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PROJECT SPOTLIGHT

Water Quality Functions of a 15-year-old Riparian Forest Buffer System

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Introduction

Riparian forest buffers have become well-established as a management practice that can reduce the surface and subsurface transport of agrichemicals to streams when used as a component of an integrated farm management system (Dwire and Lowrance 2006). Nonetheless, it remains difficult to quantify the nutrient and sediment load reductions that can be expected from riparian reforestation. This difficulty reflects, in part, a discord between the very high nutrient and sediment removal rates that many studies have demonstrated (e.g., Lowrance et al. 1997, Mayer et al. 2007) and the cautions that these potentials are not always achieved (e.g., Vidon and Hill 2004). While such cautions do not lessen the advisability of riparian reforestation to enhance stream habitat and stream ecosystem services (Sweeney et al. 2004, Jones et al. 2006, Sweeney and Blaine 2007), they do point out the need for better estimates of buffer function. Among the large number of studies that have been conducted, examinations of the temporal response

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EDITOR'S NOTE

In this issue of *NWQEP NOTES*, we continue our series on National Nonpoint Source Monitoring Program (NMP) projects that have been completed and have documented improvements in water quality due to the implementation of best management practices (BMPs).

Riparian buffers are BMPs that are widely acknowledged for reducing the transport of agricultural pollutants from the field to surface and subsurface waters. Despite numerous studies, questions remain regarding buffer function, including specific pollutant removal rates and, to a greater extent, the temporal response of reforestation of agricultural land. A study at the Stroud Preserve in southeastern Pennsylvania examined these questions through the establishment and reforestation of a riparian buffer system in an agricultural field. The buffer, designed by the USDA Forest Service, consisted of three zones – two in forest and one a grass filter strip with level spreader – totaling 35m wide. The effectiveness of the buffer in removing nutrients and sediment from overland, subsurface and stream flow was evaluated over a 15-year period. A paired watershed design was employed together with tree growth monitoring and mass balance analysis of nutrient and sediment removal.

Results indicated that the buffer system was effective in reducing subsurface nitrate by an estimated 62 kg/yr, representing 26% of upslope inputs. The buffer was also effective in reducing suspended sediments in overland flow from the cultivated field on average by 43%, with a 32% reduction through the action of the grass strip and level spreader alone. Total phosphorus in stream flow was not reduced by the buffer. The authors note the influence of tree growth on nitrate removal, where declines were only observed 10 years after planting, following a period of rapid tree growth.

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

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to riparian forestation of agricultural land, particularly at the whole watershed level, are rare. Such studies are needed not only to quantify the time required to achieve buffer function but also to control for the potential bias of comparing existing mature forest buffers with existing non-buffered agricultural riparian zones, as it is often lands less suitable for tillage that are left in forest.

This study used a paired watershed approach and mass balance analysis to quantify nutrient and sediment removal by a 3-zone riparian forest buffer system (RFBS, Welsch 1991) established in 1992 on an agricultural headwater stream in the Pennsylvania Piedmont. Originally funded by the USDA Forest Service, the Pennsylvania Department of Forestry, and the U.S. EPA Chesapeake Bay Program, the project became a U.S. EPA 319 National Nonpoint Source Monitoring Program project in 1997, supported by the Pennsylvania Department of Environmental Protection. Support was also provided by the Stroud Endowment for Environmental Research.

Study Site

The study was conducted on three small watersheds located in the Piedmont province of southeastern Pennsylvania (Figure 1) in the Brandywine River drainage. Field slopes range from 5% to 10%. Soils are mainly typic hapludults, but those in the riparian areas are aquic fragiudults. A weathered rock or saprolite extends to a typical depth of 5-7 m with bedrock consisting mainly of fractured schist.

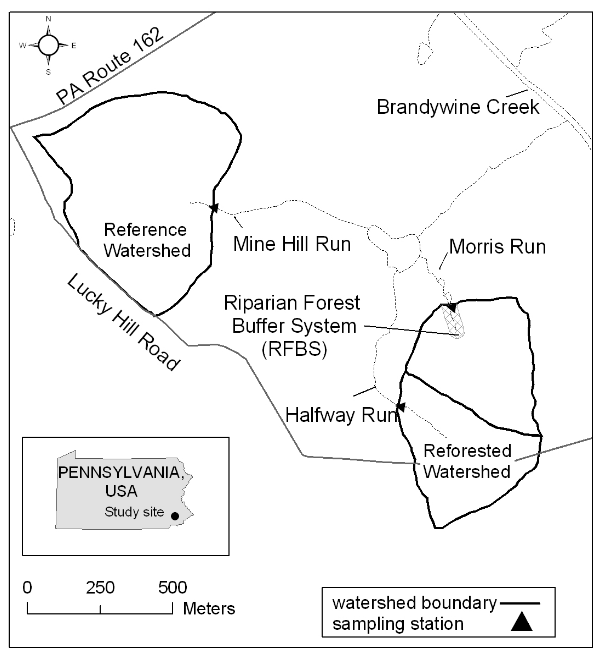

Figure 1. Location map for project watersheds on the Stroud Preserve.

