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PROJECT SPOTLIGHT

Lag Time in Water Quality Response to Land Treatment

Don Meals and Steve Dressing
TetraTech, Inc.

Introduction

Over the past three decades, numerous watershed land treatment projects have reported little or no improvement in water quality after extensive implementation of best management practices (BMPs) in the watershed. Factors contributing to such failure to achieve water quality objectives are nearly as numerous as the projects themselves – insufficient landowner participation in critical pollutant source areas, uncooperative weather, improper selection of BMPs, mistakes in understanding of pollution sources, poor experimental design, inadequate level of treatment, etc.

Another important reason watershed projects may fail to meet water quality expectations is ***lag time***. Lag time is defined as the amount of time between an action and the response to that action and is usually an inherent characteristic of natural systems. In this case, we define lag time as the time elapsed between installation or adoption of land treatment at a level projected to reduce nonpoint source pollution and the first measurable improvement in water quality in the target water body. Land treatment-water quality monitoring projects – even those designed to be "long-term" – may not show definitive results if the lag time exceeds the monitoring period.

Components of Lag Time

There are planning, time, and measurement components of lag time (Figure 1); any or all of them may come into play in a watershed project.

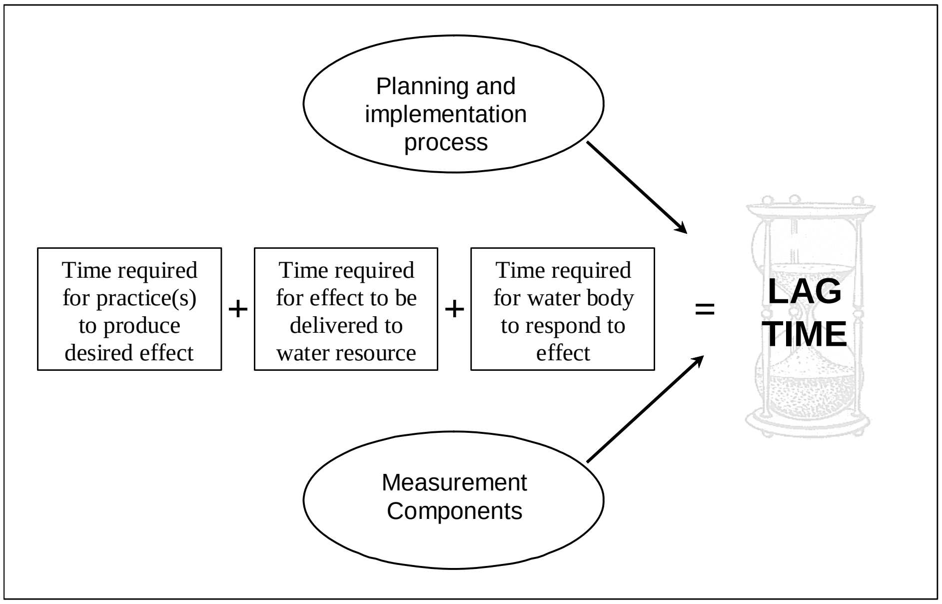

Figure 1. Components of lag time experienced in land treatment – water quality projects.

Planning Components

The time consumed by planning and implementation affects the perceived delay between the decision to act and the result. Although a project may be funded today, it will be some time – perhaps years – before that project will be planned and implementation begins. The lag time from planning to implementation of nonpoint source control practices can be significant, considering the time required to identify pollution sources and critical areas, design management measures, engage landowner participation, and integrate new practices into cropping and land management cycles. While not a true time component of lag time as defined here, stakeholders – especially the general public –will experience the planning and implementation process as part of the wait for results. The planning and implementation process is, however, extremely critical for success in water quality restoration; following a logical and comprehensive watershed planning process (e.g., USEPA 2005) will help make the wait worthwhile.

EDITOR'S NOTE

In this issue of *NWQEP NOTES*, our feature article focuses on a challenge inherent in most nonpoint source pollution control watershed projects – the lag time between implementation of best management practices (BMPs) and achievement of water quality goals. As state funding agencies are under increasing pressure to restore impaired waters and justify federal monies spent, the need for project success remains high. Lag time, which can be on the order of decades, has a direct impact on our ability to measure success through monitoring. Therefore, it's crucial that it be taken into account during project planning, implementation and evaluation. This article discusses the different components and magnitudes of lag time and offers suggestions for dealing with this difficult reality.

