National Nonpoint Source Monitoring Program

TechNOTES 11

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

The program has two major objectives:

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

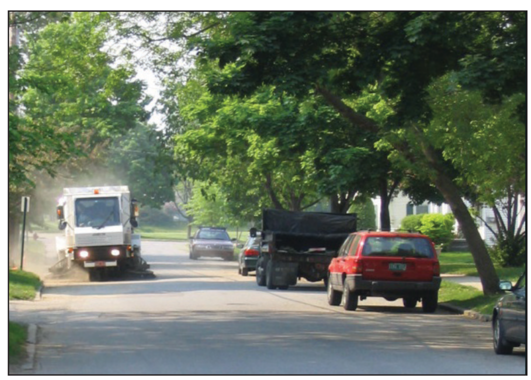
NNPSMP Tech Notes is a series of publications that shares this unique research and monitoring effort. It offers guidance on data collection, implementation of pollution control technologies, and monitoring design, as well as case studies that illustrate principles in action.

August 2014

Donald W. Meals, Steven A. Dressing, John Kosco, and Susan A. Lanberg. 2014. Land use and BMP tracking for NPS watershed projects. Tech Notes 11, June 2014. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 31 p. Available online at *https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-monitoring-technical-notes*.

Land Use and BMP Tracking for NPS Watershed Projects

Introduction



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. Just as it is important to design water quality monitoring before the watershed project begins, it is equally important to design land use and BMP tracking before implementation begins (***USEPA 1990***).

This Tech Note focuses on tracking ongoing land use and management before, during, and after BMP implementation in order to document the land-based activities that influence the generation and transport of NPS pollutants. The purpose of this tracking is to document and characterize the land treatment that could yield effects on water quality monitored at the watershed scale. Where applicable, the term "BMP tracking" refers not just to documenting the existence of a structure or practice (e.g., sediment basin, reduced tillage) but also to confirming that the management associated with a BMP (e.g., extent of residue cover, fertilizer application rate, timing, and method) and the maintenance of BMPs (e.g., sediment basin clean-out) are carried out. It has long been stated that all land use activities that may influence water quality in a watershed should be considered, guided by a thorough assessment of both point source and NPS pollutants and sources (Johnson et al. 1981). See the box for definitions applied to the land-based terminology used in this Tech Note.

The specific types of information and the level of detail needed vary according to geographic scale and project objectives. While land use and BMP information can be used for a variety of program and project purposes at scales ranging from field to nationwide, this Tech Note focuses primarily on the watershed scale. Because this information is often collected by watershed projects as an essential element for assessing both current watershed condition and progress over time, data requirements for land use and management should be addressed with the same level of rigor that is applied to the collection of water quality, flow, and weather data used for the same purposes. Just as it is for water quality monitoring, land use/BMP monitoring requirements should be assessed and specified in a quality assurance project plan (QAPP) as outlined in ***EPA Requirements for Quality Assurance Project Plans*** (USEPA 2001a).

Land-Based Terminology

BMP – best management practice, a structure installed or management action taken to reduce pollution from sources

BMP system – a combination of BMPs that are used together to comprehensively control a pollutant from the same source

Land Cover and Land Use – the type of land and how it is used, including row crops, low-density residential, mixed forest, wetlands, barren (See *USGS* (2012) for details)

Land Management – how the use and development of a particular parcel of land is carried out, including such things as crop rotations, fertilization practices, road maintenance, and BMP implementation

Land Treatment – actions undertaken to improve conservation of soil, water, or other resources, including application of BMPs

Management Measures – economically achievable measures to control the addition of pollutants to water resources, including best available NPS control practices, technologies, processes, siting criteria, operating methods, or other alternatives

Source Activities – any activities at a potential pollution origin, e.g., tillage, road salting, street sweeping, pasture management, forest road development, and BMP implementation

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

The specifics of land use/BMP tracking vary according to the objectives of the effort, the types of BMPs or land-based variables to be monitored, the scale of the project, and available resources and information. The role of objectives is described here, while details pertaining to the types of BMPs, project scale, and other factors are discussed in subsequent sections. Please note that detailed guidance on monitoring to determine the status of contract requirements or the success of programs to encourage BMP adoption is not provided in this Tech Note.

Assessment monitoring requires complete spatial coverage of source activities, but temporal variability is not generally addressed because of the short timeframe for problem assessment. Evaluating the land uses in a watershed is an important step in understanding watershed condition and source dynamics. Additional details regarding the role of land use in watershed assessment can be found in the U.S. Environmental Protection Agency's (EPA) Watershed Planning Handbook (***USEPA 2008a***).

Demonstration of progress in solving NPS problems is often approached with monitoring designed to detect either a step or monotonic trend (***Meals et al. 2011***). Information on spatial and temporal variability of source activities is required to understand pollutant loading patterns during and after the implementation of BMPs. This variability is particularly important when load and wasteload allocations are developed as part of a TMDL (total maximum daily load) because TMDLs must address seasonal variations in both impairments and allowable loads. In addition, the size of the margin of safety in a TMDL is often directly related to the level of uncertainty associated with the NPS loads.

The central focus of this Tech Note is effectiveness monitoring where relationships are sought between water quality and land-based data. 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 = f(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. Specific considerations and recommendations for land-based variables can be found in subsequent sections

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. Whereas waterbodies can be monitored at convenient points in key locations based on well understood principles, the status of land management is typically assessed by examining thousands of acres of land.

Depending on the specific study area and monitoring design, however, some parts of a larger area may be emphasized over other parts. For example, land nearest to the sampling point can sometimes have a major effect on the measured water quality, so these areas must be monitored carefully. Critical source areas that may contribute disproportionately to pollutant loads (e.g., tilled cropland on highly erodible soils) may require special focus (Maas et al. 1985, Humenik et al. 1987). Conversely, areas in stable cover that contribute little to the overall NPS problem (e.g., unharvested forest land) might receive less intensive scrutiny. Thus, the spatial coverage of land use monitoring may range from a single field (or portion of a field) to an entire river basin.

Monitoring Design

A range of monitoring designs has been used for BMP- and watershed-scale projects, including above/below, paired-watershed, and trend designs (***Dressing and Meals 2005***). 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. Both of these designs incorporate a treatment area where BMPs are to be applied and a control area where land use and management are expected to not change during the monitoring period. The control inherent in these designs makes it possible to factor out climatic and other influences if the rules associated with the designs are not violated. Requirements for paired-watershed studies (***Clausen and Spooner 1993***, ***USDA 2003***) include:

- Control and treatment watersheds should be generally similar in size, slope, location, soils, and land cover.

- Watersheds should be small enough to obtain a level and type of treatment that can be expected to have a measurable water quality response.
- Each watershed should be in a steady-state with respect to land cover and management for a number of years prior to the study.

Advantages of the paired-watershed design include:

- Climate and hydrologic differences over the years are statistically controlled.
- Water quality changes can be attributed to treatment.
- The control watershed eliminates the need to measure all components causing change.
- Watersheds need not be identical.

The requirement that the designed treatment should be expected to create a measurable response is central to the success of a paired-watershed or above/below-before/after study. This essentially means that the land treatment or BMP plan is targeted appropriately to the sources and transport pathways of the pollutants of interest and implemented to a degree where measurable water quality impacts could be expected. Projects that fall short of this goal will not achieve measurable water quality change.

While in a research setting the experimental control of a paired-watershed or above/below-before/after design makes it unnecessary to measure all components causing change, this luxury does not apply to typical NPS watershed projects where landowners are generally free to manage their land as they choose. The reality is that monitoring staff need to ensure that both the treatment and control watersheds are being managed as expected. It is often the case that the requirements for these monitoring designs are not met due to unexpected changes in land use or land management in the control watershed. For this reason a backup analysis plan is needed. The Michigan (Suppnick 1999) Section 319 National NPS Monitoring Program (NNPSMP) project, for example, had to abandon its paired-watershed design because of unexpected BMP implementation in the control watershed. Having actively tracked land treatment variables related to the measured water quality variables, however, the project was still able to relate water quality improvements to land treatment using multiple linear regression analysis. This demonstrates the need for and potential benefits of tracking activities in both the control and treatment watersheds with equal rigor.

It is common for a paired-watershed design to differ somewhat from the ideal design because it is difficult to find suitable pairs that can be managed as needed. Deviations from the ideal and their effects on subsequent data analysis should be considered up front and data collection efforts adjusted as appropriate. For example, the NNPSMP project in the Catskill Mountains (NY) selected paired watersheds that were different in size, slope, location, soils, and land cover (Bishop et al. 2005). A remote forested watershed was used as the control watershed for pairing with a larger treatment watershed dominated by a single dairy farm. Project scientists adjusted to this situation by adding monitoring variables to account for between-watershed differences in precipitation, sediment availability, and hydrologic response.

