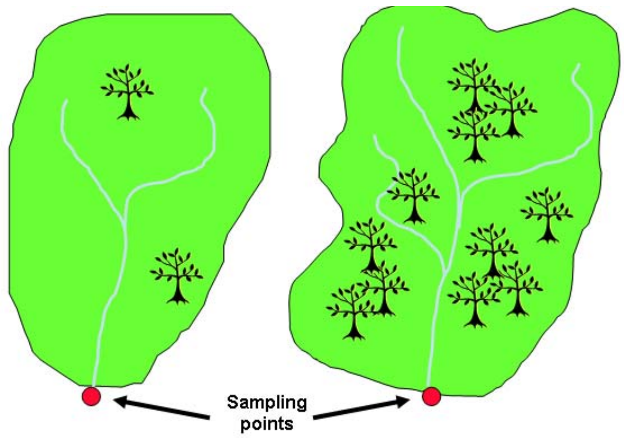

Figure 3. Comparison to a reference site.

Assumption:

- Your reference site is similar enough to your sample location site that it will provide a baseline for comparison.

Advantages:

- You can compare data that are collected at the same time, so water year differences, and other seasonal and annual variation is reduced.

Disadvantages:

- It can be difficult to find a good reference site, particularly if you are looking for an "unimpaired" or "natural" site.
- Be careful about comparing sites that are not sufficiently similar. At a minimum, you will want streams that are of a similar order, flow, geology, stream type, elevation, and land use.

When to use this:

- Use this when looking at long term indicators (biological indicators). This approach is the basis of many E/O macroinvertebrate indices monitoring programs.
- One of the challenges of this program is finding adequate reference sites. If you use this approach to directly compare chemical data, you will still need to consider whether the conditions under which you are monitoring will result in an impact in the stream (e.g. base flow vs. a storm).
- You may also still want to do upstream and downstream monitoring to assure that you are capturing all potential impacts.

Comparison to a reference conditions:

Similar to the reference site approach, this approach compares your site to a cumulative data set comprised of all reference quality sites found in the same eco-region, watershed, or sub watershed. Chemical, physical, and/or biological conditions exhibiting a high degree of variation between reference quality sites are generally discounted. The best situations to use this approach are those chemical, physical, and/or biological conditions that are consistent among reference sites but are clearly influenced by human activities.

Monitoring downstream before and after implementation:

With this approach, a site is monitored at a downstream location before and after the BMP is implemented. The difference in concentration or total loading after implementation can be attributed to your BMP.

Assumption:

- Conditions (including flow) remain the same over time and therefore all changes are attributable to the BMP implementation.

Advantages:

- You may be able to use data from an existing monitoring site with a long record.

Disadvantages:

- You cannot control for other activities upstream of your monitoring site, so this approach will not differentiate water quality changes resulting from your BMP from any other changes upstream of your BMP.
- You also cannot control for changes that happen over time. For example, if your "before implementation" period happens to be a drought and your "after implementation" monitoring occurs during a high water period, you will not be able to differentiate these impacts from the changes due to your BMP.

When to use this:

- This is a weak monitoring approach and when possible you should use other approaches, or supplement this approach.
- You may decide to use this approach because you already have an ongoing monitoring site that you can take advantage of, but if possible, look for other ways of monitoring change as well.
- This may be a useful approach under very restricted circumstances. For example, it may used if the BMP is intended to be effective only for a very short time (such as straw bales to capture construction runoff). Even in these cases, however, you must monitor under similar conditions (e.g. a rain event) and natural variability may complicate your results.

Monitoring using historic data:

This approach is very similar to before and after implementation, but you may be able to compare your results with data collected considerably before your implementation.

Advantages:

- Potentially more data to use in "before" period.