As always, please feel free to contact me regarding your ideas, suggestions, and possible contributions to this newsletter.

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Time Components

Time Required for Installed or Adopted Practice to Produce Effect

Land treatment practices are installed in watersheds to provide a wide range of effects, such as reduction in pollutant concentration or load or improvement in aquatic biota. The time required to produce such effects will vary depending upon the degree of impairment and the practices selected, as well as the nature of the effects themselves.

BMP Development. Once built, concrete and steel water and wastewater treatment works may begin to function almost at the flip of a switch, with little delay before pollutant discharge is reduced. Some nonpoint source control measures may also take effect quickly. For example, in the **Lake Champlain Basin Watersheds** (VT) National Nonpoint Source Monitoring Program (NMP) Project (1993 – 2000), implementation of livestock exclusion fencing over three months resulted in significant nutrient concentration and load reductions and reductions of fecal bacteria counts in just the first post-treatment year (Meals 2001). This response probably resulted from the immediate prevention of new manure deposition in the stream and riparian zone and the availability of sufficient streamflow to flush residual manure through the system.

However, other nonpoint source management measures may take years to become fully effective. This is especially true of vegetative practices where plant communities need time to become established. For example, in the **Stroud Preserve**

(PA) NMP Project (1992-2007), it has taken nearly ten years to achieve full establishment of a riparian forest buffer. Significant reductions in ground water nitrate movement through the buffer did not occur until forest growth had achieved a certain level (Szpir et al. 2005).

Source behavior. Lag time between BMP implementation and reduction of pollutant losses at the edge-of-field scale varies by the pollutant type and source. Erosion controls such as cover crops, contour farming, and water/sediment control basins may have a fairly rapid effect on soil loss from a crop field as the forces contributing to detachment and movement of soil particles are quickly and drastically reduced.

However, the response time of runoff phosphorus (P) concentrations to nutrient management practices is likely to be very different. Runoff losses of dissolved P are strongly controlled by soil P levels; very high soil P levels promote high levels of dissolved P in surface runoff. Where soil P levels are excessive, even if nutrient management reduces P inputs to levels below crop removal rates, it may take years or decades to “mine” the excess P out of the soil to the point where dissolved P in runoff is effectively reduced.

Time Required for Effect to be Delivered to Water Resource

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

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

Once in a stream, dissolved pollutants like nitrogen and phosphorus can move rapidly downstream with flowing water to reach a receiving body relatively quickly. Even accounting for repeated uptake and release of nutrients by sediments, plants, or animals during downstream transport (i.e., nutrient spiraling, Newbold et al. 1981), dissolved nutrients are unlikely to be retained in a river or stream system for an extended period of time. Research in Vermont observed, for example, that despite active cycling of dissolved P between water, sediment, and plants in a river system, P inputs to the river were unlikely to be held back from Lake Champlain by internal cycling for much more than a year (Wang et al. 1999).

However, unlike dissolved pollutants, sediment and its attached pollutants (e.g., P and some synthetic chemicals) can take years to move downstream as particles are repeatedly deposited, resuspended, and redeposited within the drainage network by episodic high flow events. This process can delay sediment and P transport from headwaters to outlet by years or even decades. This means that substantial lag time could occur between reductions of sediment and P delivery into the headwaters and those reductions being measured at the watershed outlet.

Pollutants delivered predominantly in ground water such as nitrate N or some synthetic chemicals move at the rate of ground water flow, typically much more slowly than the rate of surface water flow. About 40 percent of all N reaching the Chesapeake Bay travels through ground water before reaching the Bay. Relatively slow ground water transport introduces substantial lag time between reductions of N loading to ground water and reductions in N loads to the Bay (STAC 2005).

Time Required for Water Body to Respond to Effect

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

Nature of the indicator/impairment. Lag time in water quality response may depend on the indicator used or the impairment involved, especially if the focus is on biological water quality. If *E. coli* is the pollutant of concern, a relatively short lag time would often be expected between reductions of bacteria inputs and reduction in bacteria levels in the receiving waters because the bacteria generally do not persist for long in the environment compared to heavy metals or synthetic organic chemicals. The quantity in the receiving water could therefore reflect the incoming supply fairly quickly. Such response has been demonstrated in estuarine systems where bacterial contamination of shellfish beds has been reduced or eliminated through improved waste management on the land over a short period of time.