Most NPS watershed projects do not use the paired-watershed or above/below-before/after designs. Single-station watershed outlet (pour point) trend monitoring is the most frequently used design to demonstrate progress and evaluate BMP effectiveness at the watershed scale. This approach, however, has no built-in controls to account for climate and hydrologic differences over time, and the land treatment plan often causes only small or gradual water quality change. For these and other reasons, it is considered the least reliable and most challenging monitoring design for attributing water quality change to land treatment or management changes. Greater effort must be expended to gather sufficient additional data to explain or interpret water quality patterns measured with a trend design. This includes climate, flow, soils, topography, land use, and land treatment or management data. Because the experimental control needed to isolate the impacts of applied BMPs is absent, sources not being treated must also be assessed and tracked.

Tracking Details

What: Variable Selection

The appropriate set of land use/treatment variables for any monitoring plan will depend on the monitoring objectives, monitoring design, and size and other characteristics of the watershed or site to be monitored. Keep in mind that all land use and management activities that influence the generation and transport of pollutants in the project area should be tracked or accounted for unless a paired-watershed or above/below-before/after monitoring design is used. As noted earlier, even for those designs it is important to anticipate the need for information about potential pollutant sources other than those being treated with BMPs.

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

Monitoring objectives will guide the selection of variables. For example, the set of land use/treatment variables needed for BMP effectiveness monitoring is tailored to the BMP(s) and the conditions under which evaluation occurs, whereas the set of variables needed for problem assessment is usually broad (***USEPA 2008a***). In fact, a common challenge facing land use/BMP tracking efforts is inadequate problem assessment that fails to properly determine the full range of sources contributing to identified water quality problems. For example, a NPS project that considers only upland soil erosion, and therefore collects land management data focusing on soil erodibility, sediment delivery, and cropland erosion control measures may overlook streambank or streambed erosion and sedimentation problems. This may result in a failure to track riparian condition, stream stability, or other management influences on in-stream processes.

While a fairly standard set of water quality variables exists for monitoring plans to draw upon, the set of variables associated with land use and BMPs is far more extensive and far less proven. In developing potential variables, consider source characteristics and activities that generate the key pollutants of concern and especially those expected to vary or change in response to BMP implementation. Table 1 illustrates an important first step in selecting land use/treatment variables appropriate for the monitoring plan.

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

The next step involves selecting the specific water quality variables that will be monitored from identified sources and matching those with specific land use/treatment variables for which a relationship is likely. For example, variables such as the percentage of cropland under conservation tillage have been used with some success by NPS watershed projects (Suppnick 1999). This combination of variables is logical and is supported by plot- and field-scale research. Table 2 shows examples of pairing water quality and land use/treatment variables. "~Weekly" variables are those that must be monitored frequently to record the exact date or quantity associated with the metric. "~Annual" variables can be determined less frequently as they generally remain constant within a crop year.

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

Naturally, much of the effort in a NPS watershed project will focus on new management practices that are implemented. Watershed projects routinely track implementation of BMPs (i.e., presence or absence) to show that pollution control measures have been put into place or to explain the results of water quality monitoring. It is less common, however, for the quality of the BMPs to be monitored or for the tracking information to be verified.

The size of a project area often determines the level of detail obtained through land use/treatment tracking. For example, whereas structural and management practices are tracked at virtually all scales of BMP tracking, more detailed information such as adherence to established practice standards and specifications is much more likely to be tracked at the individual BMP scale than at the large basin scale. Tracking frequency varies as well, with annual or less frequent tracking common for statewide or large basin efforts and more frequent tracking for BMP-specific or small watershed-scale projects. This greater frequency for smaller-scale efforts is often accompanied by greater detail on site-specific management activities such as nutrient application rates, placement and integrity of construction site erosion controls, or forest road management.

When monitoring the effectiveness of individual BMPs at a plot- or field-scale, it is important to document the following:

- Design specifications of the practice evaluated, such as the design storm and associated capacity of a sediment basin, the plant species used in a cover crop, or the amount of residue left by conservation tillage
- Degree to which the practice was implemented, maintained, and operated according to specifications
- Management activities conducted under the scope of the practice, including manure application timing, rate, and method
- Any situations where the BMP operated under conditions outside of the design range; e.g., flagging monitoring data when the design capacity of a stormwater runoff device is exceeded because performance will often suffer

These same considerations apply to all BMPs to be evaluated at the watershed scale, with the additional proviso that both the spatial distribution and interrelationships of components in a BMP system should be addressed.

Composite indices

Watershed projects have generally settled on the use of a single variable or set of single variables to represent land management status for analysis with water quality data. These variables have been used separately or in combination to explain water quality trends in a number of projects (e.g., Suppnick 1999, Schilling and Spooner 2006). In watersheds with multiple land uses and a variety of pollution control activities it may be desirable to develop variables that integrate source activities to create composite indicators of source treatment status rather than using a long string of separate variables to represent the multiple sources and activities. These composite indices would provide a single snapshot of overall conditions much like indices developed for biological monitoring. Source treatment status index values could be generated on an annual or more frequent basis and relationships to water quality variables could be tested through statistical analysis.

Dressing et al. (1992) demonstrated the potential merits of using a nonpoint source index (NPI) to characterize water quality status before and after BMP implementation. The NPI was tested using data from the Rock Creek, ID, and St. Albans Bay, VT, Rural Clean Water Program projects. Results indicated that water quality and land treatment subindex scores can shed some light on further NPS treatment needs.

The phosphorus index (P Index) is another type of composite index, one that is usually applied to agricultural lands only. The P Index was developed to assess the potential for P moving from individual fields based on selected soil and field characteristics and management practices (*Iowa NRCS 2004*). The P index integrates source (soil test P; total soil P; rate, method, and timing of P application; and erosion), and transport factors (sediment delivery, relative field location in the watershed, soil conservation practices, precipitation, runoff, and tile flow/subsurface drainage) in a spreadsheet application that outputs both quantitative and qualitative ratings that could be used in analyses with water quality data. Acreage-weighted P Index scores could be tracked over time and combined with P concentrations or loads in receiving waters to test for relationships in agricultural watersheds.

Where: Geographic Coverage of Tracking Effort

There are three basic options for collecting data on a geographic basis:

- Collecting the same level of information throughout the project area
- Collecting information throughout the project area but with varying levels of detail reflecting the relative importance of source areas
- Targeting data collection activities to specific areas only

Resource and other (e.g., uncooperative landowners) constraints will often limit project access to parts of the watershed being monitored. This, of course, will not be a limitation for smaller scale plot or field studies. Projects must decide how to address these constraints while still obtaining the best possible dataset on land use/treatment. A common approach is to focus on those areas that are expected to have the greatest impact on measured water quality (i.e., critical areas), but the project must have assessed pollutant sources well to ensure that this approach is appropriate. When deciding to focus efforts on a targeted area, it is important to keep in mind that subsequent data analysis will attempt to relate changes within that targeted area to changes in measured water quality. If the area is too small or misses important sources that will be treated, changes made may not have a measurable impact on water quality.

When: Frequency, Duration, and Timing of Sampling

After establishing the set of variables and geographic scope of interest for land use/BMP tracking, it is necessary to establish the timing and frequency of sampling required to achieve stated objectives. Sampling frequency needs are relatively well understood for water quality monitoring compared to BMP tracking. For example, chemical sampling can be conducted at a frequency determined by evaluating constituent variability against project objectives for data precision. Biological monitoring is usually performed once or twice per year and pollutant load estimation can be handled with weekly flow-weighted composite samples and a continuous flow record. With the exception of regulated point sources and other sources with discrete discharge pipes, such rules of thumb and procedural approaches are not readily available for pollutant source tracking.

Design of a BMP tracking system often begins with the assumption that the frequency, duration, and timing of land use/treatment monitoring should match that of the water quality monitoring when the data are to be combined for analyses. Data from weekly composite water quality samples, for example, would be associated with weekly measures of source activity. However, this design should be tempered by understanding the inherent variability of what is being measured and the temporal relationship between land treatment and water quality response. Some metrics of land use/management do not in fact vary on a weekly or other time scale associated with water quality monitoring. Of equal or greater concern, however, is the fact that the lag time between management actions and their measurable impact on water quality conditions can vary considerably (***Meals and Dressing 2008***, Meals et al. 2010). It may be appropriate in some cases to begin land use/treatment monitoring months to years before water quality monitoring begins, relating the data later on a lag basis.

It is critical to track changes in land use and management over time because of the potential for associated changes in influence on hydrology and NPS pollutant generation. As a general rule, broad land use categories such as forest, agricultural, residential, and commercial may need to be documented just once at the outset of a watershed project, but may need to be tracked more frequently where land use is actively changing. For example, urbanization should be monitored at a frequency sufficient to capture the activities most likely to affect water quality, including land clearing and shaping, periods of heavy construction and truck traffic, rapid changes in impervious surface, and installation of stormwater management practices. Even in areas of stable agricultural land use, important information such as crop yields may need to be tracked annually or semi-annually where double-cropping occurs. Changes and activities within broad land use categories should also be tracked on an annual or more frequent basis, including extensive timber harvesting, shifts in major crop type, and conversion of grassland to cropland. Although relatively rare, activities such as bridge construction, dam removal, or industrial facility closure must also be noted because they can have major impacts on water quality.