The buffer system was established on one watershed ("treatment"), while a second watershed remained unaltered ("reference"). In the third watershed, all of the tilled land was reforested. This watershed served as a "positive control," providing a maximum rate and extent of water quality improvement that could be achieved. The 16.2-ha treatment Morris Run watershed is drained by a perennial first-order stream. All but a few hectares of the treatment watershed are maintained in strips (primarily corn and soybeans) under contoured crop rotation. In April, 1992, a Riparian Forest Buffer System (RFBS) surrounding Morris Run was established in accordance with the specification published by the USDA Forest Service (Welsch 1991). The RFBS (Figure 2) consists of: Zone 1, a 5-m wide streamside strip of permanent woody vegetation for stream habitat protection; Zone 2, an 18-20 m strip, upslope of Zone 1, reforested in hardwoods; and Zone 3, a 6-10 m grass filter strip with a level-lip spreader between Zone 2 and the cultivated field. The reforestation of Zone 2, initiated in 1992, consisted of a mix of sugar maple, red oak, tulip poplar, white ash, black walnut, and trembling aspen planted as 1-year seedlings at approximately 3-m spacing and protected by plastic (1.3-m) tree shelters. Prior to the planting, the buffer area consisted of mowed grass, some tilled area, and a narrow riparian strip (3-10 m) of hardwood trees and brush. In accordance with this specification, the grassland zone (Zone 3) was contoured in May 1994 to form a level-lip spreader, designed by the USDA Natural Resources Conservation Service (NRCS). The purpose of the spreader is to intercept surface runoff, which is delivered to the buffer via grassed waterways, and to release the runoff to the forested buffer as dispersed sheet flow in order to minimize concentrated flow and erosion within the forested portion of the buffer (Welsch 1991). The spreader was constructed by establishing a 3-m wide grassed area (the "level-lip") running 130 m along the original field contour, with minimal re-grading. A swale was excavated along the upstream side of the level-lip (Figure 2).

The reference Mine Hill Run watershed is 36.1 ha in area, and is drained by a perennial first-order stream. Most of the watershed is planted in alfalfa, corn, and soybeans, also under NRCS conservation tillage. A sparsely forested, brushy zone extends 50-200 m from the stream. Land use in this watershed was maintained without alteration during the study.

The reforested positive control watershed (15.1 ha) is drained by Half Way Run, which is surrounded by a mature forest extending at least 30 m from the stream. In the spring of 1991, all of the area within the Half Way Run watershed that had been in crop production (26% of the watershed area) was planted with mixed hardwood seedlings. Twenty-four per cent of the watershed, occupying its highest elevations, remained unforested, primarily in pasture.

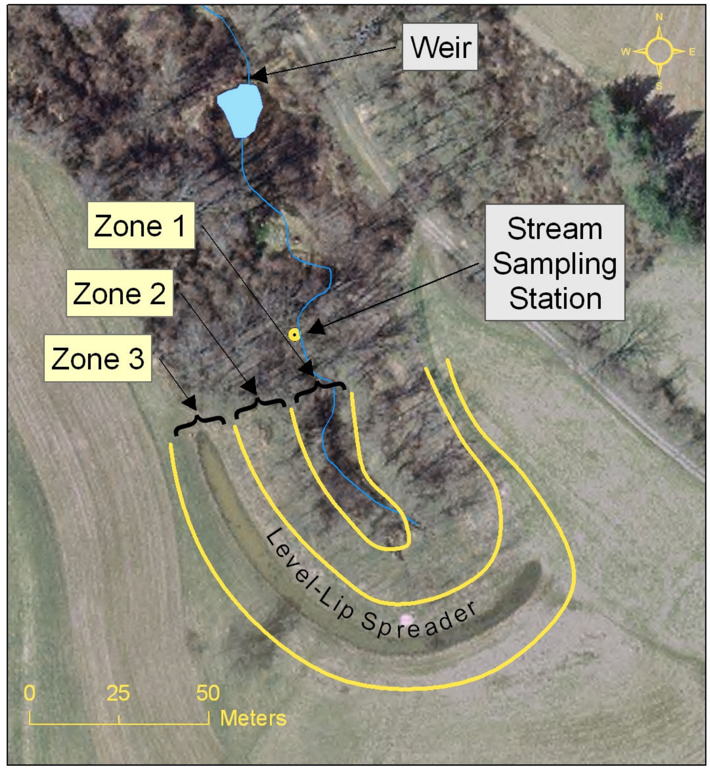

Figure 2. Morris Run (treatment) stream and the riparian forest buffer system with a level-lip spreader in April 2005.

Methods

The water quality monitoring program was based on a paired watershed design. Although the riparian forest buffer was established in the first year of monitoring (1992), the next several years, while the seedlings became established and basal area and canopy cover remained negligible, served as the calibration period. Regularly scheduled (1-3 week) stream water samples were taken in all three watersheds (treatment or RFBS; reference; and reforested) between 1992 and 2007. As a supplement to the paired watershed design, additional sampling was conducted (only in the treatment watershed) to estimate nutrient and sediment retention within the riparian buffer by mass balance. This was accomplished through quarterly sampling of an array of groundwater monitoring wells between 1992 and 2007, and through sampling of storm-generated overland flow from overland flow collectors from 1997 through 2001 and again from 2005 to early 2007.