However, significant lag times have been observed in the response of benthic macroinvertebrates and fish to land treatment. In the Middle Fork Holston River project (VA), Index of Biotic Integrity (IBI, a measure of the stream fish community) scores and *Ephemeroptera-Plecoptera-Trichoptera* (EPT, a measure of the benthic macroinvertebrate community) scores did not improve over the life of the project, even though the project resulted in a substantial reduction in sediment, nitrogen, and phosphorus loadings to the stream (Virginia Dept. Cons. and Rec. 1996). The lack of increase in the biological indicator scores indicates a system lag time between the actual BMP implementation and positive changes in the biological community structure.

Exceptions to such lag in response of stream biota can occur where in-stream aquatic habitat restoration is the BMP applied. The **Waukegan River** (IL) NMP project installed vegetative and structural stabilization and habitat structures, including a series of pool-and-riffle complexes using stone weirs to help restore the habitat functions within a channelized stream reach. Significant improvement in habitat, macroinvertebrate communities, and in the number and abundance of fish species were documented in the study reach within a few years of in-stream treatment.

In the **Lake Champlain Basin Watersheds** (VT) NMP Project (1993 – 2000), the benthic invertebrate community did improve in response to reductions of sediment, nutrient, and organic matter inputs from the land within three years of treatment (Meals 2001). However, despite observed improvement in stream habitat and water temperature, no improvements in the fish community were documented. The project attributed this at least partially to a lag time in community response exceeding the monitoring period.

Receiving water response. Even when reductions of tributary pollutant loads are observed in a short time, the variable response times of receiving water bodies may introduce a significant lag time between treatment and restoration of impaired uses. In some cases, this lag time may be relatively short. For example, researchers anticipate that the Chesapeake Bay will respond fairly rapidly to reductions in nutrient loading, as incoming nutrients are quickly buried by sediment or exported to the atmosphere or the ocean. Even beds of submerged aquatic vegetation (SAV), critical to the Bay's aquatic ecosystem, can return within a few years after improvements in water clarity (STAC 2005). In the **Totten and Eld Inlets** (WA) NMP Project (1993-2002), bacteriological water quality in shellfish beds in the estuaries improved rapidly in response to improved animal waste management in the drainage area, but unfortunately also deteriorated equally rapidly when animal waste management on the land deteriorated (Szpir et al. 2005).

St. Albans Bay (VT) in Lake Champlain tells a different story. From 1980 through 1991, a combination of wastewater treatment upgrades and intensive implementation of dairy waste management BMPs through the Rural Clean Water Program (RCWP) brought about a reduction of phosphorus loads to this eutrophic bay. However, water quality in the bay did not improve significantly, probably due to internal loading from sediments highly enriched in phosphorus from decades of point and nonpoint source inputs (Meals 1992). Although researchers at that time believed that the sediment P would begin to decline over time as the internal supply was depleted, subsequent monitoring has shown that phosphorus levels have not declined over the years as expected. Recent research has confirmed that a substantial reservoir of phosphorus continues to exist in the sediments that can be transferred into the water under certain chemical conditions and nourish algae blooms for many years to come.

Measurement Components

The fundamental time components of lag time control how long it will take for a response to occur, but they do not address the effectiveness of our measurement of the response. It is possible for a response to occur without anybody noticing, unless the response is measurable and a suitable monitoring program is in place. The design of a monitoring program determines our ability to identify a response against the background variability of natural systems.

In the context of lag time, sampling frequency with respect to background variability is a key determinant of how long it will take to document change. In a given system taking n samples per year, a certain statistical power exists to detect a trend. If the number of samples per year is reduced, statistical power is reduced, and it may take longer to document a significant trend or to state with confidence that a concentration has dropped below a water quality standard. Simply stated, taking fewer samples a year can introduce an additional "statistical" lag time before a change can be effectively documented.

Magnitude of Lag Time

The magnitude of lag time is difficult to predict in specific cases but a few examples can illustrate some possible time frames for several different types of lag time.

