NWQEP NOTES

The NCSU Water Quality Group Newsletter

Number 121 May 2006 ISSN 1062-9149

NC STATE UNIVERSITY

NC STATE UNIVERSITY
A&T STATE UNIVERSITY
COOPERATIVE EXTENSION
Helping People Put Knowledge to Work

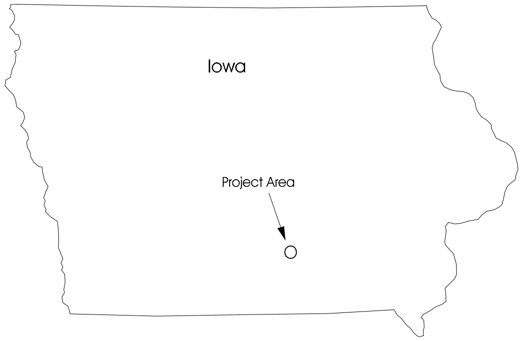

Figure 1. Location of the Walnut Creek Watershed NMP project, in Jasper County, Iowa.

IN THIS ISSUE

NWQEP NOTES is issued quarterly. Subscriptions are free. *NWQEP NOTES* is also available on the World Wide Web at http://www5. bae.ncsu.edu/programs/extension/wqg/issues/Default.htm. To request that your name be added to the mailing list, use the enclosed publication order form or send an email message to wq_puborder@ncsu.edu.

PROJECT SPOTLIGHT

Walnut Creek, Iowa: The Effects of Land Use Change on Stream Nitrate Concentrations

Keith E. Schilling
Iowa Department of Natural Resources

Jean Spooner
NCSU Water Quality Group, Department of Biological & Agricultural Engineering

Introduction

Nonpoint source nitrogen (N) pollution from the U.S. Midwest is receiving increasing attention due to excessive nutrient enrichment and eutrophication in streams and development of hypoxic conditions in the Gulf of Mexico. Nitrate-nitrogen (nitrate) export from Iowa, located in the middle of the U.S. corn belt, has been identified as a major contributor to Mississippi River pollutant loads (Goolsby et al., 1999).

Nitrate concentrations in Iowa rivers are directly related to the proportion of the watershed in row crops (Schilling and Libra, 2000). Iowa was once part of the tallgrass prairie ecosystem that covered ~68 million ha (~263,000 mi^2) in the U.S., of which more than 99 percent has been lost. Despite the plowdown of prairies that occurred between the1850s and 1890s, perennial cover was still an important part of the Iowa landscape through the 1950s because rotations of sod crops (oats, hay) with annual crops (corn, soybean) were about evenly split. However, since that time, soybean production has increased dramatically and replaced many sod-based rotations, so that total row crop area (corn and soybeans) increased up to 40 percent by 2000. Similarly, N fertilizer use in Iowa significantly increased from 1965 to 1981, averaging near 1.0 million tons per year in the 1990s. As a result of both of these trends, monitoring data have shown a two- and three-fold increase in nitrate concentrations in the Cedar and Des Moines rivers in Iowa from 1940 to 2000 (Schilling, 2005). Nitrate is delivered to Iowa streams primarily through ground water discharge as baseflow and tile drainage (Hallberg, 1987; Schilling and Zhang, 2004).

Plot scale studies (e.g., Randall et al., 1997; Brye et al., 2001) and modeling results (e.g., Vache et al., 2002) have suggested that introduction of perennial cover into an agricultural landscape can reduce nonpoint source pollution in streams, but this strategy is relatively untested at a watershed scale. The 10-year Walnut Creek Watershed Monitoring Project (Figure 1) was established in 1995 as part of the U.S. EPA National Nonpoint Source Monitoring Program (NMP), in conjunction with watershed habitat restoration and agricultural management changes implemented by the U.S. Fish and Wildlife Service (USFWS) at the Neal Smith National Wildlife Refuge (Refuge) in Jasper County, Iowa. A large portion of the Walnut Creek watershed has been in the process of conversion from row crop agriculture to native prairie and savanna since 1995 (Schilling and Thompson, 2000). The Walnut Creek watershed was paired with a highly agricultural watershed (Squaw Creek), acting as the control, to evaluate effects of large-scale prairie restoration on stream water quality. The purpose of this article is to discuss the response of stream nitrate concentrations to changing land use patterns in two agricultural watersheds and to assess the timeframe needed for observing changes in stream nitrate concentrations over time.

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 best management practice (BMP) implementation.

The Walnut Creek Watershed NMP project in south-central Iowa lies in the heart of the U.S. cornbelt – a region often implicated with contributing major pollutant loads to the Mississipi River. The study employed a paired watershed monitoring design to evaluate changes in nutrients, sediment, bacteria and stream biota due to conversion of row crop agriculture to native prairie (cool season grasses) and improved agricultural management practices. This article reports on the nitrate results of the 10-year study. As land conversion occurred gradually throughout the monitoring period, a gradual change statistical model was used as opposed to a pre/post discrete change model. Project results documented a significant decrease in nitrate concentrations as a result of land use and management changes, confirming that prairie restoration can reduce nitrate loss to streams in agricultural landscapes. The authors present the outcomes of this study, which include several interesting and important "lessons learned" on issues such as the scale of watershed studies, the lag time for detecting change, and the influence of tile drainage, all of which are widely applicable to the design and success of other nonpoint source monitoring studies in agricultural settings.

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

Laura Lombardo Szpir

Laura Lombardo Szpir
Editor, *NWQEP NOTES*
Water Quality Extension Associate
NCSU Water Quality Group
Campus Box 7637, NCSU
Raleigh, NC 27695-7637
Tel: 919-515-3723, Fax: 919-515-7448
Email: notes_editor@ncsu.edu

Although this article highlights nitrate results, the Walnut Creek NMP project also included assessments of discharge and suspended sediment, phosphorus, indicator bacteria, and stream biota. Other monitored variables will be discussed in future publications, including the final report due to be published in 2006. A copy of the final report is available on the Internet at **www.igsb.uiowa.edu**.

Methods

Study Area

The 5,218 ha (12,894 ac) and 4,703 ha (11,621 ac) watersheds of Walnut Creek and Squaw Creek (Figure 2), respectively, are in the Southern Iowa Drift Plain landscape region, an area characterized by steeply rolling hills and well-developed drainage. Basin characteristics in both watersheds are very similar and make them well suited for a paired watershed design. Soils consist mainly of silty clay loams, silt loams, or clay loams formed in loess and pre-Illinoian till with many soils characterized by moderate to high erosion potential. The watersheds are underlain by 6 to 30 m (20 to 98 ft) of pre-Illinoian till overlying Pennsylvanian Cherokee Group shale, limestone, sandstone, and coal.