Some source activities must be tracked on a more frequent, often variable, basis. Weekly records of tillage operations and manure application on cropland can be important. Nutrient management, consisting of a range of steps taken throughout the course of a single year, including such things as pre-plant fertilizer applications, soil and plant tissue testing, cover crops, and manure applications also requires more frequent data collection. Practices like rain gardens, street sweeping, and forest road management all have their own schedules that usually vary widely. For example, the mass of material collected via street sweeping may be needed on a weekly basis. Time-critical management data should be collected on a nearly continuous basis.

It may be important to track some land management activities in relation to specific events in time and magnitude, such as a storm event. Herbicide losses from cropland, for example, are strongly influenced by the proximity of application timing to the first few runoff events. Similarly, pollution potential in pasture runoff may be influenced by the stocking rate near the time of major runoff events. Performance of urban stormwater infiltration practices may be driven by storm frequency, time elapsed between storms, and storm intensity.

Periods of transition may warrant particularly intensive tracking of land use change. In the Vermont NNPSMP project, poorly-managed conversion of forested land to cropland generated very large sediment and P loads at the time the land was cleared, plowed, and fertilized (Meals 2001). In the Connecticut NNPSMP project, storm runoff and pollutant loadings were strongly influenced by stormwater retention in excavations during construction of a residential development (***Clausen 2007***).

A multi-level land use/treatment monitoring approach incorporating the types of relationships illustrated in Table 2 can address multiple temporal concerns. Components of such an approach could include the following:

- Characterization – an initial snapshot of land cover/land use, focusing on relatively static parameters (at least relative to the project period) such as waterbodies, highways, impervious cover, and broad patterns of urban, agricultural, and forest land uses
- Observations/surveys
    - Annual – an annual survey for annually-varying features such as crop type
    - Weekly – weekly observations or log entries to identify specific dates/times of critical activities like manure or herbicide applications, tillage, construction, and street sweeping
- Quantitative – data collection on rates and quantities (e.g., nutrient or herbicide application rates, road salt applications, number of animals on pasture, logging truck traffic)

The guiding principle of timing should be to collect land use/treatment data at a time resolution fine enough to potentially explain water quality observations (e.g., a spike in P concentration) as they occur.

A significant constraint associated with tracking frequency for land use/treatment data is dependence on others for such data. Data obtained from federal, state, or local agencies may only be available in annual reports and the frequency of observations may only be once per year. If landowners are the source of the data, both the frequency and quality of the data may be variable. It is important to develop contingency plans for addressing holes in datasets that depend on information from others.

How: Data Collection Methods

Terminology

This section provides basic information on a variety of methods to collect and verify information on source activities to ensure that data will be suitable for project needs. Terminology associated with land use/BMP tracking can be confusing and definitions vary considerably depending on the source. Definitions used in this Tech Note are provided in the adjacent text box. Tracking and monitoring are similar terms that are often used interchangeably, with the emphasis that tracking refers to documenting the existence of something in space as well as time over a broad area (e.g., a watershed), whereas monitoring usually connotes observing over time, with location implicit in the definition (i.e., a monitoring station). Verification is a distinct, but related activity that is important to the successful documentation and evaluation of efforts to solve NPS pollution problems. Data verification and validation are addressed in the following EPA documents:

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.

- *Guidance on Systemic Planning Using the Data Quality Objectives Process* (***USEPA 2006a***)
- *Data Quality Assessment: A Reviewer's Guide* (***USEPA 2006b***)
- *Data Quality Assessment: Statistical Methods for Practitioners* (***USEPA 2006c***)

Verification can be applied to all aspects of the BMP tracking effort. For example, it is essential that the recipient and user of BMP data agree with the data provider on BMP definitions and purposes. In other words, the recipients and providers of BMP data must be talking about the same things, and reporting based on established practice standards and specifications can be very helpful in this regard. For example, in North Carolina, Osmond et al. (2013) attempted to estimate N and P application rates by surveying farmers about fertilizer use, rate, and type. However, farmers did not initially understand that fertilizer meant all applied N, but interpreted the question to mean only applications of a complete fertilizer product or a starter fertilizer applied just before or during planting. Most farmers apply most of the N when the corn is approximately 18" tall and they did not report their second application of N, thus significantly underestimating the total amount of N on corn. An accurate accounting of what was implemented and reasonable expectations for BMP performance are necessary for appropriate reporting of progress and fair assessments of the effectiveness of individual BMPs and watershed projects in achieving water quality goals.

Documentation of when BMPs are implemented (or removed) and when they reach full maturity in the case of biological treatment systems should also be verified. This will ensure that progress is reported accurately over time and that land-based and water quality data are appropriately paired for analysis of the impacts of BMPs on water quality. Confirming BMP locations is also essential to properly pair BMP and water quality data for analyses, as well as to ensure that the implementation plan is being carried out correctly. It should be noted that many BMP implementation programs have rigorous reporting systems for tracking BMPs when they are implemented, but little follow-up monitoring over time to ensure that the BMPs are still in place and functional. Verification, therefore, becomes even more important after the installation or adoption date.

Census vs. sampling

One of two basic approaches can be used to gather accurate information about the sources within the geographic area of interest: census or statistical sampling. A census is a procedure for systematically acquiring information about the members of a given population that involves complete enumeration of the membership. A statistical sampling approach involves the collection of information from a subset of a population (e.g., selected randomly or according to a set of criteria) from which inferences about the entire population can be made.

Statistically-based sampling procedures have been promoted and described to reduce the effort needed to acquire good datasets (***USEPA 1997a***, ***1997b***, ***2001b***). Privacy concerns can complicate the sampling design if the desired information is too detailed. In addition, while statistically-based sampling procedures will reduce the time and expense required to obtain broad measures of land-based variables, critical data on conditions influencing water quality at specific locations may not be available from statistical samples, rendering the land treatment/BMP data set incomplete.

It is recommended that statistically-based sampling be used only for those watershed projects where the entire watershed is being tracked and resources are insufficient to monitor every source. A census approach is recommended for watersheds where tracking will occur only in targeted areas.

Specific methods

There are many options for tracking land use and BMPs under either a census or statistical sampling approach. Methods for tracking BMPs include direct measurements (e.g., soil tests, onsite inspections, remote sensing) and indirect methods (e.g., landowner self-reporting or third-party inspections). Selection of a specific method of BMP tracking is driven by the scale of the project, the type of BMPs involved, the kind and quality of information required (e.g., structures vs. management), and available project resources. In agricultural settings the best approach may be to create separate tracking approaches for structural (e.g., animal waste storage structures), activity-based (e.g., nutrient management), and long-term conservation practices (e.g., U.S. Department of Agriculture [USDA]

Conservation Reserve Program set-asides) because of the different methods and sampling frequencies appropriate for each type of management measure. Various options for tracking these different land treatment approaches are described in the following sections.

The most important point to keep in mind is that no single approach is likely to provide all the information needed. For example, recent work in Indiana showed that a combination of producer interviews, agency records, and direct observation was necessary to account for all BMPs that were implemented in a watershed project (Grady et al. 2013). Adequate datasets are rare because watershed projects usually have only a mixed bag of tools and methods.

The following sections identify and describe various methods for tracking BMPs and proving that the obtained BMP data are true and accurate.

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. Even in larger-scale watershed projects, BMPs can be tracked through regular inspections of installed BMPs (e.g., periodic checks of livestock exclusion fencing, observations of conservation tillage or cover crops on treated fields, or inspections of stormwater infiltration practices). It is recommended that a form be developed and used to ensure that collection of observations is complete and consistent over time.

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, and jurisdictions as diverse as the State of West Virginia and the City of Los Angeles are using them to collect and manage field data collected for stormwater programs. For example, West Virginia has developed a BMP and Land Use Change tracking system that allows data to be entered into a web-based form; see Figure 1 for an example of the BMP data entry form. The Los Angeles tool is a mobile

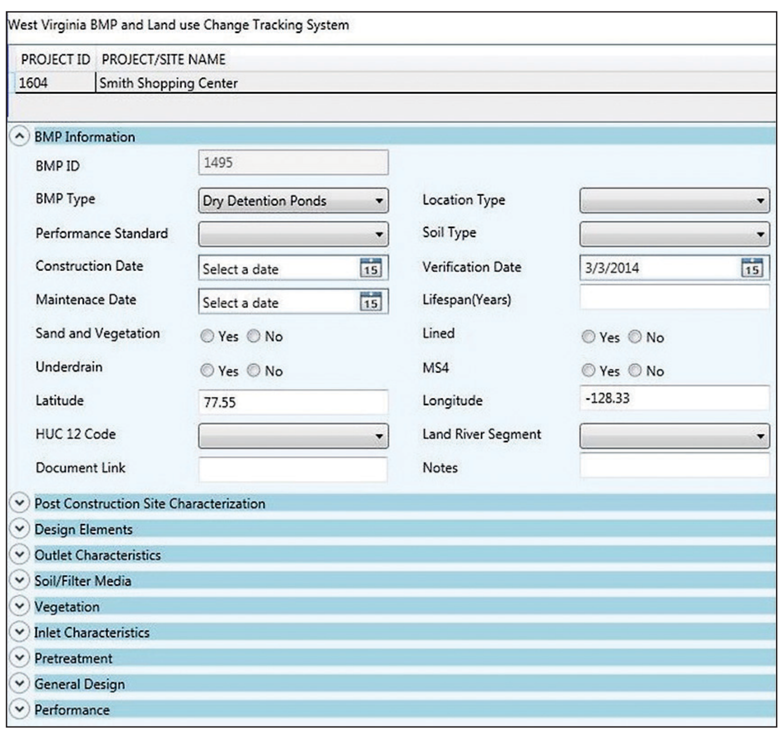


Figure 1. West Virginia BMP and Land Use Change tracking system.

application that tracks basic attributes about outfall monitoring (Figure 2).