The **Stroud Preserve (PA)** NMP Project (1992-2007) is currently evaluating the development and performance of a newly established riparian forest buffer (Szpir et al. 2005). Reforestation of the riparian area took about eight to twelve years (Figure 2), considerably longer than anticipated due to drought and deer damage. Preliminary analysis of ground water nitrate data indicate that, except for initial reductions due to taking the buffer area out of agriculture, significant nitrate removal from ground water flowing toward the stream did not occur until a major increase in tree growth began about ten occur until a major increase in tree growth began about ten years after planting. The results of the project so far suggest that water quality improvement from riparian reforestation may take on the order of a decade or more to be measurable.

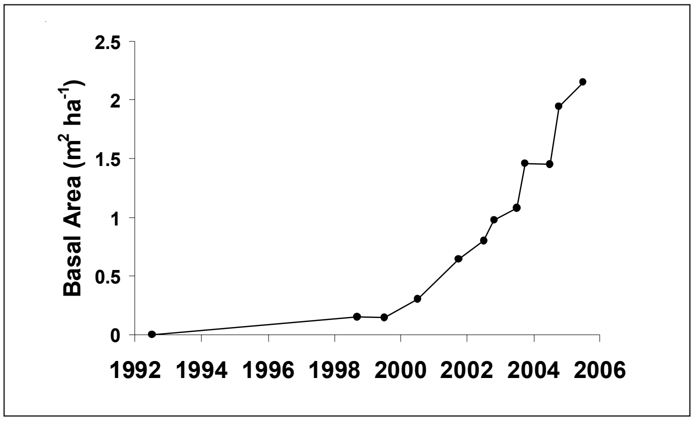

Figure 2. Changes in basal area of trees in reforested riparian buffer, Stroud Preserve National Monitoring Program Project. (Newbold 2005).

The rate of ground water movement and pollutant transport can be a major contributor to lag time in water quality response to treatment. For example:

- In the **Pequea and Mill Creek Watershed** (PA) NMP Project (1994-2003), changes in fertilizer applications to cropland did not result in changes in nitrogen concentrations in streams over the four years following land treatment due to lag time between applications and nutrients reaching stream channel. Ground water age dating conducted during the study indicated that nitrogen applied to land reached springs in two to three years, but ground water flow to the stream channel took 15 to 39 years (Galeone 2005).
- Recent research in the **Chesapeake Bay Watershed** has confirmed that a substantial lag time between implementation of management practices and reductions in nitrogen loading to the Bay is very likely (STAC 2005). Ground water supplies a significant amount of water and nitrogen to streams in the watershed, providing about half of the nitrogen load to the Bay. The age of ground water in shallow aquifers in the Chesapeake Bay watershed ranges from less than 1 year to more than 50 years. The median age of all samples was 10 years, with 25 percent of the samples having an age of 7 years or less and 75 percent of the samples having an age of up to 13 years. Based on this age as representative of time of travel, scientists estimated that in a scenario of complete elimination of nitrogen applications in the watershed, a 50 percent reduction in base flow nitrate concentrations would take about five years, with equilibrium reached in about 2040.

Modeling can provide some insight into lag time. Drawing from the experience of the Rural Clean Water Program (RCWP), Clausen et al. (1992) used a simple dynamic mass-balance model to evaluate lag time in water quality response to nutrient management applied to agricultural land. The model predicted that even following complete elimination of fertilizer P inputs to a field starting at an excessive soil P level, 32 years would be required to reach 50 percent of the new equilibrium P concentration in runoff, and over 100 years would be needed to reach 90 percent of the new equilibrium. At a lower initial soil P level, the same reduction of P inputs would take 11 years to reach 50 percent of equilibrium, and 18 years to reach 90 percent of equilibrium.

A recent, more sophisticated P mass balance model of silage corn production in Vermont (Meals et al. 2006) shows a similar picture. The model accounts for all inputs and outputs of P, as well as the dynamics of soluble and particulate P runoff and leaching. As shown in Figure 3, restriction of P inputs in manure and fertilizer to below crop removal rate beginning in year 10 results in a downward trend in soil test P. However, 25 years elapse before soil test P declines below the “high” level (in year 35) and soil test P does not decline below “optimum” levels until 40 years have elapsed.