The study area is in a humid, continental region with average annual precipitation of around 750 mm (29.5 in). During the project, annual precipitation varied from 380 to 1056 mm (15.0 to 41.6 in) whereas discharge varied from 109 to 422 mm (4.3 to 16.6 in) at the Walnut Creek watershed outlet (WNT2) and 85 to 430 mm (3.3 to 16.9 in) at the Squaw Creek watershed outlet (SQW2). Average total discharge was slightly higher in Walnut Creek than Squaw Creek, but baseflow discharge was less. The percentage of streamflow as baseflow was higher in Squaw Creek (62 percent) than Walnut Creek (57 percent). Seasonally, discharge in May and June accounted

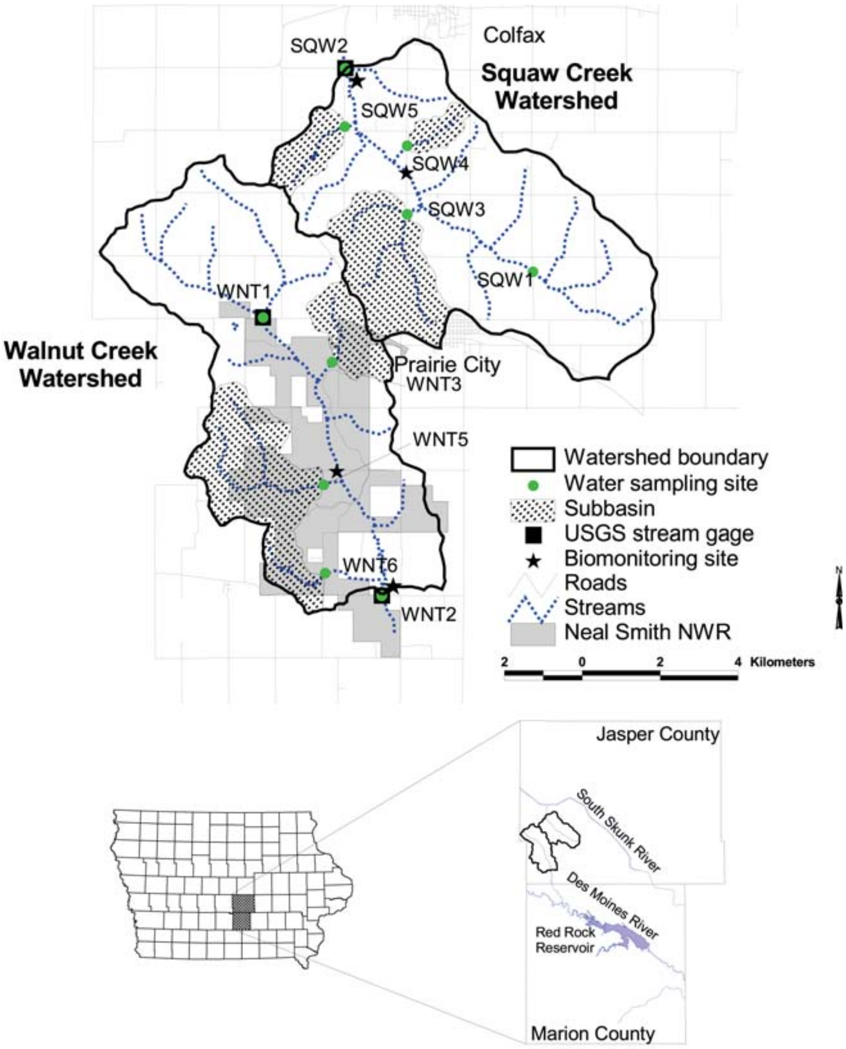

Figure 2. Walnut Creek and Squaw Creek Watersheds, including location of wildlife refuge land, subbasins and stream sampling locations.

for more than 45 percent of annual streamflow with the months of February, March, April and July averaging near 10 percent for each month. Discharge in both watersheds tends to be flashy, displaying rapid responses to precipitation.

Monitoring Design

The project used a paired watershed monitoring design with Walnut Creek as a treatment watershed and Squaw Creek as the control. Paired watershed studies offer high statistical power to detect changes in water quality from land treatment (Clausen and Spooner, 1993). The approach typically involves two monitoring periods, calibration and treatment, and two watersheds, treatment and control. In typical paired watershed studies, two similar watersheds are monitored for a calibration period and then a treatment is imposed on one of the watersheds (i.e., prairie restoration in Walnut Creek). A change in the relationship between treatment and control watersheds for a variable of interest (e.g., nitrate) is considered a treatment effect.

The project differed from typical paired watershed studies because pretreatment data collection was not sufficient to derive relationships between the treatment and control watersheds during the calibration period. Moreover, land treatment implemented by the Refuge in the Walnut Creek watershed occurred gradually throughout the entire monitoring period. For these reasons, a gradual change model that incorporated covariates from the control watershed was used instead of comparing distinct pre- and post-BMP periods as in a more typical paired watershed study. In addition, upstream (WNT1, SQW1) and downstream (WNT2, SQW2) samples were collected in the main stems of Walnut and Squaw Creek, as well as downstream samples in subbasins. This design allowed for analysis of upstream/downstream comparisons over time, as well as multiple subbasin comparisons.

Land Cover Tracking

Detailed land use/land cover mapping was conducted by field survey in both watersheds in 2005. Using a map of common land units (CLUs) in the Walnut and Squaw Creek watersheds, a tablet PC was used with a GIS interface to enter land cover and conservation practices descriptions for each CLU into the GIS database. In order for land cover tracking to be consistent with the beginning of the project, the 2005 CLU boundaries were overlaid on 1990 aerial photographs for the Walnut and Squaw Creek watersheds and the 1990 land cover for each CLUs was entered into the GIS database. GIS coverages of prairie planting sites were made available by the USFWS to track annual land use changes within the refuge boundary.

Data Collection

Surface water samples were collected at upstream and downstream locations in Walnut and Squaw Creek watersheds on a weekly to bimonthly basis from 1995 to 2005. Three subbasin sites were also sampled in each watershed during the April to September period each year (Figure 2). The upstream sampling point on Walnut Creek (WNT1) was above the refuge boundaries and allowed an evaluation of upper basin effects on water quality. For the 10-year period, approximately 205 and 144 water samples were collected at the main stems of Walnut and Squaw Creeks and at the subbasin sampling sites, respectively. These paired samples were taken on the same dates from both watersheds. Water samples were analyzed for nitrate by the University of Iowa Hygienic Laboratory (EPA Method 300.0). Three USGS stream gauging stations in the upper (WNT1) and lower (WNT2) portions of the Walnut

Creek watershed and at the Squaw Creek watershed outlet (SQW2) (Figure 2) were monitored continuously during the study. Hydrograph separation into baseflow and runoff components was performed on streamflow data collected at the three USGS gauging sites using an automated method developed by Sloto and Crouse (1996).

Statistical Methods

Statistical analyses were performed according to the guidelines of Grabow et al. (1999). To test for the gradual change in chemical concentrations over time, a multiple linear regression analysis was performed. A simplified form of the equation is given by:

$$Y=\beta_0+\beta_1 X_1+\beta_2 X_2$$

where Y is either the water quality variable or log of the variable for the treatment watershed (Walnut Creek), X_1 is the same water quality variable (or log) for the control watershed (Squaw Creek), and X_2 is elapsed time, and b_0, b_1, and b_2 are regression parameters. In this equation, the estimate of b_2 indicates the magnitude of change over time. By including covariates (e.g., variable X_1), the analysis blocks out much of the hydrologic variability and the change can be attributed to the effect of treatment, which in this case is being modeled as time (X_2). Multiple covariates were considered to develop the regression equation, including streamflow, upstream nitrate concentrations, control nitrate concentrations, and seasonality.

Streamflow data were highly skewed and transformed (log10) prior to use. No transformation was needed or performed on the nitrate data. The time-series data were also examined for temporal autocorrelation, the correlation of an observation on one day with previous observations. Nitrate and discharge data showed significant autocorrelation (lag 1 or AR(1)) patterns. Corrections for autocorrelation were made using explanatory variables and autocorrelation time series analysis.

Seasonal adjustments for each month were made to account for the seasonality evident in the nitrate and flow data. The data were 'corrected' for the average mean value of all the samples taken in a given month over the 10-year monitoring period. This adjustment was accomplished by adding a 'month' grouping or class variable to the statistical models. Tests could then be made to adjust for changes between months, while retaining nearly the entire degrees of freedom and accounting for the variations due to seasonality in the statistical models.