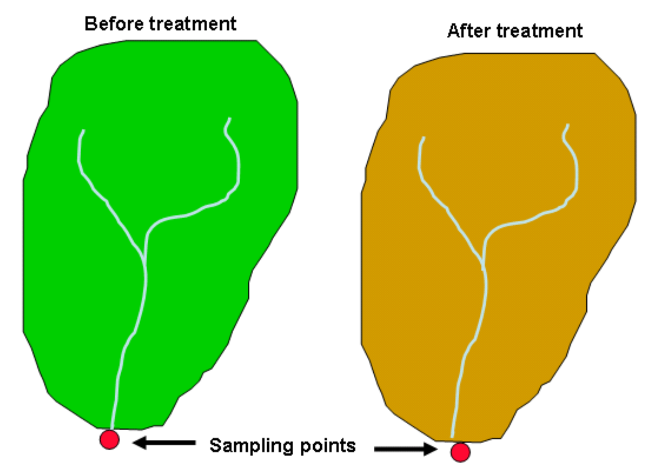

Figure 4. Monitoring using historical data.

Disadvantages:

- This approach has the same disadvantages as “monitoring downstream before and after implementation.” You cannot control for changes in weather, hydrology, land use, etc.
- ALSO, sampling and analytical techniques may change over time. Be aware of changes in detection limits, in changes of reporting units, or methodology (e.g. filtered vs. non-filtered samples). This can greatly complicate comparisons.

***Monitoring site runoff*:**

This method involves measuring the runoff that comes directly off of your monitoring site; before it enters the water body (e.g. return irrigation flows).

Assumption:

- You are able to adequately sample and quantify all the runoff from a site.

Advantages:

- Direct measurement of the impact of your implementation

Disadvantages:

- You will need to monitor runoff before and after the implementation to demonstrate the impact.
- You need to measure flow or adequately estimate the duration of the flow as concentration to demonstrate impact.

When to use this:

- Use this for smaller implementations, such as modifications in a small feeding operation.
- Use this when the impact is likely to be fairly substantial, because otherwise it might be hard to detect.
- Use this when the BMP is off-stream and runoff does not go directly to the stream (e.g. groundwater infiltration, diversion points, etc.).

SECTION 6- SITE SPECIFIC CONSIDERATIONS

Your monitoring design will determine approximately where you need to sample relative to your BMP implementation. You must still consider some site specific characteristics to assure that you get a representative sample for your project needs. This is also an important time to consider safety concerns, the time spent getting to a sampling location, legal access and other logistical issues.

Will your site affect your ability to conduct certain types of monitoring?

- Think about all possible flow conditions and other environmental conditions (e.g. anchor ice or floating ice) that you might experience at a site to determine whether the equipment required for your monitoring choice will be adequate.
- Do you need a bridge to collect a flow sample during high flow periods?
- Do you have road access to the site and if not, will you be able to carry monitoring equipment to your sites?
- Do you need electricity to run equipment?
- If you intend to download data at a remote location, do you have sufficient clearance or repeaters to get a signal from your site?

Are there time constraints associated with your site selection?

- Some sites may be ideal in many respects but may be difficult and time consuming to visit. Consider whether your budget and sampling plan can accommodate the time required to get to individual sites.
- Many pollutant samples have a maximum time between sample collection and analysis or further processing, called a holding time. For example, bacteriological samples may have a holding time of a few hours. If your samples have a short holding time, you need to assure that you will be able to collect your samples and return them to a lab within this time. Exceeding the holding time generally results in data that are of limited value. Holding times should be documented in your Sample and Analysis Plan (SAP); if not check with the laboratory that will be analyzing your samples.

Do you have legal and safe access to all your sites?

- Be respectful of all private property. If you intend to leave any equipment near the site or if you need to attach anything to bridges or pilings, make sure you have permission to do so. Contact the municipal authority or other entity that maintains public bridges or other public structures if you need to attach anything to these structures. Always contact private landowners for permission to cross their land.

- You should choose sites that will not place your field crew at risk. Does the access to the site cross hazardous conditions or terrain? Is the water too deep or too fast to safely collect a sample? Are there obstructions, steep banks, submerged wire or debris, poisonous plants, or dangerous holes that may place your samplers at risk? Be aware of all potential hazards and risks.