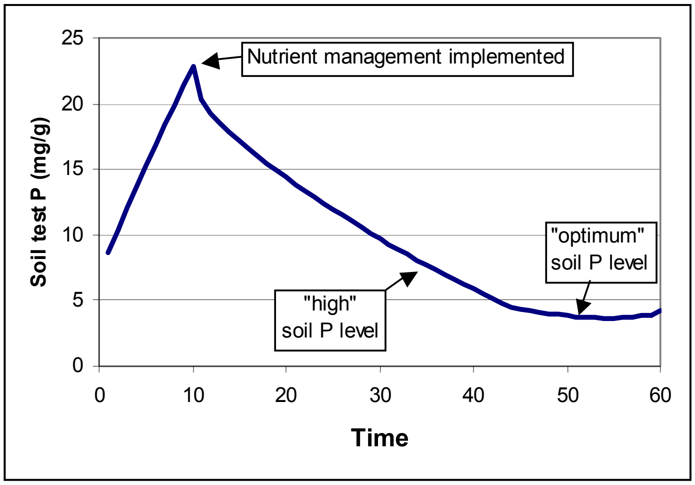

Figure 3. Simulated changes in soil test P in response to nutrient management on silage corn.

Dealing with Lag Time

In most situations, some lag time between land treatment and water quality response is inevitable. Although it is nearly impossible to predict the exact duration of the lag, in many cases the lag time will probably exceed the length of the post-treatment monitoring period, making it problematic to document a water quality response to treatment. Here are a few suggested approaches to deal with this unfortunate fact of life.

- **Recognize lag time and adjust expectations.** Once a water quality problem is recognized and action is taken, the public and political system usually expect quick results. Failure to meet such expectations may cause frustration, pessimism, and a reluctance to pursue further action. It is up to scientists, investigators, and project managers to recognize that some lag time between treatment and response is likely and to explain the issue to all stakeholders in realistic terms. It usually takes time for a water body to become impaired and it will take time to accomplish the clean-up.

- **Characterize the watershed.** Before designing a land treatment program and an associated monitoring program, important watershed characteristics likely to influence lag time should be investigated. Determining the time of travel for ground water movement is an obvious example. Watershed characterization is an important step in the project planning process (USEPA 2005) and should address important aspects of the hydrologic and geologic setting, nonpoint source pollution sources, and the nature of the water quality impairment, all of which can influence observed lag time in system response.

- **Consider lag time in selection and siting of BMPs.** Recognition of lag time may require an adjustment of the approach to targeting land treatment. When designing a land treatment program, potential BMPs should be evaluated to determine which practices might provide the most rapid improvement in water quality, given watershed characteristics. For example, practices affecting direct delivery of nutrients into surface runoff and streamflow, such as barnyard runoff management, may yield more rapid reductions in nutrient loading to the receiving water than practices that reduce nutrient leaching to ground water, when ground water time of travel is measured in years. Fencing livestock out of streams may give immediate water quality improvement, compared to waiting for riparian forest buffers to grow in. Such considerations, combined with application of other criteria such as cost effectiveness, can help determine priorities for land treatment programs in a watershed project.

  Lag time should also be considered in locating treatment within a watershed. Where sediment and sediment-bound pollutants from cropland erosion are primary concerns, for example, implementing practices that target the largest sediment sources closest to the receiving water may provide a more rapid water quality benefit than widely dispersed erosion controls in the upper reaches of the watershed.

  It is important to point out that factoring lag time into BMP selection and targeting is not to say that long-term management improvements like riparian forest buffer restoration should be discarded or that upland sediment sources should be ignored. Rather, it is suggested that planners and managers may want to consider implementing BMPs and treating sources likely to exhibit short lag times first to increase the probability of demonstrating some water quality improvement as quickly as possible. Rapid short-term improvements in water quality can increase support for practices implemented in locations that can ultimately yield permanent reductions in soil loss.

- **Monitor small watersheds close to sources.** Where documentation of the effects of a treatment program on water quality is a critical goal, lag time can sometimes be minimized by focusing monitoring on small watersheds, close to pollution sources. Lag times introduced by transport phenomena (e.g., ground water travel, sediment flux through stream networks) will likely be shorter in small watersheds than in larger basins. In the NMP, projects monitoring land treatment in small watersheds (e.g., the Morro Bay Watershed Project in California, the Jordan Cove Project in Connecticut, the Long Creek project in North Carolina, the Pequea/Mill Creek Watershed Project in Pennsylvania, and the Lake Champlain Basin Watersheds Project in Vermont) were more successful in documenting improvements in water quality in response to land treatment in the watershed than projects that took place in large watersheds (e.g., the Lightwood Knot Creek Project in Alabama and the Sny Magill Watershed Project in Iowa) in the seven to ten year time frame of the projects (Szpir et al. 2005).