Water Quality Monitoring. At the treatment Morris Run RFBS site, ten overland flow collectors were positioned at the upslope boundary of the reforested buffer zone (Zone 2), and ten more were positioned downslope from the reforested zone, near the stream. These collectors were modifications of the Low Impact Flow Event sampler described by Sheridan et al. (1996). Overland flow entered Zone 3 via two grassed waterways, each with two collectors. Overland flow entered Zone 2 only after filling the swale in the grass buffer that borders the level-lip spreader. Once the swale filled, water flowed over the level-lip spreader into Zone 2. Storms were included in the statistical analysis if there were analyzable samples in at least two collectors (out of 10) both upslope of the reforestation ("Above Zone 2") and downslope of the reforestation ("Below Zone 2"). The collectors in the waterways ("Above Zone 3") normally filled even in small events. Storm-generated overland flow was collected from the overland flow collectors after 14 storms from 1998 through 2001 and eight storms from 2001 through early 2007.

Nineteen groundwater sampling wells (5-8 m deep, screened in the lower 0.5-3 m) were installed in the RFBS watershed along transects extending radially upslope from the stream. The depth of the wells was established by auger refusal at the interface of saprolite underlain by fractured crystalline bedrock. Seven wells were located at or near the interface of Zones 1 and 2, six at the Zone 2 to Zone 3 interface, and six in the cultivated field. The wells in the field were placed around 70 m upslope from Zone 3 (Figure 3).

Streamflow from each of the three watersheds was gaged through 90° V-notch weirs, installed in 1993 (Morris Run) and 1997 (Mine Hill Run and Half Way Run). Streamflow was calculated (Grant 1989) from the water level in the stilling pond of the respective weir, which was monitored by either float-wheel or pressure transducer and logged every 15 minutes.

Stream water was sampled manually from each stream just upstream from the weir at 1-to-3-week intervals from 1992 to 1997 and at 2-week intervals from 1997 through March 2007 for nitrogen and phosphorus. Storm-generated overland flow was sampled in the overland flow collectors as it flowed into and through the buffer in the treatment watershed. Samples were analyzed for suspended sediment, nitrogen, and phosphorus. Groundwater was sampled quarterly from each of the monitoring wells for nitrogen and phosphorus from 1992 through March 2007. This article does not include additional data analyses for this project, including stormwater exports of nitrogen, phosphorus, and sediment, but these data will be included in the final report to be published early in 2009.

Nitrate (including nitrite) was determined after membrane (0.24 μm) filtration by cadmium reduction (method 353.2, U.S. EPA 1993). Ammonia-N was determined by the colorimetric automated phenate method (method 350.1, U.S. EPA 1993). Total phosphorus was determined on unfiltered samples by the ascorbic acid method (method 365.1, U.S. EPA 1993) after digestion by ammonium persulfate (method 365.1, U.S. EPA 1993). Total dissolved phosphorus was determined as total phosphorus in membrane-filtered samples. Total suspended solids in overland flow was determined by filtering an aliquot of sample onto a pre-weighed glass-fiber filter (0.7 μm nominal pore size), drying at 105° C for 24 h and reweighing the filter.

Tree Growth Monitoring. To monitor forest growth in Zone 2 of the RFBS, each tree location was inventoried for breast-height diameter once or twice annually from 1998 through 2006. Basal area was calculated from breast-height diameter. Canopy cover in the RFBS Zone 2 was estimated annually in late summer from 2002 through 2006. Each grid point of a 3 x 3-m grid within the RFBS was scored as either lying directly below tree canopy or below open sky.

Data Analysis. Analysis of variance (ANOVA) in conjunction with Tukey's least significant difference was used to test for year-to-year variations in nitrate and phosphorus concentrations in stream water and groundwater at each monitoring station, and for within-year spatial variations along the field-to-stream well transects in the treatment watershed. For the paired watershed comparisons, the differences between contemporaneous paired samples were analyzed by one-way ANOVA and Tukey's test. Sediment and nutrients transported in overland flow were analyzed by log-transforming the analyte concentration from each collector on each storm date, then computing the mean transformed concentration for each of the three col-

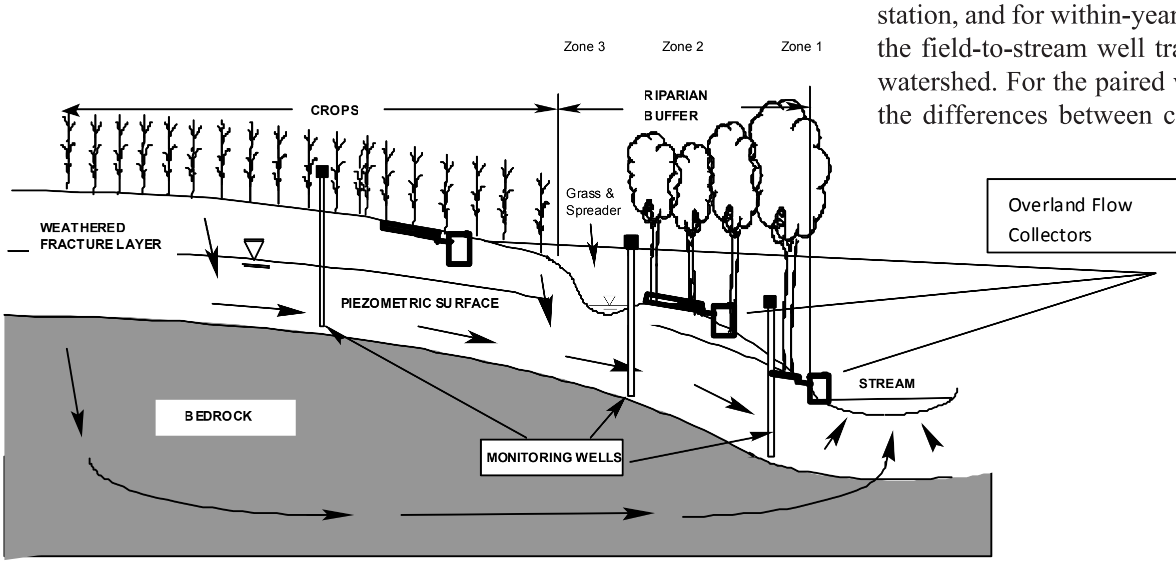

Figure 3. Location of sampling wells and overland flow collectors in relation to the crop area, the three zones of the Riparian Forest Buffer System, and stream in the Morris Run (treatment) watershed.