SECTION 7 – PROTOCOLS

Up to this point, this document has focused on decisions concerning monitoring approaches and general monitoring design. This section covers some important considerations about actual data collection. Please note that this manual is not intended to provide you with detailed descriptions of analytic techniques or procedures. Private labs or consulting firms that assist with specific analytic approaches have standard operating procedures (SOPs) that cover everything from sample collection to final reporting of the data. Refer to the Reference and Resource sections for references to further explore the technical details of different monitoring techniques.

Field data is often divided into three main types of data collection: water column data, aquatic biological data, or habitat data. Very often, all three types of data are collected, but they require different techniques and considerations, and provide different types of information. Therefore, in this section, they will be discussed separately. This section also differentiates between sampling within your waterbody and sampling upland conditions.

No matter what type of data you decide will best meet your project objectives, your primary goal is always to collect a representative sample. This requires you to consider where and when you sample and how samples are processed so the results are not compromised. Always keep the following considerations in mind:

- Are there critical periods during which you expect to see a change?
- Given the natural variability in your system, will you be able to monitor frequently enough and over a sufficient period of time to differentiate between natural changes and responses to your BMP implementation?
- Will you be able to control for other changes occurring in your project area, such as climatic variation, or changes in land use?

Water Column Monitoring:

Sampling the water is the most common approach for detecting change. This type of monitoring allows you to directly measure the concentrations of pollutants or their surrogates, or to measure a physical property of the water, such as temperature. These values also link most directly to those water quality criteria expressed as concentrations. This approach may also allow you to directly measure the load (or mass) of a particular pollutant found in a water body for a given period of time.

Advantages of water column monitoring include:

- Methods are often standardized, which means they are repeatable and comparable to samples collected at different times or in different locations.
- Samples used for chemical analysis are easy to collect.
- You often are directly measuring the pollutant of concern.

Disadvantages of water column monitoring include:

- Depending on how you collect your samples, results are often discontinuous in time and space, meaning each result is a "snap-shot" in time and is not reflective of the impact of the pollutant of concern in between collection times.
- The costs of collecting and processing samples are variable but may be quite expensive for some tests.
- The holding times for the samples may limit your ability to get samples to a laboratory for analysis.

Collecting a representative sample:

<u>How to collect a sample:</u>

The easiest type of sample collection is a "grab sample," which simply refers to filling a water bottle directly from the water body (or from a bucket dunked into the water). Integrated samplers are available which will collect a sample from the surface to the stream bottom. A series of these taken across the cross section of a stream will result in a sample integrated both vertically and horizontally.

Integrating over time requires additional special equipment: "Automatic" water samplers with pump intakes can take samples at established intervals ranging from every few minutes to samples collected at weekly intervals. See holding time considerations below if you chose such an approach. Probes are now available for some water quality parameters and coupled with a data logger will provide continuous data, assuming they are well calibrated over the data collection periods.

<u>"Fraction" to measure (particulate/dissolved; bedload/suspended load):</u>

Water samples are analyzed in an unfiltered and filtered fraction, which provides information on how much of a pollutant is in a dissolved form. This may be important if the dissolved form is more biologically relevant. For example, the dissolved fraction of many heavy metals are the fraction which are most toxic to aquatic organisms. Dissolved phosphorus is more biologically relevant as well, but in this case because this form is more readily available as a fertilizer for aquatic plants, so may be a better measure of potential eutrophication. Emerging nutrient standards, however, appear to be leaning toward total phosphorus, so you need that for comparibility and for water quality assessment.

<u>Where to collect the sample:</u>

Dissolved constituents (SRP, Nitrate, and TDS) typically are well mixed throughout moving streams (eg. runs of rivers). Therefore, a grab sample in a well-mixed part of the river is representative. Particulate constituents, however, may not be as well mixed. Sediment samplers are available to get a depth integrated sample (higher concentrations toward the bottom). Often the USGS will also collect a series of samples across the width of a stream/river because velocities change and therefore the sediment carrying capacity changes.