Results

Land Cover Changes

In 1990, row crops of corn and soybeans comprised ~70 percent of both Walnut and Squaw Creek watersheds (Table 1). In Squaw Creek watershed, row crop area increased 9 percent from 1990 to 2005 due to conversion of agricultural CRP grassland back to row crop production following passage of the Freedom to Farm Act in 1996. In the Walnut Creek watershed, row crop land decreased from 69 to 54 percent between 1990 to 2005 as a result of prairie restoration by the USFWS at the Neal Smith refuge (Table 1). From 1992 to 2005, an average of ~90 ha (222 ac) of prairie were planted each year, with areas planted in 1994 and 1995 exceeding 150 ha (371 ac). As of 2005, 1,224 ha (3,024 ac) of land in Walnut Creek watershed were planted in native prairie, representing 25 percent of the watershed. Photographs of the restored prairie at the Neal Smith refuge are shown in Figures 3, 4, and 5.

Figure 3. Monitoring wells have been installed at the refuge to track changes in groundwater quality over time.

In 2005, the refuge owned 194 ha (479 ac, 3.7 percent) in the Walnut Creek watershed that continued to be farmed on a cash-rent basis. In these areas, improved agricultural management practices are mandatory. Fall application of fertilizer is prohibited and a maximum of 112 kg/ha of N is allowed on conventional corn. The remaining land within the refuge boundary in the watershed consists of cool season grass or forest and comprises ~511 ha (1,263 ac, 9.8 percent). As of 2005, the USFWS controlled ~37 percent (1,929 ha, 4,767 ac) of the Walnut Creek watershed above the WNT2 gauging station.

Table 1. Summary of land use changes in Walnut Creek project area from 1990 to 2005.

Watershed and Subbasin	Basin Size (ha)	Year	Row Crop	Prairie	Grass[1]	Woods	Artificial[2]	Other[3]
			(percent of watershed area)					
Walnut Creek	5,220.8	1990	69.4		20.8	5.1	4.5	0.2
		2005	54.5	25.4	11.1	4.1	4.9	
WNT1	1,746.6	1990	75.3		18.5		5.7	0.5
		2005	83.2		9.7		7.1	
WNT3	296.2	1990	71.3		15.6	2.3	10.8	
		2005	43.9	35.7	7.7	1.8	10.9	
WNT5	795.7	1990	77.5		16.2	2.2	4.0	
		2005	45.8	45.9	4.0	0.2	4.1	
WNT6	201.6	1990	74.8		10.8	10.6	2.0	1.8
		2005	71.8	14.3	1.9	10.6	1.4	<0.1
Squaw Creek	4,706.9	1990	71.4		21.7	1.5	5.1	0.2
		2005	80.6		12.3	1.4	3.5	2.2
SQW1	1,164.8	1990	85.6		9.4	<0.1	5.0	
		2005	89.1		5.9	<0.1	3.2	1.8
SQW3	753.0	1990	67.2		22.1	1.6	9.0	<0.1
		2005	72.5		15.7	1.4	7.7	2.7
SQW4	118.3	1990	34.6		64.3		1.1	
		2005	60.6		38.3		<0.1	1.1
SQW5	237.2	1990	53.7		42.6		3.5	0.2
		2005	82.2		14.1		0.7	3.1

[1] includes cool season grasslands, pasture, CRP, alfalfa
[2] includes farmsteads, railroads, roads and urban areas
[3] includes cemeteries, golf course, ponds

From 1990 to 2005, N applications increased in Squaw Creek by 13 percent, whereas N applications in the Walnut Creek watershed decreased 21 percent. Pesticide applications in Walnut Creek watershed were reduced by ~28 percent compared to levels in 1990.

Figure 4. Watershed monitoring has been conducted in close cooperation with the U.S. Fish and Wildlife Service's Neal Smith National Wildlife Refuge.

Nitrate Concentrations and Trends

Over the 10-year study period, from 1995 to 2005, nitrate concentrations ranged from <0.5 to 14 mg/L at the Walnut Creek outlet (WNT2) and from 2.1 to 15 mg/L at the downstream Squaw Creek outlet (SQW2) (Figure 6). Nitrate concentrations exceeded 10 mg/L (the Maximum Contaminant Level allowed by National Primary Drinking Water Standards) at WNT2 and SQW2 33 and 52 percent of the time, respec-

Figure 5. In the fall of 1996, bison were introduced at the Neal Smith refuge. Now there are 44 bison at the refuge.

tively. Both Walnut and Squaw Creek watersheds showed a similar temporal pattern of nitrate levels, with high concentrations in the spring and early summer months coinciding with periods of fertilizer application, greatest precipitation, and high stream flow (Figure 6).

Annually, mean nitrate concentrations ranged from 10.0 to 12.7 mg/L at WNT1, 6.8 to 9.5 m/L at WNT2, 10.5 to 13.8 mg/L at SQW1 and 8.2 to 11.5 mg/L at SQW2. Greater differences among water year nitrate concentrations occurred in the subbasins (Figure 7). In Squaw Creek subbasins mean annual nitrate concentrations at SQW4 increased from 2.0 to >10.2 mg/L and concentrations at SQW5 increased from 5.1 mg/L to 15.1 mg/L. Nitrate concentrations decreased in all Walnut Creek subbasins. Mean annual concentrations decreased to lows of 8.0, 7.7, and 3.1 mg/L in subbasins WNT3, WNT5, and WNT6, respectively.

For the downstream station in Walnut Creek (WNT2), the best set of covariates included season (month), upstream nitrate concentration (WNT1), and downstream control watershed nitrate concentrations (SQW2). Results of the trend analyses and a summary of the covariates used are shown in Table 2. Although an adjustment for season and baseflow discharge at WNT2 alone did not indicate a significant trend, the addition of either the paired site or the upstream concentration indicated a statistically significant decrease in nitrate concentration over 10 years. Like many other Iowa watersheds, nitrate had a stronger relationship with baseflow than with total discharge. Baseflow discharge explained a significant amount of variability in nitrate at WNT2 (regression with date, month, and WNT2Qb). However, baseflow discharge became nonsignificant when upstream WNT1 concentrations were added to the trend model ($r^2 = 0.85$) because the upstream concentration was highly correlated with baseflow. Nitrate concentration at the downstream Squaw Creek site (SQW2) was a significant covariate. Because the nitrate concentrations increased in the Squaw Creek downstream site, two trend models are provided in Table 2 (one with the control watershed concentration covariate and one without).

For the Walnut Creek outlet (WNT2), trend analysis indicates that nitrate concentrations decreased 0.12 mg/L/year or 1.2 mg/L over the 10-year project period when the Squaw Creek control watershed was utilized as a covariate. Without adjusting for the control, the decrease was 0.7 mg/L over the 10-year period. Interestingly, without the upstream covariate, there was no significant trend in nitrate at WNT2. There was an increase in upstream WNT1 nitrate concentration over time. In Squaw Creek watershed, nitrate concentrations increased 1.9 mg/L over 10 years at the downstream site SQW2 and 1.1 mg/L over 10 years in the upstream Squaw station SQW1 (Table 2).