  In larger watersheds, monitoring indicators at points along the pathway from source to response or conducting periodic synoptic surveys over the course of a project can identify changes as they occur and document progress toward the end response. Special studies of sediment transport, soil P levels, ground water dynamics, or receiving water behavior can shed light on phenomena that affect lag time in water quality response. For example, the **Long Creek Watershed** (NC) NMP Project (1993-2002) conducted special studies of the effects of a wetland on PAH concentrations in an urban stream, the use of microbial indicators to assess land use impacts, and interactions between P and stream sediments to better explain the temporal and spatial water quality response to land treatment (Line and Jennings 2002).

- **Select indicators carefully.** Some water quality variables can be expected to change more quickly than others in response to land treatment. As documented in the **Jordan Cove** (CT) NMP Project (1996-2005), peak storm flows from a developing watershed can be reduced quickly through application of stormwater infiltration practices (Clausen 2004). NMP projects in CA, NC, PA, and VT (Szpir et al. 2005) demonstrated rapid reductions in nutrients and bacteria by reducing direct deposition of livestock waste in surface waters through fencing livestock out of streams. However, improvements in stream biota appear to come much more slowly, beyond the time frame of many monitoring efforts. Where restoration of biological integrity is a goal, this may argue for a more sustained monitoring effort to document a biological response to

Continued on p. 9

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- Understanding the Role of Agricultural Landscape Feature Function and Position in Achieving Environmental Endpoints: Final Project Report (to the U.S. Environmental Protection Agency) (1996) (118p) (*abstract and instructions for downloading the report available at: ftp://ftp.epa.gov/epa_ceam/wwwhtml/software.htm*

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land treatment. Failing that, however, selection of indicators that have relatively short lag times where possible will make it easier (and quicker) to demonstrate success.

- **Design monitoring programs to detect change effectively.** Monitor at locations and at a frequency sufficient to detect change with reasonable sensitivity. As soon as background variability is assessed (ideally before the project begins), conduct a minimum detectable change analysis (Spooner et al. 1987, Richards and Grabow 2003) to determine a sampling frequency sufficient to document the anticipated magnitude of change with statistical confidence. If the monitoring program is intended to detect trends, evaluate statistical power to determine the best sampling frequency for the project. Ideally, a paired watershed design can be utilized where two watersheds are monitored prior to and after one of the watersheds receives treatment and the other remains the control.

Conclusions

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

For more information, contact Don Meals at **dmeals@burlingtontelecom.net**.

References

Clausen, J.C., D.W. Meals, and E.A. Cassell. 1992. Estimation of lag time for water quality response to BMPs. Pages 173-180 *in* The National Rural Clean Water Program Symposium, September, 1992, Orlando, FL, US EPA ORD, EPA/625/R-92/006.

Clausen, J.C. 2004. Jordan Cover Urban Watershed Section 319 National Monitoring Program Project. Annual Report. College of Agriculture and Natural Resources, University of Connecticut, Storrs, CT.

Galeone, D.G. 2005. Pequea and Mill Creek Watersheds Section 319 NMP Project: Effects of Streambank Fencing on Surface-water Quality. *NWQEP Notes* 118: August, 2005. NC State University, Raleigh, NC.

Line, D.E. and G.D. Jennings. 2002. Long Creek Watershed Nonpoint Source Water Quality Monitoring Project – Final Report. NC State University, Raleigh, NC.

Meals, D.W. 1992. Water quality trends in the St. Albans Bay, Vermont watershed following RCWP land treatment. pp 47-58 *in* The National Rural Clean Water Program Symposium, September, 1992, Orlando, FL, US EPA ORD, EPA/625/R-92/006.

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., D. Hughell, L. Wood, E.A. Cassll, W.E. Jokela, and R. Parsons. *2006.* Interactive Spatially Dynamic Framework for Sustainable Watershed Phosphorus Management. Final Project Report. CSREES Project VT-AE-037CG. University of Vermont and Associates in Rural Development, Inc. Burlington, VT.