lector positions (Above Zone 2, Below Zone 2 and Above Zone 3) on each date. The effect of collector position on concentration was tested by a single two-way (date × position) ANOVA with one observation per cell, followed by Tukey's test. Data were back-transformed to geometric means for tabular reporting. All effects were tested at the $P<0.05$ significance level.

Mass-Balance Estimate. A mass-balance estimate of nitrate removal by the RFBS consisted of the following components: annual export from the buffer was the product of annual baseflow and mean baseflow nitrate concentration. Input from upslope was the product of groundwater flow (pro-rated from baseflow by contributing area) and average nitrate concentration in wells upslope from the RFBS. Input from groundwater recharge within the RFBS was estimated as the product of nitrate concentration in soil lysimeters at 1 m depth (0.88 mg/L) and the volume of water recharge (also pro-rated). Nitrate removal was calculated by difference from the preceding components in the treatment watershed.

Although subsurface flow pathways were not characterized, the authors are confident that the stream exports captured nearly all of the groundwater flow both because the piezometric surface conformed reasonably with surface topography and because annual water yields agreed well with regional watershed water balances of similar geology (Vogel and Reif 1993).

Results and Discussion

Tree Growth. Tree growth in the RFBS was slow from 1992 to 1998, with significant annual mortality from drought and deer damage (see Figures 4-7). Although much of the initial planting stock was replaced during these years, mortality was eventually reduced through annual application of herbicide (glyphosate) around each tree and the use of taller tree protectors (both plastic and wire mesh) as the trees matured. After 1999, rapid tree growth was evident and basal area increased 20-fold between 1999 and 2006 (Figure 4). Canopy cover reached 41% in 2002 and 59% in 2006 (data not shown).

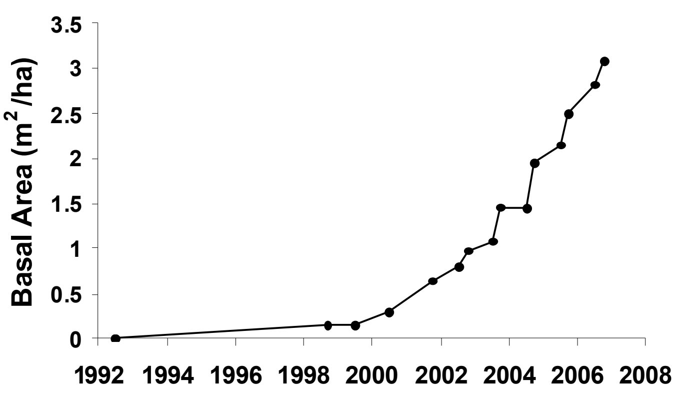

Figure 4. Graph of changes in basal area of trees in Zone 2 of the Riparian Forest Buffer System over the project period.

Figure 5. Zone 2 of RFBS in 1994, two years after tree planting.

Figure 6. Zone 2 of RFBS in 1999, seven years after tree planting.

Figure 7. Zone 2 of RFBS in 2006, 15 years after tree planting.

Stream and groundwater nitrate. In the stream draining the reforested watershed (Half Way Run), mean annual nitrate-N concentration decreased by 44% from 2.7 mg/L in 1992 to 1.5 mg/L in 1999 and remained near this level (averaging 1.6 mg/L) into the first months of 2007 (Figure 8). Because agricultural nitrogen application ceased when the watershed was reforested in 1991, the decline in nitrate between

1992 and 1999 appears to represent the flushing of the pre-existing pool of groundwater nitrate from the watershed. Over this period, the nitrate concentration declined at an exponential rate of 0.30 mg/L/yr (nonlinear regression, r^2=0.88), suggesting a relatively simple mixing and replacement of the original high-nitrate groundwater with more recent recharge from unfertilized soil. If this view is correct, it implies that the residence time of the groundwater in the watershed (the inverse of the flushing rate) was 3.3 years.

Nitrate-N concentration in Morris Run draining the RFBS averaged 3.5 mg/L in 1992 and declined for the first three years after planting. However, nitrate-N then increased to a peak in 2002 of 5.4 mg/L, after which it declined to 3.0 mg/L by early 2007 (Figure 8). Nitrate concentration in the reference stream followed similar but less accentuated trends, with a peak in the year 2000. Trends in nitrate concentration in the RFBS stream relative to the reference stream are shown in Figure 9 as $\triangle NO_3$-N, which represents the difference (RFBS-reference) between paired (same day) samples. $\triangle NO_3$-N