Other types of direct observation include quantitative windshield surveys (systematic observations made from a moving vehicle) such as those performed by the ***Conservation Technology Information Center*** (CTIC) for adoption of conservation tillage (CTIC 2013). 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 (***Cooley et al. 2012***). Similarly, a formal program of regular monitoring at specific photo points can be established to monitor BMPs where vegetation growth or landform changes are important. A detailed discussion of the use of photo points for monitoring is presented by ***Hall*** (2002).

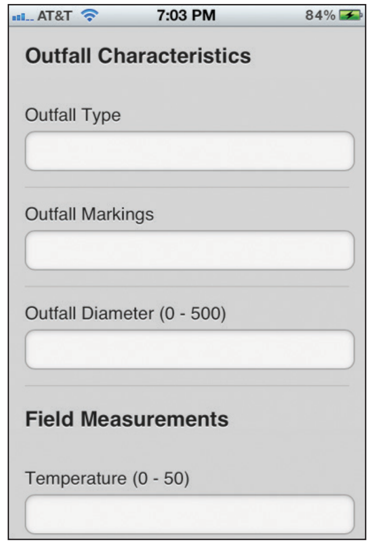


Figure 2. Los Angeles outfall monitoring tool.

Photo-Point Monitoring

- Set objectives
- Select method
- Select monitoring areas
- Establish, mark, and assign identification numbers to photo and camera points
- Identify a witness site
- Record site information and create a site locator field book
- Determine timing and frequency of photographs
- Define data analysis plans
- Establish data management system
- Take and document photos

Advantages of BMP tracking through direct observation include the ability to schedule visits and the fact that the observer controls the quality of data collected. Disadvantages include the potential for bias due to the observer's lack of understanding of management activities, scheduling that misses important events, and the inability to assess some management variables (e.g., fertilizer application rate information) through visual observation alone.

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.

Regular interviews can be used to ensure some consistency in the collection of information from independent agricultural producers. For interviews, as for log books, reporting is done by the individual responsible for the activity. Interviews conducted in person also offer the opportunity to gather additional information of importance to the study, such as unplanned management activities or unusual events. Disadvantages include the potential for both less than complete reporting of information by the person interviewed and inadequate or uneven interview skills by those conducting the interviews. It is helpful to engage an interviewer who is local to the study area and has some knowledge of or credibility in the agricultural setting of the project area.

A combination of the log book and interview approach may work well in small watersheds with a relatively small number of landowners. For example, a Vermont project successfully used a combination of log books distributed to watershed farmers and an annual interview to collect the logbook and record other information (Meals 2001). Interviews were conducted by a local crop consultant who was known and trusted in the region.

In the Jordan Cove (CT) NNPSMP project, researchers sent a 10-question household survey to each resident in the three monitored watersheds (control, traditional development, BMP development) from 1999 through 2004 (***Clausen 2007***). The approximately annual survey was intended to track information that might affect the study results, including questions on pets, lawn care, fertilizers, watering, leaf disposal, rain gutters, and car washing. Response rates varied among years and watersheds, with an overall range of 46-82 percent for the three watersheds. A comparison of survey results across years showed no pronounced differences in the three watersheds, generally indicating that residents did not change their behavior during the study period. This was an especially important assumption to confirm for control watershed residents.

Landowner self-assessment

Some jurisdictions require or provide incentives to induce agricultural producers to conduct regular self-assessments of some or all of their installed/adopted BMPs. For those self-surveys to be useful, farmers must have a clear understanding of what each BMP is so that reporting is accurate and consistent across a watershed. Self-assessments are often required elements of state regulatory programs, perhaps taking the form of annual assessment reports to a responsible agency. The quality of information gained from self-reporting usually varies across landowners, but spot checks by professionals/agency staff may be included in some of these programs to provide an additional level of confidence that assessments are reasonable.

Under the federal stormwater program, most permits require construction site operators to conduct inspections at least once every two weeks and document their inspection results in a report. An ***example of a construction inspection checklist*** is available from the State of Ohio. Industrial stormwater permit holders must also conduct periodic (monthly or quarterly) inspections and an annual site evaluation. EPA provides an example of the ***annual reporting form*** it uses for this purpose.

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. Although such assessments provide high quality information, they are likely to be both time- and labor-intensive, especially in large areas over long time periods. Some jurisdictions address these resource constraints by conducting random or rotating spot checks of a certain percentage of farms each year.

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. In some cases, information collected for one purpose (e.g., permit compliance) may not be directly relevant to the water quality problems in the watershed. Agency reports can be a good source of information about BMPs implemented in compliance with permits or cost-sharing agreements, but details can be lacking because of the nature of the program or due to privacy laws. Still, watershed projects are encouraged to consult with the agencies and others managing such programs to learn about the availability of useful project-level data before beginning their own, perhaps redundant, data collection efforts. Even if watershed-level data are not readily available, projects may find that these programs have valuable information regarding acceptable BMPs, their adoption rates, and patterns of compliance with practice standards and specifications. A sampling of such programs is provided in the attachment.

In most agricultural watershed projects, technical and financial aspects of BMP implementation are facilitated by federal (e.g., USDA), state, or local agencies (e.g., conservation districts). These agencies should be part of the watershed project team and make regular reports of BMP contracting and implementation progress. It is crucial for watershed projects to address the issue of BMP tracking at the outset because confidentiality restrictions often limit the producer information that federal or other agencies can share.

Records from the USDA-Natural Resources Conservation Service (NRCS) are often used as a source of verification information because NRCS is the primary agency involved in BMP planning and implementation in many agricultural watershed projects. According to the NRCS electronic ***Field Office Technical Guide***, conservation practice standards and statements of work indicate certain elements of practice implementation/installation that field staff must report into NRCS records. National requirements for two practices are shown in Table 3, but state NRCS offices may add their own specific requirements.

As noted above, confidentiality issues may restrict access to agency records at this level of specificity. Unless individual landowner permission is obtained, it may be necessary to aggregate data to a watershed or county level.

Table 3. NRCS reporting requirements for two BMPs (*USDA 2013*).

Nutrient Management (590)	Riparian Forest Buffer (391)
Extent of practice applied (acres)	Extent of practice applied (acres)
Records of crops produced, yields, residue management	Width and extent of buffer zones
Records of soil, manure, or other tests used to implement the plan	Actual plant materials and protective measurers
Records of recommended nutrient application rates	Certification that the practice meets NRCS standards
Records of nutrient applications, dates, and methods	
Certification that the practice meets NRCS standards	

In cases where project-specific BMP information is not available, routine agency records may contain some useful information. The NRCS maintains an ***online database*** of conservation practices implemented with cost-share assistance. Although this database is accessible only through the NRCS computer network, the information is usually considered public and can sometimes be obtained through NRCS county or state offices. However, the utility of this database is limited for watershed projects because data are aggregated at the county level, some implementation is not reported due to confidentiality restrictions, and cumulative implementation is difficult to ascertain because operation and maintenance of practices is not tracked. In addition, the information in the system is verified and finalized annually, so provisional data within the current year may be incomplete or inaccurate.

Records-review approaches to verification can be effective in areas where most or all BMPs are implemented with agency cost-share. However, this approach sometimes has significant limitations because non-cost-share practices are not included in most records, nor are operation and maintenance or management information. Sparse on-the-ground spot checks will not be sufficient to overcome this limitation.

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. A survey is the process of collecting data from a population or a subset of a population through such means as questionnaires, interviews, and visual enumeration. When a survey is conducted on a sample selected from a target population, statistical techniques are used to make inferences about that population. Note that such efforts must be carefully designed with rigorous statistical methodology and conducted by trained practitioners to ensure that results can be extrapolated to the entire area of interest with acceptable confidence. It should be noted that third-party sources of survey information may be constrained by privacy laws.