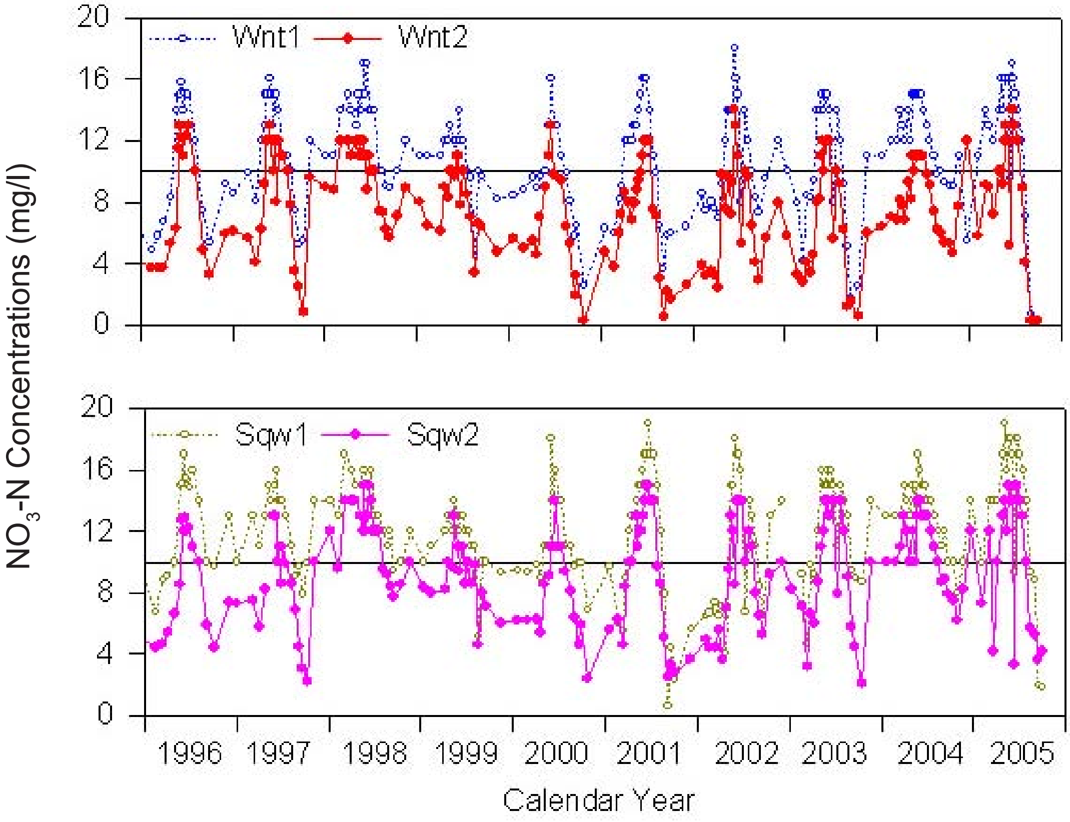

Figure 6. Time series plots of nitrate concentrations measured at upstream and downstream sites in Walnut and Squaw Creek watersheds.

Continued on p. 9

NCSU Water Quality Group Publications List and Order Form
(May 2006)

Publication Number	Reports & Journal Articles	Price($)	Quantity	Total($)
WQ-131	Stream Restoration: A Natural Channel Design Handbook (2003) (129p) *http://www.ncsu.edu/sri/stream_rest_guidebook/guidebook.html*	35.00	_______	_______
WQ-130	Changes in a Stream's Physical and Biological Conditions Following Livestock Exclusion (2003) (7p)	Free	_______	_______
WQ-129	Changes in Land Use/Management and Water Quality in the Long Creek Watershed (2002) (11p)	Free	_______	_______
WQ-128	2002 NC Stream Restoration Conference (Conference Agenda and Proceedings) (2002) (73p)	10.00	_______	_______
WQ-127	Hydraulic Geometry Relationships for Urban Streams Throughout the Piedmont of North Carolina (2002) (11p)...	Free	_______	
WQ-126	Pollutant Export from Various Land Uses in the Upper Neuse River Basin (2002) (9p)...	Free	_______	
WQ-125	Efficiencies of Temporary Sediment Traps on Two North Carolina Construction Sites (2001) (9p)...	Free	_______	
WQ-124	Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations (2000) (32p)... *(http://www.ncsu.edu/waterquality/section319/index.html)*	Free	_______	
WQ-123	Nonpoint-Source Pollutant Load Reductions Associated with Livestock Exclusion (2000) (9p)	Free	_______	
WQ-120	Comparing Sampling Schemes for Monitoring Pollutant Export From a Dairy Pasture (1998)	Free	_______	
WQ-119	Performance Evaluation of Innovative and Alternative On-Site Wastewater Treatment Systems in Craven County, NC (1998) (12 p)	Free	_______	
WQ-109	Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Forestry (EPA/841-B-97-009) (1997)	Free	_______	
WQ-103	WATERSHEDSS: A Decision Support System for Watershed-Scale Nonpoint Source Water Quality Problems (Journal of the American Water Resources Association) (1997) (14p)	Free	_______	
WQ-105	Linear Regression for Nonpoint Source Pollution Analyses (EPA-841-B-97-007) (1997) (8p)	Free	_______	
WQ-104	Water Quality of First Flush Runoff from 20 Industrial Sites (Water Environment Research) (1997) (6p)	Free	_______	
WQ-100	Water Quality of Stormwater Runoff from Ten Industrial Sites (Water Resources Bulletin) (1996) (10p)	Free	_______	
WQ-96	Goal-Oriented Agricultural Water Quality Legislation (Water Resources Bulletin) (1996) (14p)	Free	_______	
WQ-92	The Rural Clean Water Program: A Voluntary, Experimental Nonpoint Source Pollution Control Program and its Relevance to Developing Countries (1995) (18p)	Free	_______	
WQ-83	Effective Monitoring Strategies for Demonstrating Water Quality Changes from Nonpoint Source Controls on a Watershed Scale (Wat. Sci. Tech.) (1993) (6p)	Free	_______	
WQ-21	Setting Priorities: The Key to Nonpoint Source Control (EPA 841-B-87-110) (1987) (50p)	Free	_______	
WQ-60	Selecting Priority Nonpoint Source Projects: You Better Shop Around (EPA/506/2-89/003) (1989) (39p)	5.00	_______	_______
WQ-24	Selecting Critical Areas for NPS Pollution Control (J. Soil & Water Conservation) (1985) (4p)	Free	_______	
WQ-26	Appropriate Designs for Documenting Water Quality Improvements from Agricultural NPS Control Programs (USEPA) (1985) (5p)	Free	_______	
WQ-27	Increasing Sensitivity of NPS Control Monitoring Programs (Water Res. Assoc. Proc.) (1987) (15p)	Free	_______	
WQ-30	Pollution From Nonpoint Sources: Where We Are and Where We Should Go (J. Env. Science & Technology) (1987) (6p)	Free	_______	
WQ-32	Determining Statistically Significant Changes in Water Pollutant Concentrations (J. Lake & Reservoir Mgmt.) (1987) (7p)	Free	_______	