Newbold, J.D., J.W. Elwood, R.V. O'Neil, and W.Van Winkle. 1981. Measuring nutrient spiralling in streams. *Can. J. Fish. Aquat. Sci*. 38:860-863.

Newbold, J.D. 2005. Personal communication. Stroud Water Research Center, Avondale, PA.

Richards, R.P. and G. L. Grabow. 2003. Detecting reductions in sediment loads associated with Ohio's Conservation Reserve Enhancement Program. *J. American Water Resour. Assoc.* 39(5):1261-1268.

Scientific and Technical Advisory Committee (STAC) Chesapeake Research Consortium. 2005. Understanding "Lag Times" Affecting the Improvement of Water Quality in the Chesapeake Bay. STAC Publication 05-001.

Edgewater, MD**.** http://www.chesapeake.org/stac/Pubs/LagTimeReport.pdf

Spooner, J., C. J. Jamieson, R. P. Maas, and M. D. Smolen. 1987. Determining Statistically Significant Changes in Water Quality Pollutant Concentrations. *Lake Reserv. Manage*.3:195-201.

Szpir, L.A., G.L. Grabow, D.E. Line, J. Spooner, and D.L. Osmond. 2005. 2005 Summary Report: Section 319 National Monitoring Program Projects. *National Nonpoint Source Watershed Project Studies, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC.*

USEPA. 2005. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-05-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Virginia Department of Conservation and Recreation. 1996. *Alternative Watering Systems for Livestock - The Middle Fork Holston River Builds on Success.* http://www.epa.gov/owow/NPS/Section319II/VA.html.

Wang, D., S.N. Levine, D.W. Meals, J.P. Hoffmann, J.C. Drake, and E.A. Cassell. 1999. Importance of in-stream nutrient storage to phosphorus export from a rural, eutrophic river in Vermont, USA. In *Lake Champlain in Transition: From Research Toward Restoration*, eds. T.O. Manley and P.L. Manley, pp. 205–223. *Water Science and Application*, Vol. 1, American Geophysical Union, Washington, D.C.

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INFORMATION

319 NPS Success Stories

EPA has added 8 new stories to the Section 319 Nonpoint Source Success Stories Web site. The Web site features projects receiving grant funds from the Clean Water Act section 319 Nonpoint Source Program that have achieved documented water quality improvements, including the achievement of water quality standards and removal from state section 303(d) lists of impaired waters. The Web site now features 8 additional new stories from Alabama, American Samoa, Connecticut, Nevada, New Hampshire, North Carolina, Texas, and Vermont. The Web site was launched in August 2005, and now features a total of 32 success stories representing 23 different States, Territories, and Tribes. Visit the Web site at: **http://www.epa.gov/nps/success**.

New Water Quality Trading Guide Available From CTIC

CTIC, under a cooperative agreement with the U.S. Environmental Protection Agency, has developed a new guide, *Getting Paid for Stewardship: An Agricultural Community Water Quality Trading Guide*, to help agricultural advisors understand why agricultural producers may want to participate in water quality trading and how water quality trading works. This free guide is available for download at: **http://www.conservationinformation.org/?action=learningcenter_publications_waterqualitytrading.**

New EPA Draft Document: National Management Measures to Control Nonpoint Source Pollution

EPA announces the availability of a new draft guidance document: *National Management Measures to Control Nonpoint Source Pollution from Hydromodification.* This technical guidance and reference document is appropriate for use by state, territory, and tribal managers, as well as the public, in the implementation of nonpoint source (NPS) pollution management programs in streams, lakes, estuaries, aquifers, and other waterbodies affected by hydromodification. At this time, EPA is requesting public comments on the draft document (See Federal Register Notice at **http://www.epa.gov/fedrgstr/EPA-WATER/2006/July/Day-17/w11248.htm**).

The draft guidance enhances and updates the technical information contained in EPA's 1993 Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, published under section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). Whereas the 1993 guidance was regulatory, this document does not set new or additional standards for either CZARA section 6217 or Clean Water Act section 319 programs.

The draft guidance contains information on management measures and corresponding practices that EPA considers effective for managing hydromodification and reducing nonpoint source pollution of surface and ground water. The document discusses the broad concepts of assessing and addressing water quality problems on a watershed level, and presents recent technical information about how certain types of NPS pollution can be reduced effectively. Because it is national in scope, the guidance does not address all practices or techniques specific to local or regional soils or climates. Implementation of the guidance will result in increased use of scientifically sound, cost-effective hydromodification management measures, and will support states in their efforts to implement their Nonpoint Source Control Programs.