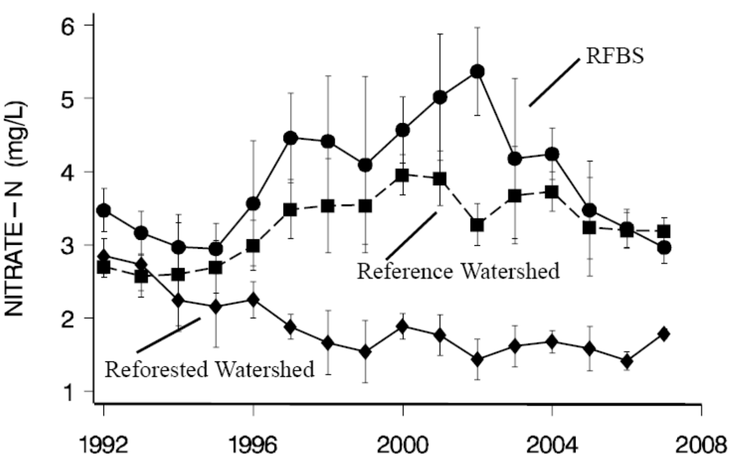

Figure 8. Graph of mean annual stream-water nitrate-N concentrations. Error bars are ±1 standard deviation.

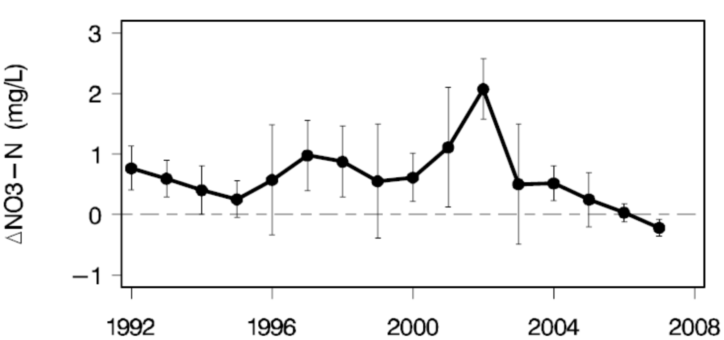

Figure 9. Graph of mean annual average of differences in paired same-day samples between the treatment stream and the reference stream. Error bars are ±1 standard deviation.

showed relatively little trend until 2001 when it increased sharply to a peak in 2002, after which it steadily declined to 2007 (Figure 9). $\triangle NO_3$-N fell below its initial 1992 value in 2006 (P<0.05). Year 2007 – 15 years after reforestation – was the first year that nitrate in the RFBS fell below that of the reference stream ($\triangle NO_3$-N < 0, P<0.05).

The authors attribute the complex trends in stream-water nitrate in the RFBS watershed to the combined dynamics of groundwater nitrate and tree growth. Groundwater nitrate-N in the field (just upslope from the RFBS) increased from 2.5 mg/L in 1992 to a peak of 7.5 mg/L in 1997 (Figure 10). The nitrate-N concentration remained near 7 mg/L through 2003, then declined steadily to about 3 mg/L in 2007. The 1992-1997 increase likely reflects higher fertilizer application during the period 1992 to 2002 than during the period prior to the study, although this cannot be verified because application rates prior to 1992 were not recorded. Thus, the decline in upslope groundwater nitrate that began in 2004 was probably related to the reduction in 2002 in the rate of nitrogen application to the hay strips in the field. As Figure 10 shows, nitrate concentrations within the RFBS (Zone 3 and the reforested portion of the buffer or Zone 2), as well as in the stream water draining the RFBS, increased in parallel with the increase in upslope nitrate, but with a lag of 3 to 4 years. This delay is consistent with the response to the cessation of nitrogen application observed in the reforested watershed (Figure 8). These results suggest that groundwater nitrate concentrations within the RFBS and stream were strongly influenced by variations in the groundwater nitrate that entered the RFBS in subsurface flow from the upslope fields. By contrast, the subsequent declines in RFBS groundwater and stream-water nitrate concentrations that began in 2003 cannot be fully explained as a response to upslope inputs because they preceded the decline in upslope nitrate by one year, rather than lagging it by several years. Rather, the timing of these declines is consistent with the onset of rapid tree growth in the RFBS (Figure 4). The authors interpret this as evidence that the observed forest growth contributed to nitrate removal within the RFBS during that period.

The multi-year time lag between upslope inputs and stream-water outputs precludes meaningful mass balance estimates on an annual basis, but over longer averaging periods the lag-effects become less important. Thus, using average annual concentrations and baseflows between 1998 and 2006, we estimate that the RFBS (~ 1 ha) removed 62 kg of nitrate per year from riparian buffer subsurface flow. This removal represents 26% of upslope inputs (Figure 11). If, as the paired watershed results suggest, the growing forest began to reduce stream-water nitrate concentration only as of 2003, then this average removal rate represents an average of removal that occurred prior to an influence of the reforestation, i.e., in a herbaceous (largely grass) buffer, together with a higher rate of removal effected by the reforestation.