Some contaminants, such as petroleum products or some organic chemicals, are lighter than water. In these cases, a sample that is integrated from top to bottom will provide a good average concentration, but sampling the surface water and in backwaters may provide the information you need about maximum exposure to hazardous materials.

<u>Sample handling and holding times:</u>

It is usually obvious properties of water such as temperature that will begin to change as soon as the water is removed from the stream; therefore, these "field" parameters must be measured immediately. Most parameters will change once the water is collected. Consequently, all water quality analyses include special protocols for handling the sample and have a specified "holding time," the maximum time allowable before the sample is analyzed. Handling protocols may include bottle type, temperature, or light versus dark conditions. Some samples cannot be frozen; some samples must be filtered immediately; some samples can be preserved with acid to prolong their holding times. If any of these conditions are not met, your sample is no longer considered representative of conditions in the stream and all the effort of collecting the sample and analyzing it will be wasted.

<u>Technical expertise required (calibration, data loggers, field equipment):</u>

Some types of sampling, such as total station surveying or properly setting up data loggers, are more intensive and require a higher level of training than others. It is best to get adequate training ahead of time, do "dry runs" ahead of time and /or hire or partner with people who have the requisite skills. Do not attempt to count on techniques that you will not be able to properly calibrate, set up, service or otherwise use.

Biological Monitoring:

Understanding the distribution, abundance and types of organisms living in a stream or river provides a direct measure of the health of your stream or river ecosystem. This type of monitoring has also become increasingly important because of the value of "indicator species", which are organisms or groups of organisms that respond in a characteristic way to types of pollutants or other stressors. A comparison of the relative abundance of these indicator species to what is expected in comparable unpolluted water bodies (reference streams) can indicate ongoing or past pollution, even when it is not evident in water column samples.

Advantages of biological monitoring include:

- Aquatic life is one of the beneficial uses to be protected in most water bodies, and this monitoring approach therefore directly measures this use.
- Biological monitoring integrates impacts to streams that have occurred over time.
- Samples used for biological monitoring are often relatively easy to collect.
- Fewer sampling times are needed to assess the overall biological integrity.

Disadvantages of biological monitoring include:

- This approach requires reference sites or comparable "natural habitats" for comparison, and these sites may be very difficult to find.
- The high degree of heterogeneity in these populations can complicate the need to collect a representative sample.

- Detecting change in biological communities does not necessarily provide insights into the nature of the pollutant or stressor. Therefore, this type of monitoring often must be coupled with additional studies to determine the pollutant of concern.
- Although collecting the sample is relatively easy, identifying the organisms in the sample requires skilled personnel. Therefore, sample analysis may be quite expensive.

<u>Macroinvertebrates:</u>

At each site, sample in the same habitat (riffle or pool, near shore or midstream) or attempt to collect a representative type of habitats. You may want to collect “drifters” as well as the aquatic organisms live on surfaces. This will require different sample equipment and may require sampling at night or for extended periods of time.

<u>Periphyton:</u>

Like the macroinvertebrates, at each site, sample in the same habitat (riffle or pool, near shore or midstream) or attempt to collect a representative type of habitats. Conduct an assessment of the different substrate types in the reach and determine a sampling strategy. Typical substrates include removable portions of vascular plants, mosses, snags, roots, leaf mats, and rock. Do not consider sediment as a target substrate. With respect of the different types of periphyton communities, know which periphyton analysis is to be conducted to ensure you are collecting the correct periphyton samples and properly preserving the samples.

<u>Fish</u>:

Prior to sampling consider what species and size (life stages) of fish you are attempting to collect. Fish sampling should be conducted prior to habitat monitoring (below) so as not to disturb the fish communities prior to sampling. Sample all habitat types available to fish within the sampling reach, making an effort to sample all of the fish observed. Different equipment is required for different stream types, such as using a backpack for small wadable streams or a boom shocker for non-wadable large rivers. Be aware of the barriers to fish movement within the reach and note these in your field data sheets.