* new addition to publication list

Publication Number	Reports & Journal Articles (continued)	Price($)	Quantity	Total($)
WQ-33	Water and Sediment Sampler for Plot and Field Studies (J. Environmental Quality) (1987) (6p)	Free	_______	
WQ-35	Agricultural Nonpoint Source Control: Experiences from the Rural Clean Water Program (J. Lake & Reservoir Management) (1988) (6p)	Free	_______	
WQ-36	Determining the Statistical Sensitivity of the Water Quality Monitoring Program in the Taylor Creek Nubbin Slough, Florida, Project (J. Lake & Reservoir Management) (1988) (12p)	Free	_______	
WQ-65	Determining and Increasing the Statistical Sensitivity of Nonpoint Source Control Grab Sample Monitoring Programs (Colorado Water Resources Research Institute) (1990) (17p)	Free	_______	
WQ-70	North Carolina's Sediment Control Program (Public Works) (1991) (3p)	Free	_______	
WQ-98	Farm*A*Syst Fact Sheets (7 fact sheets) (1997) (*http://h2osparc.wq.ncsu.edu/info/farmassit/index.html*)	Free	_______	
WQ-99	Home*A*Syst Fact Sheets (5 fact sheets) (1997) (*http://h2osparc.wq.ncsu.edu/info/farmassit/homeindx.html*)			
WQ-89	Rural Clean Water Program Technology Transfer Fact Sheets (10 fact sheets) (1995) (*http://h2osparc.wq.ncsu.edu/info/concepts.html*)	Free	_______	
WQ-91	Watershed Management: Planning and Managing a Successful Project to Control Nonpoint Source Pollution (contains a list of resources specific to North Carolina) (1995) (8p) (*http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag522.html*)	Free	_______	
WQ-86	Paired Watershed Study Design (EPA 841-F-93-009) (1993)	Free	_______	
WQ-48	Pesticide Fact Sheets (10 fact sheets) (1988)	4.00	_______	_______
	Literature Reviews and Bibliographies			
WQ-121	Nonpoint Sources (Review of 1998 Literature) (Water Environment Research) (1999) (16p)	Free		
WQ-118	Nonpoint Sources (Review of 1997 Literature) (Water Environment Research) (1998) (17p)	Free	_______	
WQ-106	Nonpoint Sources (Review of 1996 Literature) (Water Environment Research) (1997) (17p)	Free	_______	
TOTAL =	Total Amount of Purchase			$__________

IMPORTANT NOTES ABOUT ORDERING PUBLICATIONS:

Prices include postage within the U.S. Prices for publications to be sent outside the U.S. may be higher. Please call or write for this information. All prices are subject to change without notice. The price list is updated with each issue of *NWQEP NOTES*. Requests are filled while supplies last. Only one copy of each free publication is available. FEIN #56-6000-756

To order: Fill out order form and enclose with payment.
Please make checks payable to **NCSU Water Quality Group**
____ Check here if requesting we bill your institution
____ Check here if enclosing payment

Please note: ***Only institutions can be billed. Individuals must enclose payment with order form.***

Send order to: Publications Coordinator, NCSU Water Quality Group, Campus Box 7637, Raleigh, NC 27695-7637 Fax: 919-515-7448, email: wq_puborder@ncsu.edu. An electronic order form is also available at: http://www.ncsu.edu/waterquality/issues/pub_order.html.

Ordered by:
Name:____
Institution:____
Street Address:______________________________________
City, State, Zipcode: ___________________________________
Telephone:____

________ Please place my name on the mailing list for *NWQEP NOTES*, the quarterly newsletter on nonpoint source pollution published by the NCSU Water Quality Group (with support from the U.S. Environmental Protection Agency) (subscriptions are free).

- NCSU Water Quality Group home page: http://www.ncsu.edu/waterquality/
- U.S. Environmental Protection Agency's Office of Water publications list: http://www.epa.gov/OW/info
- WATERSHEDSS — Water, Soil, Hydro-Environmental Decision Support System, Internet-based management tool: http://www.water.ncsu.edu/watershedss/
- 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*

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA) Grant No. X825012. 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

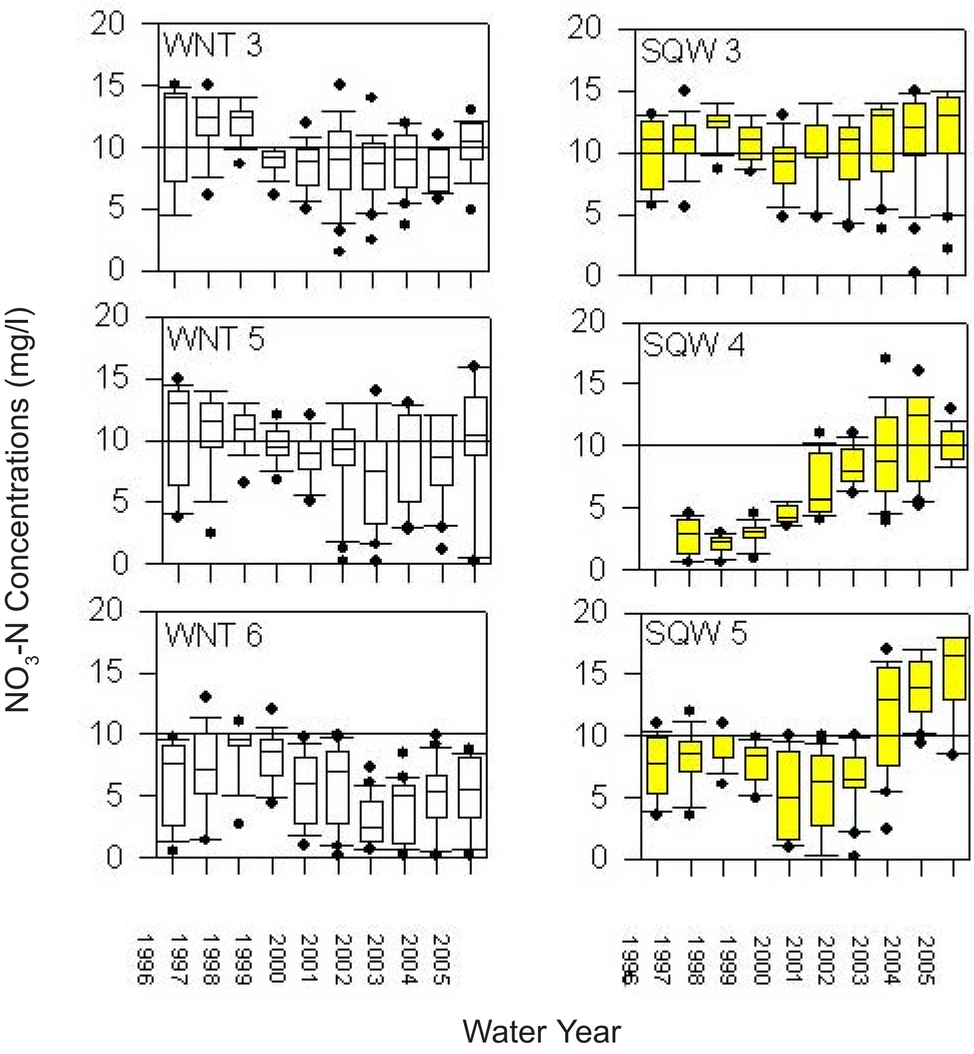

Figure 7. Box plots of nitrate concentrations by water year at subbasin monitoring sites in Walnut and Squaw Creek watersheds.

Nitrate concentrations decreased significantly in each of the Walnut Creek subbasins and the decreases were of greater magnitude than the trend observed at the main Walnut Creek station (WNT2). Nitrate concentrations decreased 3.4, 1.2, and 2.7 mg/L at WNT3, WNT5, and WNT6, respectively. Nitrate concentrations increased in all subbasins in the Squaw Creek over the same period; nitrate in surface water in SQW4 and SQW5 subbasins increased 11.6 and 8.0 mg/L, respectively. The magnitude of increase in the Squaw Creek subbasins was considerably greater than the decrease measured in Walnut Creek subbasins.

Discussion

Over the 10-year monitoring period, nitrate concentrations decreased significantly in the Walnut Creek watershed, but increased significantly in Squaw Creek watershed, both at the watershed outlet and in subbasins. Evidence from both watersheds points to land use change as the cause.