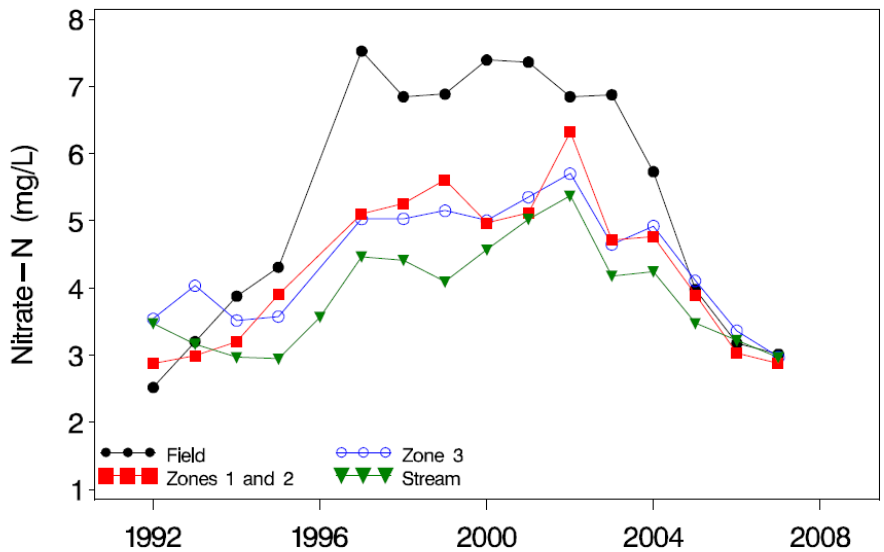

Figure 10. Graph of mean annual nitrate concentrations in groundwater and stream water in the treatment watershed over project period. Standard deviations for individual points averaged 1.35 (range: 0.41 to 2.0) mg/L for groundwater and 0.61 (range: 0.25 to 1.2) mg/L for stream water. Sample sizes ranged from 15 to 28 per year.

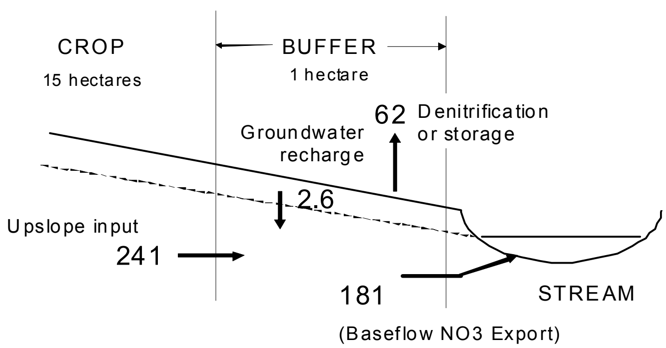

Figure 11. Schematic of subsurface nitrate budget (kg/y) for the Morris Run treatment watershed 1998-2006.

A recent meta-analysis of nitrogen removal by riparian buffers (Mayer et al. 2007) reported an average removal rate of 72% for forested buffers, substantially higher than found in the present study. High removal rates have typically been observed in settings where the subsurface flow is constrained to shallow pathways rich in organic carbon and/or in contact with the root zone (Peterjohn and Correll 1984, Simmons et al. 1992, and Hill et al. 2000). In contrast, buffers may be relatively ineffective where water flows through deeper pathways to reach the stream (Böhlke and Denver 1995, Vidon and Hill 2004). In the relatively high relief Piedmont setting of the present study, it is likely that flow is preferentially constrained to the shallow saprolite, but that flow through the underlying fractured bedrock is significant (Rose 1992). This mix of shallow and deep pathways may explain the modest rates of nitrogen removal reported in this study.

Stream and groundwater phosphorus. Total phosphorus concentrations in stream water varied from year to year without consistent trends in any of the three streams – averaging 0.045, 0.037, and 0.026 mg/L in the RFBS, reference, and reforested streams, respectively between 1992 and 2007 (data not shown).

Dissolved phosphorus averaged approximately 67% of total phosphorus and similarly showed no temporal trends. Dissolved phosphorus in groundwater in the cultivated field of the RFBS watershed averaged 0.028 mg/L without long term trends ($P>0.05$). Groundwater concentrations within the buffer (Zones 2 and 3), however, were initially similar to those of the cultivated field, but between 1997 and 2007 averaged 0.019 mg/L which was significantly less ($P<0.05$) than in the cultivated field. These within-buffer concentrations were lower than the average (0.045 mg/L) in the stream draining the RFBS watershed. This result is consistent with observations that stream-water phosphorus in agricultural streams is controlled less by groundwater supply than by inputs of sediments from overland flow (Taylor and Kunishi 1971). Thus, although the buffer may have removed phosphorus from subsurface flow, this removal does not appear to have influenced stream water concentrations significantly. Other studies (Peterjohn and Correl 1984, Osborne and Kovacic 1993, Clausen et al. 2000) have similarly reported an absence of significant phosphorus removal from groundwater flow.

Overland flow. Overland flow was collected from 24 storms between 1997 and 2007. The geometric mean sediment concentration of water was 105 mg/L as it entered the RFBS from the grass waterways (Table 1, Above Zone 3), and was reduced to 72 mg/L as it flowed from the level-lip spreader into Zone 2 (Above Zone 2), and to 60 mg/L as it exited Zone 2 (Below Zone 2) toward the stream. Assuming that infiltration of water during stormflow was negligible, these concentrations imply that the RFBS removed 43% of the sediment transported from the field, while Zone 3 and the level spreader alone removed 32%. Both of these reductions were significant ($P<0.05$), but the incremental amount (11%) removed by Zone 2 alone was not significant ($P>0.05$). Although this result shows that more sediment was removed by the grass buffer with its level spreader than in the reforested Zone 2, it does not necessarily imply that Zone 3 was a more effective filter than Zone 2 in removing sediment. Preferential deposition of coarser, more rapidly settling particles typically produces enhanced removal efficiency within the first few meters of a filter strip, regardless of vegetation (Daniels and

Gilliam 1973, Cooper et al. 1987, Syverson and Borch 2005). The 43% removal observed in this study, while substantial, was lower than removal rates of 60-to->90% reported by several other studies of riparian buffers (e.g., Peterjohn and Correll 1984, Sheridan et al. 1999, Schoonover et al. 2006, Lee et al. 2003). This study's lower removal rate may be partially explained by the role of other conservation measures practiced on the study site. Overland flow reached the buffer only after leaving contoured strips and traversing grassed waterways which themselves may have removed much of the filterable sediments. The use of the level-lip spreader in this project seems to be a crucial element to sediment removal by the buffer.