Habitat Monitoring (Physical and Riparian Vegetation):

Advantages of habitat monitoring include:

- Collecting habitat data including physical and riparian vegetation samples will provide the “big picture” over time because it is incorporating landscape influences.
- Physical data reflects hydrological impacts.
- Collecting habitat data can be a relatively low cost.

Disadvantages of habitat monitoring include:

- Monitoring the habitat through collecting physical and riparian vegetation may not reflect actual water quality, but collecting variables such as flow can be used to calculate sediment loads.

- Collecting physical and riparian vegetation data may be subjective, because it is not strictly quantifiable (e.g. a cobble may be someone else's gravel).
- Due to the subjective nature of habitat monitoring, it implies the lack of repeatability.

Stream bed properties (embeddedness, pebble counts):

Sample similar habitat (riffle, run, or pool) from site to site. Attempt to find sites that are not influenced by large, sediment bearing tributaries, unless this is the impact are you are specifically monitoring. Similarly, find sites that are not influenced by diversions or drop structures, or where the substrate is not natural (e.g. rock hauled into a channel for a low water crossing).

Near shore or riparian conditions:

The width and extent of riparian corridors of vegetation along a shoreline and the types of plants growing in these areas may all provide significant insights into pollutant movement into:

- a stream or other water body,
- increased shading to maintain cool water temperatures,
- the capacity of a stream bank to resist erosion, and
- the value of these areas as wildlife habitat.

If any of these are objectives of your TMDL or were part of your implementation plan, you should consider monitoring these areas directly. Approaches include photo points, transects, "greenline" data, and measures of canopy cover.

Stream bank properties:

Erosion along a stream bank may be a significant source of sediment and nutrients into a waterbody. Bank recession measurements or direct measurements of height and length of raw stream banks are both good approaches to determining the degree to which a BMP has modified bank erosion.

Stream morphology:

Stream morphology includes its width-to-depth ratio, the slope of the stream, how sinuous the stream is, and whether the stream is in a single channel or braided in multiple channels. Any of these measurements may respond to some BMPs, especially those that affect sediment bank stability or sediment entering a stream. These measurements can be made by various surveying techniques in the field. Aerial photography may also provide useful information on sinuosity, channel form, and width.

Monitoring outside of the water body:

Many monitoring plans are greatly enhanced by collecting additional information that will help you better understand the impact and effectiveness of your BMP, and achieve your project objectives. Examples of additional monitoring may include:

- land use patterns pre and post BMP implementation,
- land owner and stakeholder interviews regarding land use, and
- current TMDLs or watershed management plans.

SECTION 8- QUALITY ASSURANCE AND QUALITY CONTROL

How frequently should you monitor and how many samples should you collect?

The frequency of sample collection will depend on what you are monitoring and how variable its abundance or mass is throughout your monitoring period. The frequency of sampling will also be determined by the natural variability in your system.

If you want to show a statistically valid difference in your pollutant of concern that can be attributed to your BMP implementation, you must have some prior knowledge of the variability within your system. To assure that your monitoring program will produce statistically valid results, check with a statistician, or the person who will be analyzing your data to assist you in determining your sample size.

To help you determine your sample size, review the following (USGS & Patuxent Wildlife Research Center, 2005):

- What are your monitoring objectives?
- What is the response time for your BMP implementation?
  - What is the smallest number of years over which you would like to detect a change?
  - What is the smallest percentage change you would like to detect over those years?
  - The fewer number of years over which you would like to detect a trend, the greater number of samples you will need.
- How will you analyze your data?
  - Sample sizes will also be defined by what statistical test you use to analyze the data, and different tests may require different sample sizes.
  - What is your ability to detect a change?
- How variable is your data likely to be?
  - Any calculation of how many samples you need for your monitoring program should be treated simply as an educated guess. There are too many variables involved that are out of your control. The minimum sample size will depend upon the sampler’s desire of confidence in the data and sample variability.
  - What is your measure of uncertainty?
  - What is the type of system that you are monitoring?
- How precisely do you want to measure changes or trends?
  - The lower the precision, the lower number of samples you will need. Conversely, the higher the precision, the larger number of samples you will need.
- How much money and manpower you have?
  - Any monitoring program whose goal is to detect small changes over a short period may be expensive.
  - The less willing you are to be caught “crying wolf” the more samples you will need to detect a change.
  - How many times a year you want to sample?