EPA published the three documents listed below to assist state, regional, and local environmental professionals in tracking the implementation of agricultural, forestry, and urban BMPs. The focus of these documents is on the statistical approaches needed to properly collect and analyze data that are accurate and defensible. Information is provided on methods for selecting sites for evaluation, sample size estimation, sampling, and results evaluation and presentation. Probabilistic sampling designs are discussed – including simple random sampling, stratified random sampling, cluster sampling, and systematic sampling – to meet specific objectives for tracking and evaluating the implementation of BMPs. The documents also include methods for evaluating data through statistical hypothesis testing and an examination of measurement and sampling errors.

- *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures – Agriculture* (**USEPA 1997a**)
- *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures – Forestry* (**USEPA 1997b**)
- *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures – Urban* (**USEPA 2001b**)

The CTIC ***annual tillage/crop residue*** survey in the Midwest (CTIC 2013) is a good example of an on-the-ground statistical survey. The cropland roadside transect survey method illustrated in Figure 3 is designed to gather readily visible information on tillage and crop residue management systems. Experience has shown that the most likely candidates for conducting a transect are counties with a grid road system, fields that are readily visible from the road, crop planting dates that fall within a relatively short period of time, and substantial adoption of conservation tillage. The purposes of the survey are threefold: (1) to provide information that can be used by individual soil and water conservation districts and others in establishing priorities for educational or

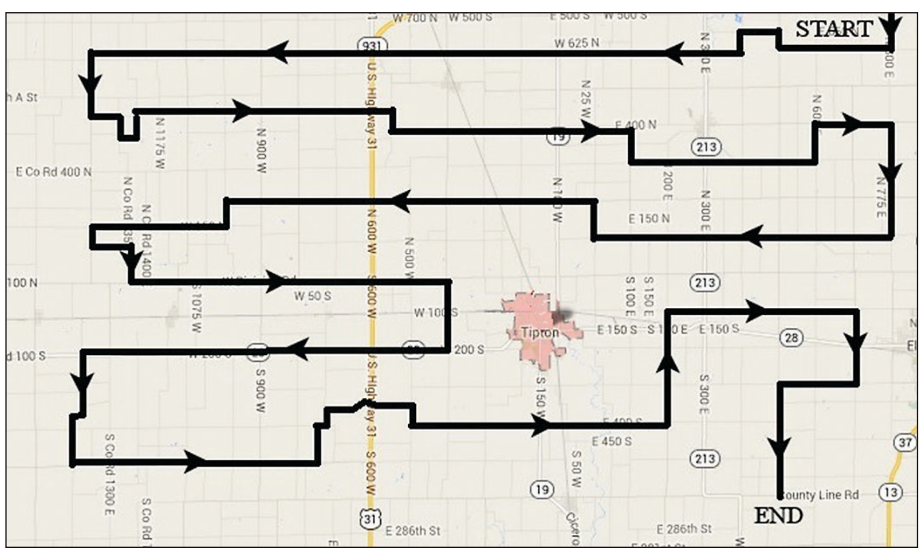


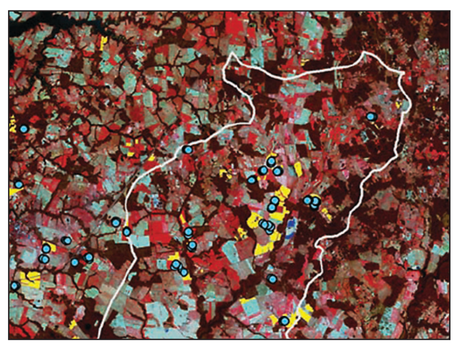
Figure 3. Sample county road transect route for CTIC annual survey (after CTIC 2013).

other programs; (2) to evaluate progress achieved in reaching county or statewide goals; and (3) to provide accurate data on the adoption of conservation tillage systems by crop for the CTIC National Crop Residue Management Survey. CTIC describes the specific steps involved in conducting the survey, addressing issues such as establishing a driving route, selecting the survey date and team, collecting the survey data, and calculating the crop acreage and percentage of coverage for each tillage system. CTIC suggests that users can have 90 percent or more confidence in the accuracy of results from a properly-conducted survey. Several states have used transect data to allocate cost-share funds, develop new resource management goals, and to provide information to the general public about the impact of progress on land use trends.

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 hand-held photographs. In some regions, the USDA-Farm Service Agency conducts annual low-altitude aerial photography to assess compliance with crop insurance programs. If this photography can be accessed with appropriate permissions, it can provide an annual record of crop rotations, changes in field boundaries, land development, and other features.



False-color infrared satellite image of a Maryland watershed (Hively et al. 2009)

Sullivan et al. (2008) evaluated the usefulness of Landsat TM data as a tool to depict conservation tillage in the Little River Experimental Watershed in Georgia. Satellite imagery was used to calculate four commonly used spectral indices. Ground truth data consisted of a windshield survey, assigning each site a tillage regime (conventional or conservation tillage) at 138 locations throughout the watershed. Results indicated an overall accuracy of 71 to 78 percent for classifying field tillage from satellite imagery. In the Chesapeake Bay Watershed, Hively et al. (2009) used satellite imagery to evaluate cover crop extent and calculate cover crop nutrient uptake efficiencies at the landscape scale. A vegetation index calculated from satellite data was a successful predictor of aboveground biomass for fields, explaining 73 percent of observed variation in vegetative cover.

Remote sensing has also been used for some stormwater applications, primarily in estimating impervious cover for a watershed. For example, the impervious surface area of the entire State of Minnesota was ***mapped*** using Landsat data.

A wide range of remote sensing datasets are available for free or at low cost, including data products at the ***USGS's National Map*** or ***Earth Resources Observation and Science (EROS) data center***. Other datasets include Landsat data, elevation, greenness, "Nighttime Lights," and coastal and Great Lakes Shorelines (USEPA 2008a). Commercial web-based resources such as ***Bing Maps*** and ***Google Earth*** can be useful tools for land use monitoring. Although the date of the imagery in these or other resources may not exactly match what is required for a specific project, features such as roads, farmsteads, rivers, and lakes are readily apparent and general land use types (e.g., urban, agriculture, or forest) can be identified and mapped in preparation for acquisition of more current detailed data. Images clipped from web-based aerial photography can be added to log books or interview forms to facilitate collection of land use and BMP data directly from producers.

Hybrid approaches

Some BMPs can be detected and verified by some methods, but not by others. BMPs implemented through government programs with cost-share may be documented through agency reporting systems, but these records do not include BMPs implemented outside of financial and technical incentive programs. Structural BMPs such as diversions or sediment control basins and BMPs that change the character of the land surface like cover crops or timber harvests can be observed either on the ground or from above. Management variables such as location, rate, timing, and method of manure or fertilizer application, however, cannot be reliably observed. Such management data must be obtained directly from land owners or managers. Whether accomplished from the ground or by remote sensing, land use and BMP tracking must be conducted at the right time of year to assess seasonally-active BMPs like cover crops. Hybrid approaches that include more than one verification tool are more likely to give complete and reliable results in a diverse land treatment program.

Tomer et al. (2008) conducted a conservation practice inventory for the South Fork of the Iowa River to describe the extent and placement of key agricultural conservation practices in the watershed and evaluate the results in the context of four years of concurrent, detailed water quality data. The researchers used a combination of methods to verify the existence of conservation practices, including:

- Determining cropping rotations using annual classified satellite data made available by the National Agricultural Statistics Service (NASS)

- Creating an inventory of conservation practices installed by NRCS that consisted of four steps:
    1. A search of records of the agency's progress reporting system with contributions from four local NRCS field offices
    2. Interpretation of aerial photos to map visible conservation practices such as terraces and grass waterways
    3. A drive-by survey to provide a snapshot of tillage practices throughout the watershed and confirm data from the progress reporting system and interpretations of air photos where possible
    4. A combined map and survey geographic information system (GIS) data base detailing practices by field (excluding all ownership information)

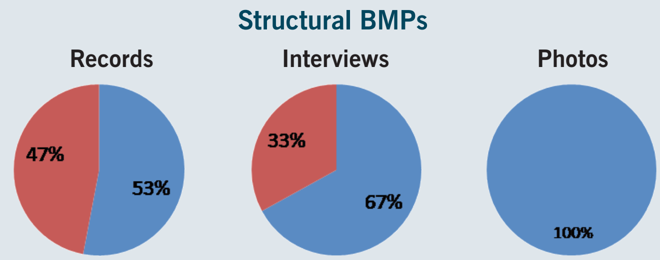
Evaluation of conservation practices in the watershed was conducted by GIS overlay with NRCS Soil Survey Geographic data (e.g., highly erodible land [HEL], hydric soils), stream proximity, and crop rotations and anticipated manure application areas (determined as described above). All this information was placed into a single spreadsheet, which was sorted and filtered to determine areas where resource concerns and conservation practices did and did not overlap. Comparison of resource concerns with the conservation practice inventory showed that although 90 percent of fields with HEL had some erosion control practices installed, less than 10 percent of cropland was managed using no-till and surface residue was inadequate following soybeans.