Nitrate concentration in overland flow did not change significantly in Zone 3, but increased ($P<0.05$) with passage through Zone 2 (Table 1). Despite this increase, the average concentration of nitrate-N exported from Zone 2 toward the stream (0.26 mg/L) remained below average stream-water and groundwater concentrations (>2 mg/L, Figures 8 and 10). On an annual basis, storms accounted for <10% of total nitrogen export from the watershed (based on intensive storm sampling not reported here). Thus the nitrate supplied by the RFBS to overland flow detracted negligibly from the overall performance of the buffer. Ammonia concentrations in overland flow were not significantly ($P>0.05$) affected on passage through the buffer and, like those of nitrate in overland flow, were too low to be a factor in buffer performance.

Total dissolved phosphorus did not change ($P>0.05$) in its passage through Zone 3, but increased in Zone 2 to concentrations averaging 26% higher than those entering Zone 3 ($P<0.05$) (Table 1). Particulate phosphorus, in contrast, declined by 22% across the whole buffer ($P<0.05$), but did not change significantly in Zone 2. The decline in the concentration of particulate phosphorus was comparable to the increase in total dissolved phosphorus concentration, yielding no net effect of the buffer on total phosphorus in overland flow. This result contrasts with other reports of high (~75%) removal of total phosphorus from overland flow in reforested buffers (Clausen et al. 2000, Vellidis et al. 2003). The absence of removal in this study may be in part attributable to unmeasured upslope removal in the grass waterways.

Conclusions

A reforested riparian zone was established in an agricultural field in the Mid-Atlantic Piedmont in 1992. This study found that a 35-m wide 3-zone riparian forest buffer system removed 26% of the subsurface nitrate and 43% of the suspended sediments delivered from upslope. Total phosphorus was not removed by the buffer. The influence of tree growth on nitrate removal became apparent approximately ten years after planting. The grass filter strip between the forest and the cultivated field, contoured to disperse concentrated overland flow into the reforested area, also functioned effectively to remove suspended sediments. It is important to recognize that this study did not address the indirect influences of riparian reforestation on water quality that arise from habitat improvements, including enhancement of habitat area within the stream (Sweeney et al. 2004). These improvements, in turn, enhance the ability of the stream to take up and process nutrients through processes such as in-stream denitrification that are critical to the protection of downstream ecosystems (Mulholland et al. 2008). The final report is pending and will be posted on the Stroud Water Research Center at http://www.stroudcenter.org.

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INFORMATION

LID Center Releases Green Highways and Green Streets Website

The Low Impact Development Center, Inc. has launched a new resource website for Green Highways and Green Streets projects: http://www.lowimpactdevelopment.org/greenstreets. This website provides information on basic research, pilot projects, standards and specifications, planned and constructed projects that the Center has been involved in across the country through work with US EPA, the National Academy of Sciences, FHWA, state and local DOTs, Municipal Planning Organizations, and industry. Links to other green streets programs are provided on the site. This is the first iteration of what will be a comprehensive resource to help build and restore the nation's infrastructure using green approaches.

The NCSU Water Quality Group publications list and order form can be downloaded at http://www.ncsu.edu/waterquality/issues/pub_order.html

EPA Releases Climate Strategy for Water

US EPA recently released a strategy – *National Water Program Strategy: Response to Climate Change* – that outlines national actions to reduce adverse effects on water from climate change. EPA anticipates that climate change will likely increase certain water pollution problems, change the availability of drinking water supplies and have a significant impact on coastal areas. Visit http://www.epa.gov/water/climatechange/.

New Manual for Stormwater BMPs using Trees and Structural Soils in Highly Paved Areas

Virginia Tech has been working for the past four years with Cornell and U.C. Davis developing a stormwater management technique that uses structural soils (load-bearing tree soils) under pavement as a stormwater reservoir in conjunction with trees. This approach allows incorporation of all the hydrologic elements, including storage, infiltration, and evapotranspiration.

The technology transfer items are now available for download at http://www.cnr.vt.edu/urbanforestry/stormwater. Included is a 55-page manual, a PowerPoint presentation, and information on four demonstration sites around the country. Some journal articles have already been published and the citations are available on the site. Research papers are continuing to emerge and citations will be posted as they are released.

For more information, contact Dr. Susan D. Day, Assistant Professor, Dept of Forestry & Dept of Horticulture, Virginia Tech, 540-231-7264, sdd@vt.edu

EPA Publishes Draft Handbook for Developing Watershed Total Maximum Daily Loads (TMDLs)

US EPA's Office of Water has issued a draft *Handbook for Developing Watershed TMDLs* available now for public comment at: http://www.epa.gov/owow/tmdl/techsupp.html. The public comment period closes on February 18, 2009.