What other steps might you need to follow?

"Standardization of methods is a fundamental prerequisite to any monitoring program" (Karr, 1991). You will need to define your methods for sampling in the field. Please note that these methods should reflect the analytical standards and procedures of the individual laboratory that you are working with. These methods should include:

- Establishing sampling reaches,
- Selecting sampling sites and habitat types,
- Selecting reference sites,
- Determine the season for sampling, and
- The methods of monitoring your response variables (which includes defining your field QAQC protocols and data acquisition).

<u>Quality of data required may determine protocols:</u>

- Do you need a certified lab?
- Do you need credible data certification?
- Does your state have certification / credible data requirements? Check with the environmental quality agency in your state.

<u>Lab vs. field techniques</u>

Section 7 Protocols, outlines factors to be aware of when using collecting samples in the field for laboratory analysis. For example, the holding times of your samples may limit sample collection. Be sure to determine the specific analytic approaches of the labs or consulting firms you are working prior to collecting samples.

<u>Detection limits:</u>

You need to get detection limits from the labs you plan to use to process your samples. The detection limits will vary with lab protocols and standard procedures. The detection limit will determine your ability to differentiate between signal and noise. It is very important to consider these ahead of time to determine if a test is even worth it. For example, for many years mercury detection limits were higher than the water quality criteria; therefore, if you had alarmingly high concentrations, your test would give you information. If you had less than the detection limits you could not determine whether you were above or below the criterion.

SECTION 9 – DATA MANAGEMENT

Data management should be considered before any sampling begins. Data that are poorly recorded, tracked, or lost represent an enormous and often irretrievable loss in information as well as time and money.

The following considerations are a minimum when managing your data.

- Develop an identification system for sites and individual samples that is clear and unambiguous. Keep separate records that will explain this system to future monitors.

- Keep a log book of all samples, recording when (date and time) and where (unique site IDs) that the samples were collected, who collected the samples, recording important information concerning holding times and processing of samples, conditions when the sample was collected, and the final outcome of the samples.

- Field sheets or field notebooks are the first entry point for data. Design these sheets to guide the field sampler through a monitoring protocol, so that nothing is forgotten or overlooked. Store these original hard copies in a secure filing system. It is good practice to write down everything you see. It may not seem important at the time but that cow you saw in the creek could help you in your data interpretation. Do not trust your memory because monitoring sites tend to look all the same after awhile.

- Transcribe field data and analytical results into a reliable electronic program such as a database or spreadsheet. Keep in mind that electronic programs and platforms change rapidly. You may wish to store your data in several electronic formats with backups to assure that you will not lose access to data because of electronic changes or failures. Do not discard your data sheets after the data have been entered into the database.

- Make sure that the unique identification system is used in this file. The format and program you use will depend on the complexity of the data you are collecting and the analysis you intend to conduct. This becomes your raw data file.

- Make sure that you double check all entries, or have a second person check your entries, to reduce the possibility of transcription errors. Define all fields in your data file. Make sure that units and detection limits are always recorded.

- Scan the data for extreme values or outliers. Any decisions made to drop these values from further analysis should be documented.

- Scan similar sets of data to see if they correlate. For example, a sample with high Total Suspended Solids (TSS) likely will have high turbidity, and a sample with high Total Dissolved Salts (TDS) will likely have high conductivity.

- Maintain a metadata file to record QAQC results, information about variances from standard procedures, other data (e.g. weather, unusual conditions, variances from protocols, etc).