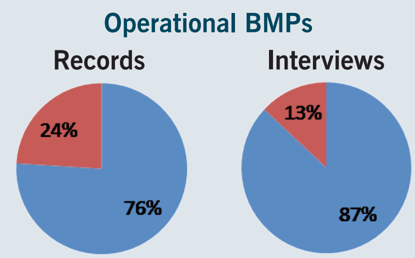
Grady et al. (2013) demonstrated and evaluated three different methods for obtaining geospatial information for BMPs in a mixed-use watershed in central Indiana (see sidebar). The researchers obtained geospatial information for BMPs through government records, producer interviews, and remote sensing aerial photo interpretation. Aerial photos were also used to validate the government records and producer interviews. This study shows the variation in results obtained from the three sources of information as

Locating Best Management Practices by Three Methods

Eagle Creek Watershed, IN
NIFA-CEAP Watershed Project

To assess the effects of BMPs on water quality, researchers needed to identify all BMPs implemented in an agricultural watershed since 1995 under a variety of state and federal programs. Results showed that examination of government records, interviews with producers, and analysis of aerial photography yielded different information and that multiple approaches were required to find all BMPs.





Practices identified by a particular source only.
Practices identified by source and at least one other source.

Grady et al. 2013

well as the benefits and drawbacks of each method. The study found that government records identified the majority of BMPs, but were incomplete and difficult to obtain. Interviews were information-rich, but time-consuming to conduct. Use of photography was an effective means to confirm and supplement records and interviews. Combined data collection techniques provided the clearest picture of conservation practices in the watershed compared to any single approach.

Data Management and Quality Assurance/Quality Control

Data management planning should be an integral part of developing a monitoring plan, with data from land use/treatment tracking fully factored into the plan. Land use/treatment data must be managed and stored to the extent possible with the same considerations given to water quality data. Methods should be documented and each data point given temporal and spatial tags to facilitate integration with water quality data for subsequent analyses.

While water quality monitoring has established quality assurance/quality control procedures, land use/treatment monitoring is a developing field where procedures are still evolving and frequently untested. Some approaches to collecting land use/treatment data will have built-in verification. For example, ground-truthing is used to confirm the accuracy and precision of satellite imagery interpretation. Other approaches are often trusted but seldom verified. Specifically, USDA records of BMP implementation associated with cost-share programs are routinely assumed to be accurate with little or no effort made by those receiving the information (e.g., water quality agency) to confirm that the reports are consistent with BMPs on the ground. Such data are frequently found to fall short of project need because USDA often collects this information for different purposes and information content is usually limited due to confidentiality requirements.

While projects are encouraged to incorporate procedures for land use/treatment tracking within their water quality monitoring QAPP, it is recognized that this not a well-developed process. Several approaches to tracking land use (e.g., satellite imagery, soil testing) are based on rigorous documented science, but BMP tracking usually involves multiple approaches, many of which may not follow widely accepted standard operating procedures or methods. Moreover, data on land use and management are typically obtained from multiple outside sources (e.g., state and federal agencies, universities, and landowners). As such, the collection and application of these data should be guided by a QAPP for secondary data. Information on developing secondary data QAPPs is available from several EPA web sites, including the following:

- *NRMRL QAPP Requirements for Secondary Data Projects* (***USEPA 2008b***)

- *EPA New England Quality Assurance Project Plan Guidance for Environmental Projects Using Only Existing (Secondary) Data* (**USEPA 2009**)
- *Guidance for Evaluating and Documenting the Quality of Existing Scientific and Technical Information* (**USEPA 2012**)

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. Because specific, farm-level information about livestock, crops, farm inputs such as fertilizer and pesticides, and basic farm management is usually only available if disclosed by the individual farmer, watershed projects often have incomplete information or inconsistent levels of detail from farm to farm. Project investigators are often put into the position of having to reduce the level of detail to the least common denominator across farms or of patching together as much information as they can and then determining how to use it later. Confidentiality policies also drive government agencies that collect land use or management data to aggregate their data – even information collected on a site-specific basis – to a geographic scale (e.g., county, HUC-12) that reduces the utility of the data to a watershed project evaluating water quality influenced by specific drainage areas.

There are several effective ways to address the issue of confidentiality. Landowners can share information directly or give permission for agencies to share their information with monitoring personnel. This permission should be sought for all participating landowners if possible. For plot- or field-scale work, obtaining such permission may be easy because only a single cooperating landowner is involved. Obtaining permission from multiple landowners in a large watershed may be more challenging. An agreement on the part of all concerned to "anonymize" site-specific BMP data in reports made public may be necessary (e.g., identification of participants as "Farm A" and "Farm B"). Project staff can collect information themselves, through interviews with producers, or through windshield surveys. In some watershed projects, monitoring agencies have been able to sign a memorandum of understanding (MOU) with implementation agencies to allow sharing of some BMP data under certain circumstances of anonymity or aggregation of quantities and locations within subdrainage areas.

Cost-share vs. Non-cost-share

In many watershed projects, BMP implementation is largely driven by government cost-share programs and BMP tracking understandably focuses on this sector. However, in many cases, especially in large watersheds, landowners may install practices independently, without external funding or design assistance. Because these practices can influence NPS activities as much as "officially" implemented BMPs, it is essential that the existence of purely voluntary practices be tracked as well. Practice performance is another challenge in tracking independent BMPs. When BMPs are installed according to agency standards, a certain level of performance is usually assumed. When BMPs are installed independently, this performance is uncertain and some level of functional equivalence to standard BMPs must be determined.

Examples

Systematic verification of BMP implementation and performance is preferable to simply assuming that all reported practices have been installed and operate as planned. Several studies have illustrated the risk involved in assuming that installed BMPs continue to function effectively.

Bracmort et al. (2004 and 2006) conducted a retrospective examination of structural BMPs implemented in the Black Creek watershed, Indiana, about 20 years earlier. Evaluation of the current condition of the BMPs found that one-third of the practices no longer existed and that the two-thirds that still existed were in fair condition and partially functional. Evaluators based their assessments on visual inspection and comparison to selected original design dimensions. The rating scale ranged from three for a BMP that was fully functional and still met its original design purpose to one for a BMP that no longer performed as designed. Efficacy of BMPs in reducing NPS pollution (evaluated by modeling) varied with their condition. Under good conditions, BMPs reduced average annual sediment and phosphorus yields by 32 percent and 24 percent, respectively. As BMPs deteriorate, their ability to reduce sediment and total P diminishes. Modeling results for BMPs in varying deteriorating conditions revealed that the average annual sediment yield was reduced by only 10 percent, which is nearly 3 times less than the reduction corresponding to BMPs in good condition.

A manure storage BMP that no longer performs a management function.

Jackson-Smith et al. (2010) used intensive field surveys and interviews with program participants to assess the accuracy of using official records as a measure of short- and long-term BMP use in a northern Utah watershed. The researchers reviewed the official NRCS contract files for each of the 90 individuals who participated in the Little Bear River Watershed Project (LBRWP) from 1992 to 2006. They also examined aerial photographs of each participant's land marked with the physical locations of contracted BMPs. Face-to-face interviews were conducted with 55 of the original 90 participants. Following each interview, the original database of LBRWP BMPs was updated to note instances where the participant reported information that conflicted with that obtained from the NRCS files. Overall, this assessment determined that project participants could not verify implementation for 88 (16 percent) of the contracted BMPs. Most of these were instances where all available evidence pointed to a failure to successfully implement the practice, but a handful of cases involved misclassified BMPs where a different type of practice was actually carried out. In almost every case of non-implemented BMPs, respondents simply did not recognize the practice as being part of their original project. In addition, it was determined that over 20 percent of implemented BMPs appeared to be no longer maintained or in use. BMPs related to crop production enterprises and irrigation systems had the lowest rate of continued use and maintenance (74 to 75 percent of implemented BMPs were still in use), followed by pasture and grazing planting and management BMPs (81 percent of implemented BMPs were still in use). By contrast, nearly every instance of fencing and riparian protection structures in the files was found to have been implemented on the study farms. The study findings suggested that official watershed program contracts and related records can be a very useful resource for describing patterns of conservation behaviors at the watershed scale, but that they may not provide a complete and accurate description of BMP adoption and related behaviors instigated by a conservation program. Management practices (e.g., nutrient management) were found to be particularly susceptible to non-implementation and maintenance.

A ***survey*** of local government stormwater managers in North Carolina was conducted in 2007 to report the extent to which local governments were implementing, financing, managing, and enforcing post-construction, engineered, structural stormwater BMPs (Bruce and Barnes 2008). Although many of the survey respondents were still in the early stages of setting up a program, it was commonly acknowledged that a major challenge was making sure BMPs continue to function properly. The survey included a number of specific questions about how BMPs were tracked, inspected, and maintained. For example, responses to a question about structural BMP performance are summarized in Table 4.

A field ***survey*** of nearly two hundred structural stormwater management BMPs was conducted in Virginia's James River basin in 2008 to attempt to isolate critical stormwater BMP design, construction, and maintenance factors of existing stormwater BMPs, and use this information to improve BMP design guidelines (Hirschman et al. 2009). The survey began with data provided by municipalities on BMP type and location, followed by a randomized sample selection, development of a BMP field evaluation form, and field evaluations. Using a relative performance score (1-10 scale) to rate performance, the study found that most BMPs had adequate performance. Wet ponds, dry ponds, infiltration and grass channels received somewhat lower mean scores, and level spreaders received significantly lower scores.