The draft document identifies the issues for practitioners to consider and tools and resources that can help when planning for and developing watershed TMDLs. The draft document also identifies the benefits of developing watershed TMDLs, as well as the challenges and ways to address them. Throughout the draft document, there are examples, tips and resources provided to further support TMDL practitioners in understanding how to develop watershed TMDLs to cost-effectively develop allocations to restore impaired waters. Finally, the draft document evaluates the connections between watershed TMDLs and other water programs and identifies opportunities for integrating watershed TMDLs and their results into other watershed management efforts, such as monitoring, watershed planning, watershed-based permitting and water quality trading.

Comments or questions on this draft document should be sent to Michael Haire in OWOW's Watershed Branch at haire.michael@epa.gov.

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MEETINGS

Call for Abstracts

Fifth National Conference for Nonpoint Source and Stormwater Outreach: Achieving Results with Tight Budgets: May 11-14, 2009, Portland, OR. Visit conference website http://epa.gov/nps/outreach2009. Abstracts due January 30, 2009.

2009 IECA Southeast Chapter Muddy Water Blues: Providing Innovative Solutions to Complex Regulations: May 12-13, 2009, Asheville, NC. View conference details and submit abstracts online at http://guest.cvent.com/i.aspx?1Q,P1,26F47356-B188-4DC0-BF3E-DBA4756ED083. Abstracts due February 18, 2009.

Meeting Announcements — 2009

Februrary

2009 USDA-CSREES National Water Conference: February 8-12, 2009, St. Louis, MO. View conference website at http://guest.cvent.com/i.aspx?5S,M3,0ab16141-de82-4b79-8b4a-3d6728d3a5d1

May

AWRA 2009 Spring Specialty Conference: Managing Water Resources in a Changing Climate: May 4-6, 2009, Anchorage, AK. Visit conference website at http://www.awra.org/meetings/Anchorage2009/index.html

20th Annual Nonpoint Source Pollution Conference: May 18-20, 2009, Portland, ME. Visit conference website at http://www.neiwpcc.org/npsconference

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA). Project Officer: Tom Davenport, Office of Wetlands, Oceans, and Watersheds, EPA. 77 W. Jackson St., Chicago, IL 60604. Website: http://www.epa.gov/OWOW/NPS

July

Soil & Water Conservation Society 2009 Annual Conference: Delivering Conservation, Today and Tomorrow: July 11-15, Dearborn, MI. Visit conference website at http://www.swcs.org/en/conferences/2009_annual_conference/call_for_papers/

NCER 2009: 3rd National Conference on Ecosystem Restoration: The Spirit of Cooperation: July 20-24, 2009, Los Angeles, CA. Visit conference website at http://www.conference.ifas.ufl.edu/NCER2009

August

StormCon '09: The North American Surface Water Quality Conference & Exposition, August 16 - 20, 2009, Anaheim, CA. Visit conference website at http://www.StormCon.com

September

17th National Nonpoint Source Monitoring Workshop: Reducing Nutrients and Documenting Results: September 14-17, 2009, New Orleans, LA. See Call for Papers on this page.

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Call for Papers

17th National Nonpoint Source Monitoring Workshop: Reducing Nutrients and Documenting Results

Sept. 14-17, 2009 – New Orleans, Louisiana

The Annual Nonpoint Source (NPS) Monitoring Workshop is an important forum for sharing information and improving communication about controlling and monitoring NPS pollution issues and projects. The focus of the 17th National Workshop is on nutrients and lessons learned that can be factored into State Nutrient Reduction Strategies.

Specific topics of interest highlighted at the 17th annual workshop will include:

- Stream and Wetland Restoration Practices for Nutrient Management
- Controlled Drainage Practices for Agricultural Nutrient Management
- Innovative Agricultural Nutrient Conservation and Management Practices
- Nutrient TMDL and Watershed Action Plan Implementation
- Bio-Assessment Tools & Methodology for Nutrients
- Monitoring Landscape Changes Associated with Nutrient Management
- Manure Management
- Evaluating the Effectiveness of Environmental Management Systems
- Coastal NPS Efforts
- Managing Nutrients from Urban NPS and Stormwater
- Interpreting Nutrient Monitoring Data
- Monitoring Behavioral Changes Associated with Nutrient Management Practices

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Workshop Queries Contact Person
Thomas E. Davenport, USEPA, davenport.thomas@epa.gov

Call for Papers

- Name of Author/Presenter
- Organization
- Address, City, State, Zip
- Telephone
- Email Address
- Title of Presentation
- Abstract (500 words max)
- Biography (300 words max)
- Special Audio/Visual Equip Needs

Submit to: Elsa Mittelholtz
elsa.mittelholtz@tetratech.com
703.385.6000, ext.160
fax 703.385.6007

Call for Workshops

- Name of Instructor(s)
- Organization
- Address, City, State, Zip
- Telephone
- Email Address
- Title of Workshop
- Abstract (750 words max)
- Biography (300 words Total for Instructors)
- Special Audio/Visual Equip Needs

Submit to: Steven Dressing
steven.dressing@tetratech.com
703.360.6054

Deadline: March 31, 2009. We are seeking enthusiastic individuals interested in sharing their experiences and lessons learned. Applicants will be notified of the selection committee's decisions by May 15, 2009. Successful applicants are required to provide completed presentations by August 22, 2009. Oral presentations are limited to 20 minutes. All speakers must register in advance for the conference (discounted early registration fees will apply).

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