- Calculated data (e.g. statistical analyses, summary data, graphs, etc.) will use the data in your original raw data files but be careful to never change these original data. Always document any calculations you conduct, including conversions, sources of data for statistical tests or graphs, etc.

SECTION 10 – ANALYSIS OF DATA

Statistical methods provide a wide array of techniques for extracting information from water quality monitoring data. The specific analyses to be used will depend on ***the objectives*** of your project, the system you are working in and the type of data.

Common types of data for assessing BMPs:

Trend Data
Before and After (BACI)
Paired Watersheds
Time Series

Data analysis assumes that you have managed and organized your data (Section 9) and you have your data in a format for conducting analyses.

The following information needs to be considered for data analysis.

- QA/QC – need to know if your data are defensible before you go to all of the trouble of data analysis. Adding a bad data to a good data set compromises the entire data set.

- Has the intensity of the sampling changed from intensive monitoring to trend (or vice versa)

- You need to think about how the data were collected and by whom. It is important to know if the same methods were used or if you need to separate the data by method.

- Do you have a large enough data set or sample size (n) to evaluate your project How much data do you have? How many monitoring stations? How many years and how often per year?

- It is important to know the details of your data and to investigate inconsistencies when necessary. For example, when analyzing stream flow data are you analyzing height or discharge measurements? Were the data collected under similar precipitation? Are they event, seasonal or annual flow data? If water quality data are collected along with stream flow, are you in the rising or falling limb of the hydrograph? Are you measuring spring runoff or base flow? And are you in the upper or lower reaches of a watershed?

- There are significant differences between no data, zero, and data that are below detection limits; these differences should be clearly defined in your datasets and be taken into account in the analysis process.

- In the analysis process, it is important to be able to distinguish your independent and dependent variables.

- The selection of analysis method or methods should reflect the objectives of your project. Often you will need more than one analysis method to assess the effectiveness of your BMP.

Due to the large variability in the types of water quality data collected and questions that can be answered, it is difficult to identify specific tools that will be needed. Some very common data analysis techniques are listed below. However, it is highly recommended to contact a statistician to assist with data analysis and interpretation. Additional information on selecting the "appropriate" analysis tool can be found at: http://www.epa.gov/nheerl/arm/bibliography.htm

Common Descriptive and Summary Statistics:
Summary statistics are a very good place to start the analysis. However, be careful in your interpretation of data using only summary statistics.

- Arithmetic mean
- Geometric mean
- Median
- Distributions (are your data normally distributed?)
- Measures of variability (standard deviation, coefficient of variability, skewness)

It is important to be able to identify outliers in your data and understand the implications of and data analysis with and without outliers.

Exploratory Data Analysis:
Simple graphs are a very good way to look for overall patterns in your data. They can help identify trends as well as deficiencies in your data. Common graphing methods are:

- Histograms
- Time series
- Comparisons
- Pie charts

Comparative Statistics:
Comparative statistics are used to assess the strengths of the relationships among different datasets (e.g., stream flow and sediment concentration, paired watershed, BACI.) Some common techniques are:

- Correlations
- Regressions
- Student t-tests

It is important to know the difference between a correlation and a regression relationship. Both describe the strength of relationship between two quantitative variables. Correlation (r) does not distinguish between explanatory and response variables. Regressions (r^2) distinguish between dependent (response) and independent (explanatory) variables.

SECTION 11 – INTERPRETING AND USING THE DATA

Ideally, by this step you have addressed all of the issues in the previous sections and are ready to interpret the results from your analyses. To effectively use your water quality data to assess the effectiveness of a BMP you will need to analyze and interpret your data within the context of your stream system (watershed) and your project objective. However, it is important to note that this may be an iterative process. By analyzing and interpreting your data within the context of your project objective, you may come to the conclusion that you 1) are collecting the "wrong" data; 2) have not collected enough data; or 3) need additional information to fully interpret your data. In which case, you will reassess which data you need to collect and modify your SAP.