In Walnut Creek, prairie restoration and land management changes implemented at the Refuge reduced stream nitrate concentrations. Nitrate reductions are thought to be the result of several factors: a) reduced water flux through the soil under perennial cover compared to row crop systems; b) removal of water and nitrate by deep roots of prairie vegetation and increased denitrification; c) elimination of fertilizer N inputs; and d) reduction of overland flow N contributions during runoff events. In subbasins where land use changes affected a high proportion of the watershed area, nitrate concentrations decreased 1.2 to 3.4 mg/L over 10 years. At the watershed outlet (WNT2), nitrate concentrations decreased significantly (1.2 mg/L over 10 years), though the rate of change was less than in the subbasins. These changes can be directly attributed to the land use and management changes because the statistical model developed to estimate the nitrate concentration reductions included explanatory factors to account for seasons, variable discharge, and changes occurring in the control watershed. Changes in nitrate concentrations in Walnut Creek,

Table 2. Summary of results of statistical models used to detect changes in nitrate concentrations over time.

Station	**Covariates**	**Slope (mg/L/year) (Negative = decrease)**	***P*>t on slope estimate**	**r^2**	**Changeover 10 years (mg/L)**
WNT2	Season WNT1N03 SQW2	- 0.119	<0.0001	0.89	- 1.2
WNT2	Season WNT1NO3	- 0.066	<0.0001	0.86	- 0.7
WNT1	Season Log(WNT1Qb)	+ 0.116	0.0166	0.73	+ 1.2
WNT3	Season Log(WNT2Qb)	-0.340	<0.0001	0.50	- 3.4
WNT5	Season Log(WNT2Qb)	-0.116	0.0820	0.66	- 1.2
WNT6	Season Log(WNT2Qb)	-0.274	<0.0001	0.57	- 2.7
SQW2	Season Log(SQW2Qb)	+ 0.191	0.0001	0.71	+ 1.9
SQW1	Season Log(SQW2Qb)	+ 0.108	0.0629	0.60	+ 1.1
SQW3	Season Log(SQW2Qb)	+ 0.091	0.0935	0.000	+ 0.9
SQW4	Season Log(SQW2Qb)	+ 1.158	<0.0001	0.635	+ 11.6
SQW5	Season Log(SQW2Qb)	+ 0.797	<0.0001	0.206	+ 8.0

Qb = baseflow

for example, cannot be attributed simply to changing weather patterns because the effects of seasons and discharge were controlled in the model.

The decrease at WNT2 occurred despite an increasing trend in nitrate concentration at the upstream site (WNT1). Given the significant correlation of nitrate between the upstream and downstream sites (r^2 of 0.94 and 0.78, Walnut and Squaw Creeks, respectively), dilution of stream water with lower nitrate concentration inputs must have occurred between the two sites to produce a decreasing trend at WNT2. However, it is also evident that contributions of nitrate from upstream areas dominate the nitrate concentrations at the watershed outlet (Figure 6). Evidence from chemical load data (Schilling, 2002) and two synoptic surveys (Schilling and Wolter, 2001; Schilling, 2001) also indicates that headwater regions in Walnut Creek contribute a greater proportion of nitrate to the stream than do downstream regions. Once nitrate is delivered to the stream network from row crop-dominated headwater regions, nitrate appears to be diluted by the downstream watershed area containing the prairie, but concentrations remain elevated.

In the Squaw Creek watershed, a different relationship between nitrate concentrations and land use change emerged. Significant increases in nitrate concentrations (>8 mg/L) were measured in two subbasins. Also, nitrate at the Squaw Creek watershed outlet increased by ~2 mg/L during the 10-year project. In the two subbasins with increasing nitrate (SQW4 and SQW5), the amount of land in row crop increased by 26 and 29 percent, respectively, with a corresponding decrease in CRP grass land cover. Nitrate concentrations increased dramatically in SQW4 by over 11 mg/L in 10 years; most of the change occurred from 1999 to 2003. Even in Walnut Creek, an increasing trend in stream nitrate concentrations was evident in upstream WNT1 where row crop in the watershed area increased by nine percent. It is unknown whether the increase in nitrate concentrations in these areas can be attributed to increased fertilizer inputs or mineralization of organic N, but the influence of row crop land cover on stream nitrate concentrations is plainly evident.

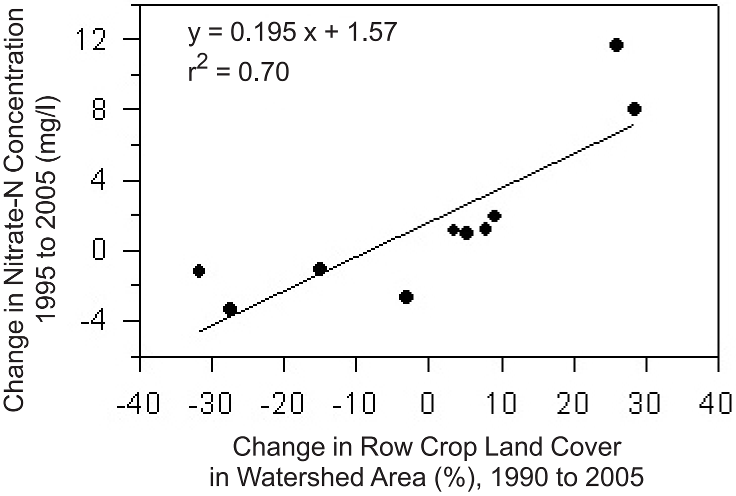

Figure 8. Relation of change in stream nitrate concentrations (as determined by statistical methods) with change in percentage of land cover in row crops in watersheds and subbasins.

An important lesson from the Walnut Creek NMP project is that water quality changes in stream nitrate concentration from land use change were more easily measured in the subbasins than at the watershed outlets. The rate of decrease in nitrate in the main stem of Walnut Creek was less than that measured in the smaller subbasins, and the rate of increase in nitrate in Squaw Creek was considerably greater in the subbasins than at the watershed outlet. The watershed outlets (WNT2 and SQW2) did not isolate areas of change well because they integrated water contributions from a large landscape area. With headwater contributions of stream nitrate playing such an important factor in downstream nitrate concentrations, changes in stream nitrate concentrations at the watershed scale were easily obscured by upstream areas. When areas of land use change were isolated at the subbasin scale, substantially greater water quality changes were observed.

The amount of change in nitrate concentrations in both watersheds (10 sites) was significantly related to the degree of change in watershed row crop land (Figure 8). While converting row crop to native prairie at the Refuge reduced the amount of row crop in the various watershed areas and reduced stream nitrate, converting CRP grass back to row crop in the Squaw Creek watershed increased the amount of row crop and greatly increased stream nitrate. The regression suggests that for every 10 percent change in row crop area in Walnut and Squaw Creek watersheds, a change of 1.95 mg/L nitrate may be expected to occur over 10 years.

In this study, the rate of nitrate increase following grassland conversion to row crop was greater than the rate of nitrate decrease following conversion of row crop land to prairie. Whereas a similar degree of land use change occurred in the Walnut and Squaw Creek subbasins that showed the greatest nitrate concentration changes, the rate of increase in nitrate concentration in Squaw Creek was more than double the rate of decrease in Walnut Creek. This comparison is complicated by several factors. Some of the difference in rate of change may result from the more gradual implementation of prairie restoration in Walnut Creek compared to rapid plowdown of CRP grassland in Squaw Creek. Furthermore, tile drainage contributions from areas converted back to row crop would increase the rate by which changes in water quality could be observed in streams. In contrast, most drainage tiles located in Walnut Creek prairie restoration plots were plugged or pulled wherever encountered by refuge staff.

Lag Times for Detecting Changes

The rate of change, as well as the lag time elapsed between land use change and water quality response , is governed by the hydrogeology of the watersheds, particularly by the velocity of ground water flow to deliver nitrate to streams. Uplands in Walnut and Squaw Creek watersheds consist of loess mantling pre-Illinoian till, whereas their floodplains are comprised of mainly silty alluvium. In the absence of tile drainage, nitrate leached from soils moves with shallow ground water to discharge to streams. In the Walnut and Squaw Creek watersheds dominated by low permeability glacial materials and glacial-derived alluvium, ground water flow velocities are slow.