Table 4. Respondents' assessment of performance of structural BMPs (*Bruce and Barnes 2008*).

	Functional		Dysfunctional[1]		Not Sure	
BMP	Count	Percent	Count	Percent	Count	Percent
Stormwater wetlands	27	51	1	2	25	47
Bioretention	31	58	3	6	19	36
Wet detention basin	40	75	2	4	11	21
Dry detention basin	38	72	3	6	12	23
Grass swale	39	74	1	2	13	25
Filter strip	24	45	2	4	27	51
Level spreaders	17	32	13	25	23	43
Infiltration devices	21	40	2	4	30	57
Manufactured or proprietary BMP systems	11	21	9	17	33	62
Permeable pavement	4	8	12	23	37	70
Rooftop runoff management (a.k.a. "green roofs")	3	6	2	4	48	91
Sand filter	13	25	1	2	39	74
Number who answered question	53		53		53	

[1] Dysfunctional BMPs were defined for purposes of the questions as those that do not meet the design criteria in the applicable BMP manual, the design criteria in the approved engineered drawings, or the structural requirements in the approved engineered drawings, due either to chronic insufficient maintenance or to other factors such as poor design, poor construction, storm damage, landscaping alterations, etc. (BMPs that are simply in need of some routine maintenance as set forth by applicable maintenance manuals [e.g., mulching, forebay dredging] should not be included in responses to this set of questions.)

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.

All too often projects have failed to assess accurately the timeframe over which monitoring of water quality and land use/treatment must be carried out to address lag time associated with BMP implementation and resulting changes in water quality. Absent an assessment of pathways and timeframes for pollutant generation and transport to receiving waterbodies, the timing and duration of monitoring efforts needed to document and relate BMP implementation to water quality changes are often based on unverified assumptions or budget constraints. There is no chance of relating water quality changes to land treatment if monitoring does not cover the timeframe over which BMPs are implemented and can be expected to have a measurable impact on water quality at monitoring locations. Further, the selection, design, location, and intensity of land treatment must be sufficient to provide the desired outcome. Coupled with an estimate of minimum detectable change (MDC) in water quality (***Spooner et al. 2011***), an estimate of the timing and degree of pollutant reduction achievable through BMP implementation should provide a strong foundation for designing a successful monitoring effort.

The ability to control for factors other than land treatment (e.g., weather, hydrology, land use change) is a key factor in presenting a plausible case for making the connection between BMPs and water quality change. Control refers to isolating the treatment effect by eliminating or accounting for the influence of other factors that may affect the response to the treatment. Watershed projects try to accomplish such control by employing a ***project design*** (Tech Notes 2) that includes monitoring for important explanatory variables (covariates) and applying appropriate statistical tools to include and adjust for these covariates in the analysis. Properly conducted, a paired or above/below watershed monitoring design can provide good control over non-BMP factors that influence water quality (***Clausen and Spooner 1993***, ***Dressing and Meals 2005***). By factoring explanatory variables into ***trend analyses*** (Tech Notes 6) we remove some of the noise in the data to uncover water quality trends that are closer to those that would have been measured had no changes in climatic or other explanatory variables occurred over time (***Meals et al. 2011***).

Correlation and regression are common statistical tools used to relate land treatment to water quality. This is achieved by documenting significant associations between BMP and water quality variables. Although association by itself is not sufficient to infer causal relationships, it can contribute to a plausible argument that pollution control activities have resulted in environmental improvement, especially if the influence of other factors is accounted for. Data on both the temporal progress and spatial extent of land treatment and other watershed land use/management activities should be used to build an association between land treatment and observed water quality.

For example, land treatment and management data can be analyzed and associated with water quality on a temporal scale in the following ways:

- **Define monitoring periods:** Where monitoring duration is sufficient to address lag time, documentation of BMP implementation can be used to define critical project periods, like pre- and post-treatment periods in before/after and paired-watershed designs, or to establish a hypothesis on the timing of a step trend.

- **Explain observed water quality:** Knowledge of not only BMP implementation history but also dates of tillage, manure or agrichemical applications, construction, street sweeping, logging activities, and other watershed management activities can be extremely useful in explaining observed water quality patterns, especially extreme or unusual values. Such explanation might range from simply noting the occurrence of an event like a manure application as coincident with a spike in P concentration in a stream to using data on manure application events to stratify water quality data for subsequent analysis.
- **Quantify the level of treatment over time:** Quantitative expressions of land treatment can become the independent variable in an analysis of correlation between land management and water quality. One can analyze land treatment data collected in the watershed monitoring program to form such variables as:
    1. Number or percentage of watershed animal units under appropriate animal waste management
    2. Acres or percentage of cropland in cover crops
    3. Acres or percentage of cropland under conservation tillage
    4. Annual manure or fertilizer application rate[1] and extent
    5. Extent and capacity (event or annual depending on monitoring design) of stormwater infiltration practices

Such variables can be tested for correlation with mean total P concentration, annual suspended sediment load, or other annual water quality monitoring variables.

On a spatial scale, land treatment and management data can be used for the following:

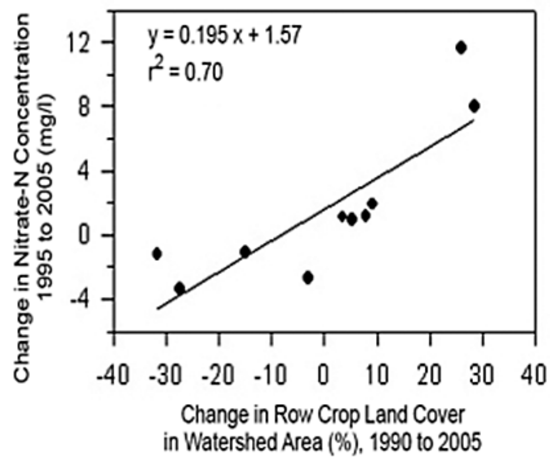
- **Document areas receiving BMPs:** Use knowledge of land treatment locations to:
    - Select appropriate watersheds for analysis in a multiple-watershed design (e.g., identify watersheds where BMPs are present and absent)
    - Confirm conditions in above/below and nested-watershed designs (e.g., document presence or absence of management activities, crops grown, livestock populations in prospective monitored areas)
    - Document the integrity of the control and treatment watersheds in a paired-watershed design (e.g., track continued use of livestock exclusion fencing by landowners in treatment watershed, continued livestock access in control watershed)
- **Relate land treatment to critical source areas:** A comparison of critical pollutant sources to locations that received treatment can assist in understanding

[1] Manure or fertilizer application rate can be tracked in various ways depending on monitoring design, including total or average by crop or net total or average vs. crop needs.

effectiveness of land treatment efforts and establishing expectations for how much of the NPS problem the land treatment program potentially addresses. For example, mapping critical source areas and treatment sites on the same map and conducting a simple GIS overlay analysis can indicate how much of the land treatment effort was applied to critical areas.

Examples of spatial linkage include the Sycamore Creek (MI) NNPSMP project which used multiple linear regression to link TSS load to the percentage of land under no-till cropping (Grabow 1999). Additional explanatory variables included total storm discharge and peak stream discharge.

The Walnut Creek (IA) NNPSMP project used a simple linear regression to show association of two independent monitored variables: stream nitrate concentrations and tracked conversion of row crop land to restored prairie vegetation (Schilling and Spooner 2006). By linking the two monitored variables, the project was able to suggest a clear association between restoring native prairie and reducing stream nitrate levels.



Relating Changes in Stream Nitrate Concentrations to Changes in Row Crop Land Cover in Walnut Creek, Iowa

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.

References

Bishop, P.L., W.D. Hively, J.R. Stedinger, M.R. Rafferty, J.L. Lojpersberger, and J.A. Bloomfield. 2005. Multivariate analysis of paired watershed data to evaluate agricultural best management practice effects on stream water phosphorus. *J. Environ. Qual.* 34:1087-1101.

Bracmort, K., B. Engel, and J. Frankenberger. 2004. Evaluation of structural best management practices 20 years after installation: Black Creek watershed, Indiana. *J. Soil Water Cons.* 59(5): 191-196.

Bracmort, K. S., M. Arabi, J. R. Frankenberger, B. A. Engel, and J. G. Arnold. 2006. Modeling long-term water quality impact of structural BMPs. *Trans. ASABE* 49(2): 367–374.

Bruce, S. and G. Barnes. 2008. ***Survey of local government post-construction BMP maintenance and enforcement in North Carolina: report of findings***. Triangle J Council of Governments, Research Triangle Park, and UNC-Chapel Hill School of Government Campus, Chapel Hill, NC, 28 p. (Accessed 8-22-2014).