The first step will be to determine that you are collecting the "right" data to assess your BMP. This is a question that should be asked during the entire process. How do you know if you have collected enough data? In many cases this is a criterion that can and should be defined *a priori*. A clearly written monitoring project objective will define when you have met your objective. The criterion can be set to a water quality standard, a delisting of a stream segment or a percentage decrease in a pollutant. In monitoring projects that are determining baseline, the criterion may be that additional data collected do not result in a change in the long-term mean or coefficient of variation of the water quality data of concern.

The following information needs to be considered when interpreting and using your data.

Interpreting the data:

It is important that your data be interpreted within the "proper" context. Are you interested in a specific water quality criterion? Are you trying to assess or determine loads (TMDL, mass balances, source ID) or concentrations? Your data may show that you exceed a TMDL but are well below a specific target concentration.

Using the data:

Is the monitoring working (i.e., are you detecting what you want to detect)?
Are the data telling you what you want to know? Are you able to detect trends? Are these the expected trends based on your system, the BMP and the climatic conditions?
Are you able to assess if the BMP is working? These are often statistical tests, but need to be assessed within the context of your objective and the stream system.

Future work:

Ideally, a successful, well executed monitoring project that meets its objectives will lay the ground work for future projects. These may include implementation of new BMPs or similar BMPs with in the same watershed system, if they proved successful. A good, well documented water quality dataset can be invaluable for locating future projects. It can also be used to determine if the monitoring program needs to be changed or modified. This could mean changing a monitoring program from intensive to trend (or vice versa). As always, this will depend on how the project objects are defined.

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RESOURCES

NRCS products and tools from the National Waters and Climate Center:
http://www.wcc.nrcs.usda.gov/products.html

Monitoring protocols: National Water Quality Monitoring Handbook, specifically Section 614 <http://policy.nrcs.usda.gov/media/pdf/H_450_600_a.pdf>

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APPENDIX A- SPECIFIC MODELS TO CONSIDER AND PROTOCOLS

Models:

AGricultural Non-Point Source Pollution Model (AGNPS): continuous simulation surface runoff model designed to assist with determining BMPs, the setting of TMDLs, and for risk & cost/benefit analyses (http://www.ars.usda.gov/Research/docs.htm?docid=5199).

Soil Water Asssessment Tool (SWAT): a river basin scale model developed to quantify the impact of land management practices in large and complex watersheds. SWAT is a public domain model supported by the USDA Agricultural Research Service (http://www.brc.tamus.edu/swat/).

Kinematic runoff and erosion model (KINEROS2): is an event oriented, physically based model describing the processes of interception, infiltration, surface runoff and erosion from small agricultural and urban watersheds (http://www.tucson.ars.ag.gov/kineros/).

Revised Universal Soil Loss Equation (RUSLE): an online soil assessment tool using the soil loss equation (A = R * K * LS * C * P) (http://www.iwr.msu.edu/rusle/).

Rangeland Erosion Model (RHEM):
http://www.ars.usda.gov/research/projects/projects.htm?ACCN_NO=406982&showpubs=true

SNTEMP:
http://smig.usgs.gov/cgi-bin/SMIC/model_home_pages/model_home?selection=sntemp

Streeter Phelps - Dissolved Oxygen Model:
http://cedb.asce.org/cgi/WWWdisplay.cgi?5014377

River and Stream Water Quality Model (QUAL2K): a one dimensional river and stream water quality model for a well mixed, vertically and laterally channel with steady state hydraulics (http://www.epa.gov/athens/wwqtsc/html/qual2k.html).

Better Assessment Science Integrating Point and Nonpoint sources (BASINS 4): a free GIS tool for watershed analysis and monitoring (http://www.epa.gov/athens/wwqtsc/html/basins.html).

US EPA Water Quality Models and Tools: This site includes information and guidance on several simulation models and tools for watershed and water quality monitoring (http://www.epa.gov/waterscience/models/).

Resources for Bioassessment Protocols:

US Environmental Protection Agency. "Biocriteria." 2007. <http://www.epa.gov/waterscience/biocriteria/>

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