Overall, the distance that ground water flowed during the 10-year monitoring project can be estimated by:

$$V = -K(dh/dl)/n$$

where V is the average linear velocity (m/s), K is the hydraulic conductivity (m/s), dh/dl is the hydraulic gradient (dimensionless) and n is the porosity. Assuming the K of the upland loess to be 0.2 m/yr (0.66 ft/yr) (Weisbrod, 2005), the gradient to be 0.04 and the porosity to be 0.3, the estimated ground water flow velocity is 0.027 m/day (0.089 ft/day). The distance that ground water would have flowed in 10 years is 98.6 m, or 323 ft. Thus, land use changes located at a distance beyond ~100 m (325 ft) from a stream would not be expected to have as much of an effect on base-flow contributions to stream water quality during 10 years of monitoring as land conversion closer to the stream. Most of the upland prairie plantings are located beyond this distance to a perennial stream. However, tile drainage can greatly accelerate the transfer of water quality effects to streams following land cover change.

In upland areas of the Neal Smith refuge, prairie restoration occurred largely in areas where tile drainage is minimal, not well maintained, or has been removed. In these areas, the lag time between nitrate concentration reductions from upland prairie restoration to change in stream nitrate levels is likely governed by ground water velocity. In contrast, row-cropped headwater regions of both Walnut and Squaw Creek watersheds are tile-drained. Most stream initiation points in both watersheds occur as tile outlets from headwater catchments, with first-order streams often beginning at road crossings as tile drainage discharge into a road culvert. In these tile-drained upland areas, land cover can have a large and rapid effect on water quality as subsurface water bypasses slow ground water transport and is rapidly directed to streams via tile lines. Thus, land use change in tile-drained uplands may have had a disproportionate effect on nitrate measured at the watershed outlets.

In the floodplain, a similar assessment of travel distance was made, though with less certainty due to variable alluvial stratigraphy. Depending on whether ground water flow was concentrated in coarser or finer alluvial sediments, ground water may have flowed from 34 to 1,157 m (110 to 3,796 ft) in 10 years. Considering that the width of the Walnut Creek floodplain varies between 183 and 366 m (600 and 1200 ft), it is believed that water quality improvements from all but the most recent prairie plantings occurring on the Walnut Creek floodplain have probably arrived at the stream and are affecting observed water quality. This would be consistent with dilution of upstream nitrate concentrations occurring as stream water moves through the lower portion of the Walnut Creek watershed.

One final note on the lag time for observing changes in ground water delivery of nitrate to streams is considered. The mean residence time for ground water in a ground watershed (the average amount of time needed for ground water to "turn over" in a ground water catchment area) can be estimated from aquifer porosity, saturated aquifer thickness and the areal recharge rate due to precipitation (Haitjema, 1995). The mean residence time for ground water in Walnut Creek is estimated to be approximately 14 years, although there is considerable uncertainty in this estimate. It is likely that the travel time for ground water in floodplains is less than the 14-year average, while the travel time for ground water located in uplands is probably much greater than 14 years. Therefore, the amount of time needed to detect all the water quality changes due to ground water from all areas of the watershed is ultimately on the order of several decades. This suggests that the full impact of land use change in both Walnut Creek and Squaw Creek is yet to be realized.

Conclusion

The Walnut Creek Monitoring Project began with an ambitious goal to implement a water quality program to document water quality improvements resulting from large-scale watershed restoration and management. Project results indicate that prairie restoration in an agricultural watershed can improve water quality with regard to nitrate concentrations and loads. Planting ~25 percent of the Walnut Creek watershed in native prairie resulted in a reduction of nitrate of ~1.2 mg/L over 10 years and 8 to 12 mg/l in subbasins. While this reduction cannot be considered substantial, it does shed light on the difficulty of detecting nitrate concentration changes in an agricultural setting where natural and anthropogenic N sources are ubiquitous and physical characteristics affecting nitrate delivery are highly variable. Upstream contributions from tile-drained, upland row crop areas had a significant effect on downstream water quality such that prairie restoration occurring primarily in the core of the watershed had the effect of diluting upstream nitrate contributions.

Nonetheless, native prairie restoration should be viewed as a viable conservation strategy for improving water quality in streams. Data from the Walnut Creek project extends the plot scale results (Randall et al., 1997; Brye et al., 2001) to a watershed scale to confirm that reintroduction of perennial grasses in the agricultural landscape can serve to reduce nitrate loss to streams. Project results highlighted the close relation of stream nitrate concentrations to land use change from row crops to grasslands. In Walnut Creek, converting row crop to grass reduced nitrate concentrations over time, but in Squaw Creek, stream nitrate concentrations rapidly increased when grasslands were converted back to row crops. Thus, it must be emphasized that grasslands placed in agricultural settings for water quality benefits should be part of a long-term solution to water quality problems if the water quality benefits are to be fully realized.

Early in the project, there was some question that the size of the Walnut Creek watershed might be too large to detect water quality changes. Results suggest that water quality changes were greater and much easier to detect in small subbasins compared to the watershed outlet. Considering that the Walnut Creek watershed is itself a rather small 12-digit HUC in Iowa, expectations for detecting water quality improvements from changing land use in even larger watersheds may need to be tempered given the results of this project. However, because all subbasins comprise part of larger and larger watershed areas, perhaps documenting improvements in stream water quality from conservation practices should be focused on small subbasins where changes can be detectable in shorter time frames. Detecting water quality improvements in larger watersheds will likely require a dedicated long-term monitoring effort on the order of several decades. But the value of proving the effectiveness of the conservation practices in small basins is undeniable.

References

Brye, K.R., J.M. Norman, L.G. Bundy, and S.T. Gower. 2001. Nitrogen and carbon leaching in agroecosystems and their role in denitrification potential. J. Environ. Qual. 30:58-70.

Clausen, J.C., and Spooner, J. 1993. Paired watershed study design: EPA-841-F-93-009, 8 p. Office of Water, Washington, D.C.

Grabow, G.L., J. Spooner, L. Lombardo, and D.E. Line. 1999. Detecting water quality changes before and after BMP implementation: use of SAS for statistical analysis. NWQEP Notes, Number 93, NCSU Water Quality Group, Campus Box 7637, Raleigh, NC.

Goolsby, D.A., Battaglin, W.A., Lawrence, G.B., Artz, R.S., Aulenbach, B.T., Hooper, R.P., Keeney, D.R., Stensland, G.J., 1999. Flux and sources of nutrients in the Mississippi-Atchalfalalya River Basin. White House Office of Science and Technology Policy Committee on Environmental and Natural Resources Hypoxia Work Group.

Haitjema, H.M. 1995. On the residence time distribution in idealized groundwatersheds. J. Hydrol. 172:127-146.

Hallberg, G.R., 1987. Nitrates in Ground Water in Iowa. In: Rural Ground Water Contamination, D'Itri, F.M., Wolfson L.G. (Editors). Lewis Publishers, Chelsea, Michigan, pp. 23-68.

Randall, G.W., D.R. Huggins, M.P. Russelle, D.J. Fuchs, W.W. Nelson, and J.L. Anderson. 1997. Nitrate losses through subsurface tile drainage in Conservation Reserve Program, alfalfa, and row crop systems. J. Environ. Qual. 26:1240-1247.