Clausen, J.C. 2007. ***Jordan Cove watershed project section 319 final report***. Department of Natural Resources Management and Engineering, College of Agriculture and Natural Resources, University of Connecticut, Storrs, CT, 113 p. (Accessed 8-22-2014).

Clausen, J.C. and J. Spooner. 1993. ***Paired watershed study design***. EPA 841-F-93-009. Prepared for S. Dressing, U.S. Environmental Protection Agency, Office of Water, Washington, DC, 8 p. (Accessed 8-22-2014).

Cooley, E., A. Wunderlin, A. Radatz, D. Frame and K. Klingberg. 2012. ***Heisner family dairy project summary: understanding nutrient & sediment loss at Heisner family dairy***. Discovery Farms, University of Wisconsin – Extension, Madison, WI, 16 p. (Accessed 8-22-2014).

CTIC. 2013. ***Cropland roadside transect survey 2013 - procedures for using the cropland roadside transect survey for obtaining tillage/crop residue data***. Conservation Technology Information Center, West Lafayette, IN, 10 p. (Accessed 8-22-2014).

Dressing, S.A., J.C. Clausen, and J. Spooner. 1992. A tracking index for nonpoint source implementation projects. IN: ***Seminar publication: proceedings of the national Rural Clean Water Program symposium – 10 years of controlling nonpoint source pollution: the RCWP experience***. EPA/625/R-92/006, U. S. Environmental Protection Agency, Cincinnati, OH, pp. 77-87. (Accessed 8-22-2014).

Dressing, S.A. and D.W. Meals. 2005. ***Designing water quality monitoring programs for watershed projects, Tech Notes 2, July 2005***. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 20 p. (Accessed 8-22-2014).

Grabow. G.L. 1999. Untitled, Summary of analyses performed for Sycamore Creek Section 319 NNMP project. Water Quality Group, North Carolina State University, Raleigh, NC.

Grady, C., A. P. Reimer, J. R. Frankenberger, and L. S. Prokopy. 2013. Locating existing best management practices within a watershed: the value of multiple methods. *J. Am. Water Resour. Assoc.* JAWRA-12-0035-P.

Hall, Frederick C. 2002. ***Photo point monitoring handbook***. Gen. Tech. Rep. PNW-GTR-526. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR, 134 p. (Accessed 8-22-2014).

Hirschman, D., L. Woodworth, and S. Drescher. 2009. ***Technical report - stormwater BMPs in Virginia's James River Basin: an assessment of field conditions & programs (part of the*** *Extreme BMP Makeover* ***project)***. Center for Watershed Protection, Inc., Ellicott City, MD, 69 p. (Accessed 8-22-2014).

Hively, W.D., M. Lang, G.W. McCarty, J. Keppler, A. Sadeghi, and L.L. McConnell. 2009. Using satellite remote sensing to estimate winter cover crop nutrient uptake efficiency. *J. Soil Water Cons.* 64(5):303-313.

Humenik, F.J., M.D. Smolen, and S.A. Dressing. 1987. Pollution from nonpoint sources: where we are and where we should go from here. *Environ. Sci. Tech.* 21(8):737-742.

Iowa NRCS. 2004. ***Iowa technical note no. 25 - Iowa Phosphorus Index***. Iowa Natural Resources Conservation Service, Des Moines, IA, 32 p. (Accessed 8-22-2014).

Jackson-Smith, D.B., M. Halling, E. de la Hoz, J.P. McEvoy, and J.S. Horsburgh. 2010. Measuring conservation program best management practice implementation and maintenance at the watershed scale. *J. Soil Water Cons.* 65(6):413-423.

Johnson, D.D., J.M. Kreglow, S.A. Dressing, R.P. Maas, F.A. Koehler, F.J. Humenik, L. Christensen, and W.K. Snyder. 1981. Conceptual framework for assessing agricultural nonpoint source projects. Biological and Agricultural Engineering Department, North Carolina State University, Prepared for J.W. Meek, U.S. Environmental Protection Agency, Washington, DC, 67 p.

Maas, R.P., M.D. Smolen, and S.A. Dressing. 1985. Selecting critical areas for nonpoint-source pollution control. *J. Soil Water Cons.* 40(1):68-71.

Meals, D.W. 2001. Lake Champlain Basin agricultural watersheds section 319 national monitoring program project, final project report: May, 1994-September, 2000. Vermont Dept. of Environmental Conservation, Waterbury, VT, 227 p.

Meals, D.W. and S.A. Dressing. 2008. ***Lag time in water quality response to land treatment***. Tech Notes 4, September 2008. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 16 p. (Accessed 8-22-2014).

Meals, D.W., S.A. Dressing, and T.E. Davenport. 2010. Lag time in water quality response to best management practices. *J. Environ Qual.*39:85–96.

Meals, D.W., J. Spooner, S.A. Dressing, and J.B. Harcum. 2011. ***Statistical analysis for monotonic trends, Tech Notes 6, November 2011***. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 23 p. (Accessed 8-22-2014).

Osmond, D.L., K. Neas, A.M. Johnson, and S.L. Cahill. 2013. Fertilizer use in regulated river basins: is it what we think? *J. Contemporary Water Res.and Educ.* 151:20-26.

Schilling, K.E. and J. Spooner. 2006. Effects of watershed-scale land use change on stream nitrate concentrations. *J. Environ. Qual.* 35:2132-2145.

Spooner, J. S.A. Dressing, and D.W. Meals. 2011. ***Minimum detectable change analysis***. Tech Notes 7, December 2011. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA, 21 p. (Accessed 8-22-2014).

Sullivan, D.G., T.C. Strickland, and M.H. Masters. 2008. Satellite mapping of conservation tillage adoption in the Little River experimental watershed, Georgia. *J. Soil Water Cons.* 63(3):112-119.

Suppnick, J. 1999. Water chemistry trend monitoring in Sycamore Creek and Haines Drain, Ingham County, Michigan 1990-1997. Staff report MI/DEQ/SWQD-99-085, Surface Water Quality Division, Michigan Department of Environmental Quality, 38 p.

Tomer, M.D., T.B. Moorman, D.E. James, G. Hadish, and C.G. Rossi. 2008. Assessment of the Iowa River's South Fork watershed: Part 2. Conservation practices. *J. Soil Water Cons.* 63(6):371-379.

USDA. 2003. *National water quality handbook. 450–VI–NWQH*, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC, 368 p. (Accessed 8-22-2014).

USDA. 2013. *Field office technical guide*. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC (Accessed 8-22-2014).

USEPA. 1990. *Rural Clean Water Program – lessons learned from a voluntary nonpoint source control experiment*. U.S. Environmental Protection Agency, Office of Water, Nonpoint Source Control Branch, Washington, DC, 33 p. (Accessed 8-22-2014).

USEPA. 1997a. *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures - agriculture*, EPA 841-B-97-010, U.S. Environmental Protection Agency, Office of Water, Washington, DC, 92 p. (Accessed 8-22-2014).

USEPA. 1997b. *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures - forestry*, EPA 841-B-97-009, U.S. Environmental Protection Agency, Office of Water, Washington, DC, 95 p. (Accessed 8-22-2014).

USEPA. 2001a. *EPA requirements for quality assurance project plans, EPA QA/R-5*. EPA/240/B-01/003. Reissued May 2006. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, 40 p. (Accessed 8-22-2014).

USEPA. 2001b. *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures - urban*, EPA 841-B-00-007, U.S. Environmental Protection Agency, Office of Water, Washington, DC, 105 p. (Accessed 8-22-2014).

USEPA. 2006a. *Guidance on systematic planning using the data quality objectives process, EPA QA/G-4*. EPA/240/B-06/001. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, 121 p. (Accessed 8-22-2014).

USEPA. 2006b. *Data quality assessment: a reviewer's guide, EPA QA/G-9R.* EPA/240/B-06/002. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC (Accessed 8-22-2014).

USEPA. 2006c. *Data quality assessment: statistical methods for practitioners, EPA QA/G-9S*. EPA/240/B-06/003. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC (Accessed 8-22-2014).

USEPA. 2008a. *Handbook for developing watershed plans to restore and protect our waters.* EPA 841-B-08-002, U.S. Environmental Protection Agency, Office of Water, Washington, DC, 400 p. (Accessed 8-22-2014).

USEPA. 2008b. *NRMRL QAPP requirements for secondary data projects*. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, 2 p. (Accessed 8-22-2014).

USEPA. 2009. ***EPA New England quality assurance project plan guidance for environmental projects using only existing (secondary) data***. U.S. Environmental Protection Agency New England, Quality Assurance Unit Office of Environmental Measurement and Evaluation, Boston, MA, 10 p. (Accessed 8-22-2014).

USEPA. 2012. ***Guidance for evaluating and documenting the quality of existing scientific and technical information***. U.S. Environmental Protection Agency, Science and Technology Policy Council, Washington DC, 9 p. (Accessed 8-22-2014).

USGS. 2012. ***The USGS land cover institute***. U.S. Department of the Interior, U.S. Geological Survey (Accessed 8-22-2104).