Comments should be sent to Chris Solloway, Assessment and Watershed Protection Division (4503T), U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460. Non-US Postal Service comments should be sent to Chris Solloway, Assessment and Watershed Protection Division, U.S. Environmental Protection Agency, EPA West, Room 7330 N, 1301 Constitution Avenue, NW, Washington, DC 20004. Faxes should be sent to (202) 566-1437. Comments may also be sent via email to **Solloway.chris@epa.gov**.

You can get more information about the guidance or download the document (in PDF format) at **http://www.epa.gov/owow/nps/hydromod/index.htm**. Copies of the complete draft can also be obtained by request from Chris Solloway at the above address, by e-mail at **Solloway.Chris@epa.gov**, or by calling (202) 566-1202.

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MEETINGS

Call for Abstracts

USDA-CSREES National Water Conference: Research, Extension and Education for Water Quality and Quantity: Jan 28-Feb 1, 2007, Savannah, GA.

Visit website: **http://www.soil.ncsu.edu/swetc/waterconf/2007/home07.htm**. Abstract proposals for oral and poster presentations will be accepted through September 15, 2006. Concurrent sessions will feature over 100 oral presentations in the following areas:

- Agricultural Best Management Practices
- Rural Environmental Protection
- Conservation and Resource Management
- Watershed Assessment & Restoration
- Human Dimensions

In addition, space is available for 150 posters and exhibits to highlight results on research, education, and extension programs addressing water quality and quantity issues locally, regionally, and nationally.

2nd National Low Impact Development Conference: March 12-14, 2007, Wilmington, NC. Abstracts for oral and poster presentations are due September 15, 2006. Presentation Subject Areas:

- Impediments and Public Acceptance
- Design and Construction
- Operations and Maintenance
- Monitoring and Modeling
- Water Quality and Environmental Benefits
- Case Studies
- LID Education

Visit the Conference Website at: **http://www.soil.ncsu.edu/swetc/lid/home.htm.**

2nd National Conference on Ecosystem Restoration (NCER): April 22-27, 2007, Kansas City, Missouri. Abstracts due October 15, 2006. Visit website for more information: **http://conference.ifas.ufl.edu/NCER2007**

Meeting Announcements — 2006

September

14th National Nonpoint Source Monitoring Workshop: Sept 24-28, Minneapolis, MN. See announcement at right.

October

Stream Restoration in the Southeast: Accomplishments and Opportunities: Oct 2-5, Charlotte, NC. See website: http://www.ncsu.edu/sri/2006conference/abstracts.html

November

Research Symposium: Pathogens: Pathways and Monitoring in Natural and Engineered Systems: Nov 2, Blacksburg, VA. Contact Dr. Tamim Younos at email: tyounos@vt.edu.

AWRA 2006 Annual Water Resources Conference: Nov 6-9, Baltimore, MD. See website: **http://www.awra.org/meetings/Baltimore2006/topics.html**

Innovations in Reducing Nonpoint Source Pollution: Nov 28-30, Indianapolis, IN. A conference organized by the Rivers Institute at Hanover College in collaboration with The Nature Conservancy and USCID. Visit website for more information at http://www.riversinstitute.org/.

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14th National Nonpoint Source Monitoring Workshop

Measuring Project and Program Effectiveness
September 24-28, 2006
Minneapolis, Minnesota
Courtyard Marriott at the Depot

About the Conference: The 14th year of this workshop will once again bring together land managers and water quality specialists to share information on the effectiveness of BMPs in improving water quality, effective monitoring techniques, and statistical analysis of watershed data. The workshop will focus on the successes of Section 319 National Monitoring Program projects and other innovative projects from throughout the U.S. Topics include: detecting change in water quality from agricultural or urban BMP implementation; modeling applications for NPS pollution control; integrating social indicators and environmental monitoring; innovative management and monitoring in agricultural and urban landscapes; nonpoint source TMDLs; monitoring impacts from agricultural drainage management; riparian area and stream protection/restoration; and programs for animal operations and nutrient management. **http://www.ctic.purdue.edu/NPSWorkshop/NPSWorkshop.html**

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