Schilling, K.E. 2001. Prairie restoration as a BMP for watershed water quality improvement: evidence from the Walnut Creek watershed, Jasper County, Iowa. p. 138-144. *In*: Bernstein N.P. and L. and Ostrander (eds.). Proc. 17th North American Prairie Conference, Seeds for the Future; Roots of the Past, North Iowa Community College, Mason City, IA.

Schilling, K.E. 2002. Chemical transport from paired agricultural and restored prairie watersheds. J. Environ. Qual. 31:1184-1193.

Schilling, K.E. 2005. Relation of baseflow to row crop intensity in Iowa. Agriculture, Ecosystems & Environment 105:433-438.

Schilling, K.E. and Libra R.D. 2000. The relationship of nitrate concentrations in streams to row crop land use in Iowa. Journal of Environmental Quality 29:1846-1851.

Schilling, K.E. and C.A. Thompson. 2000. Walnut Creek watershed monitoring project, Iowa: monitoring water quality in response to prairie restoration. Journal of the American Water Resources Association 36(5):1101-1114.

Schilling, K.E. and C.F. Wolter. 2001. Contribution of baseflow to nonpoint source pollution loads in an agricultural watershed. Ground Water 39:49-58.

Schilling, K.E. and Zhang Y.K. 2004. Contribution of baseflow to nitrate-nitrogen export in a large agricultural watershed, USA. Journal of Hydrology 295:305-316.

Sloto, R.A., and M.Y. Crouse. 1996. HYSEP: A computer program for streamflow hydrograph separation and analysis. U.S. Geol. Surv. Water Res. Invest. Rep. 96-4040, USGS Lemoyne, Pennsylvania.

Vache, K.B., J.M. Eilers, and M.V. Santelmann. 2002. Water quality modeling of alternative agricultural scenarios in the U.S. Corn Belt. J. Am. Wat. Resourc. Assoc 38:773-787.

Weisbrod, T. P. 2005. Modeling the influence of land use on shallow groundwater flow and nitrate transport, Neal Smith National Wildlife Refuge, Jasper County, Iowa. Unpublished MS thesis, University of Iowa, 136 p.

■

SPECIAL ANNOUNCEMENT

We are saddened by the sudden death of Dr. Frank Humenik on March 28, 2006. Dr. Humenik founded the NCSU Water Quality Group in 1980 through a USDA/EPA grant, and has been a leader in the field of animal waste management and water quality protection in the U.S. and throughout the world. We will miss Frank very much, and greatly appreciate all that he contributed to further advance the art and science of nonpoint source pollution control.

■

INFORMATION

Coastal Georgia Green Growth Guidelines

Georgia DNR's Coastal Management and Coastal Nonpoint Source Management Programs announce the availability of the new "Green Growth Guidelines," funded by NOAA under the Coastal Zone Management Act and developed in partnership with the Coastal Georgia Regional Development Center and EMC Engineering. Techniques such as site fingerprinting, low impact development practices, alternative stormwater and bank stabilization techniques are detailed. The economic benefits of conservation development are also analyzed and presented, as are the benefits to residents and the coastal community.

Specific objectives are to:

- Demonstrate how site fingerprinting and sensitive land planning can identify and protect natural resources
- Provide developers with instructions on how to build with minimal impact to the environment

- Compare low impact and conventional residential subdivision designs to show economic and environmental benefits of low impact development
- Demonstrate alternative stormwater drainage solutions that protect the quality of receiving waterbodies
- Introduce various soft engineering techniques used to protect and stabilize coastal stream banks from erosion

Georgia's Green Growth Guidelines manual is now accessible online at: **http://crd.dnr.state.ga.us/content/displaycontent.asp?txtDocument=969**. The guidelines are intended for the development community, engineers and land planners, local governments, natural resource managers, conservation advocates, and citizens. DNR anticipates this to be a living document with additions and updates planned.

New Book on Stream Stewardship

The Izaak Walton League of America has released *A Handbook for Stream Enhancement & Stewardship*, written by the staff of the Izaak Walton League's water programs. The Handbook is a basic resource intended to help individuals, groups, organizations, companies, communities, and governments plan and carry out environmentally sound, cost-effective stream corridor assessment, enhancement, and stewardship programs as they strive to bring degraded stream systems back to levels of stability and ecological well-being. This book is not intended as a technical manual for professionals, rather as a resource for volunteers.

The book is available from McDonald & Woodward Company at **www.mwpubco.com**, via email at **mwpubco@mwpubco.com**, by calling 800-233-8787, or by mail at 431-B East College Street, Granville, Ohio, 43023. The book costs $34.95. Agencies, organizations, businesses, and educational institutions are eligible for bulk discounts.

EPA Releases TWIST Database Tool for Managing Onsite Wastewater Treatment Systems

The US EPA Office of Water announces the release of *The WastewaterInformation System Tool* (TWIST), a free off-the-shelf, user-friendly management tool that allows state and local health departments to effectively inventory and manage septic systems and alternative decentralized wastewater treatment systems in their jurisdictions. TWIST is designed to track information such as homes and facilities served, permits, site evaluations, types of systems, inspections, and complaints.

Visit the US EPA Decentralized Wastewater Web site (**www.epa.gov/owm/septic**) for basic information about TWIST and ordering information.

■

WWW RESOURCES

Nutrient Management Planning Website

National Association of State Departments of Agriculture (NASDA), in cooperation with the Environmental Protection Agency (EPA) and USDA's Natural Resources Conservation Service (NRCS), has launched a new website for nutrient management planning information. The website is **http://www.cnmpwatch.com**.

The CNMP Watch website is designed to assist the agricultural livestock industry and others with information and guidance related to nutrient management plans and comprehensive nutrient management plans (CNMPs). The project was developed through NASDA's Research Foundation with a grant from EPA. The website includes news, events, nutrient management tools, manure management technologies, and links to other websites.

■

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 due July 28, 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

Submission Guidelines:

Abstracts for oral and poster presentations will be accepted through July 28, 2006. After July 28th, poster abstracts will continue to be accepted on a space available basis. The program committee will review all abstract submissions, make selections of oral and poster presenters and notify all authors in August 2006, whether accepted for presentation or not.

Link to Abstract Submission Form: **http://www.soil.ncsu.edu/extension/training/abstracts/index.php?num=5**

Link to Conference Website: **http://www.soil.ncsu.edu/swetc/lid/home.htm**

Meeting Announcements — 2006

July

StormCon '06: 5th Annual North American Surface Water Quality Conf & Expo: July 24 to 27, Denver, CO. See website: http://www.stormcon.com/sc.html

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/.

■

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, anad 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.

Conference website: **http://www.ctic.purdue.edu/NPSWorkshop/NPSWorkshop.html**

Contact:
Greg Johnson
Minnesota Pollution Control Agency
651-296-6938
gregory.johnson@pca.state.mn.us

Tammy Taylor
CTIC
765-494-1814
taylor@ctic.purdue.edu

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA) Grant No. X825012. 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

NCSU Water Quality Group
Department of Biological and Agricultural Engineering
North Carolina Cooperative Extension Service
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637

NC STATE UNIVERSITY

NCSU Water Quality Group
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637
Telephone: (919) 515-3723
Fax: (919) 515-7448
Website: http://www.ncsu.edu/waterquality/

Personnel

Jean Spooner
Robert O. Evans
Kristopher Bass
James Blackwell
Michael R. Burchell II
Jon Calabria
Daniel Clinton
Brandon Culberson
Barbara A. Doll
Garry L. Grabow
Karen R. Hall
William F. Hunt
Gregory D. Jennings
Bonnie Kurth
Daniel E. Line
Dave Penrose
Lara R. Rozzell
Catherine S. Smith
Laura Lombardo Szpir