

# Chapter 18

## Rock Creek Watershed, Ohio: National Institute of Food and Agriculture–Conservation Effects Assessment Project

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**T**he goal of the Ohio National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP), Land Use and Water Quality Trends in Rock Creek Watershed (Seneca County, Ohio), 1982–2005: Impact of Core-4 Conservation Practices, was to use data gathered by the National Center for Water Quality Research (NCWQR) at Heidelberg University at a monitoring station on Rock Creek in Tiffin, Seneca County, Ohio, in combination with historical data on conservation practice implementation in the watershed to determine trends in water quality since 1982 and to evaluate the strength of the evidence that these trends resulted from the implementation of conservation practices in the watershed.

Specific project objectives included the following:

1. Prepare water quality data and conduct trend analyses for the period of 1982 to 2003 for flow, suspended solids, total phosphorus (TP), soluble reactive phosphorus (SRP), nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ), and total Kjeldahl nitrogen (TKN). When data are available, extend the trend analyses through the year 2005.
2. Update county-level agricultural practice trend analyses to cover the same time period. Information should include no-tillage and conservation-tillage acres, Conservation Reserve Program (CRP) and other conservation acres, farm acres, crop acres in beans, corn, and wheat, animal units, sales of nitrogen (N) and phosphorus (P) fertilizer, and manure N and P based on animal units and standard coefficients.
3. Compare water quality trends and agricultural practice trends statistically to determine if cause and effect can be supported and to look for evidence of lag times between management changes and water quality changes.
4. Convert agricultural information, to the extent permitted by availability of data, from county-level statistics to georeferenced field-scale data in a Rock Creek geographical information system database using aerial photography available from the Seneca County USDA Natural Resources Conservation Service (USDA NRCS) and USDA Farm Service Agency offices.
5. Locate and/or develop the necessary geographical information system layers and build an Annualized Agricultural Nonpoint Source Pollution (AnnAGNPS) model of the Rock Creek Watershed, if possible, with cells that correspond to fields and other management units. Include explicit determination of tile drainage on a field by field basis. Calibrate

the model to reproduce observed flow, sediment, and nutrients. Validate it with data not used for calibration.

6. Use the model to explore the impacts of different placement of practices on the landscape, and for other management issues for which it is appropriate, and to address issues related to time lags in water quality response to management changes.
7. Report the results of this research through presentations at professional meetings or in one or more peer-reviewed papers. Develop media, such as extension fact sheets, to convey the results to the agricultural and management communities. Use the Web and water-related listserves to call attention to the project and its results.
8. Perform probabilistic risk assessment of AnnAGNPS output under different scenarios and compare results with a similar assessment of the observed Rock Creek data. Is AnnAGNPS capturing the distribution of flows and concentrations as well as the average or total quantities?

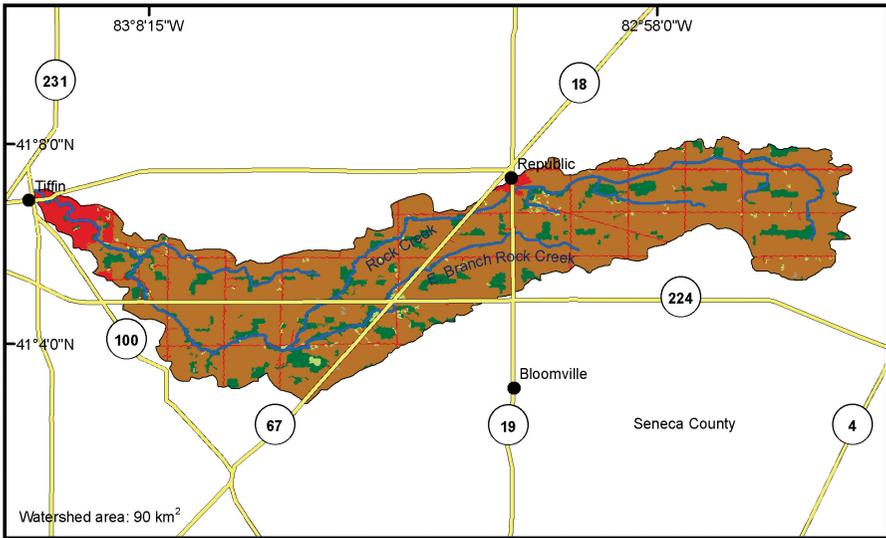
## Watershed Information

Rock Creek is a third-order tributary of the Sandusky River and is located wholly in Seneca County in north central Ohio (figure 18.1). Rock Creek enters the Sandusky River at Tiffin, Ohio. Rock Creek drains an 89.6 km<sup>2</sup> (34.6 mi<sup>2</sup>) watershed with soils that are developed primarily on end-moraine glacial deposits. Land use in the basin is 82% agriculture, 16% forest, and 2% urban and other land uses. Cropland consists of 50% soybeans, 30% corn, and 20% wheat. The main region of urban influence is the City of Tiffin located at the far western (downstream) edge of the watershed, at the confluence of Rock Creek and the Sandusky River. Only 25% of the city is actually located within the watershed boundary. The Sandusky River flows into Lake Erie, which is the principal water resource of concern.

Soils in the Sandusky River Watershed consist of three primary soil groups (Blount, Pewamo, and Glynwood) and are a function of the bedrock geology, which is a mixture of limestone, sandstone, and shale, and the surficial geology, which is a mixture of moraine and lake deposits. These soils are mostly loams and silt loams and are formed in loamy till of high carbonate content. Topography and soils in Seneca County are described as having slopes of 2% or less, although Rock Creek has more relief than much of the rest of the county because it is mostly adjacent to a major end moraine. Slopes of 1% or less are tile drained. Although only a small area of the Rock Creek Watershed has soils designated as highly erodible, ~65% of watershed soils are considered to be potentially highly erodible. Highly erodible soils have a maximum potential for erosion that equals or exceeds eight times the tolerable erosion rate. Actual erosion may be lower as the maximum erosion potential does not account for cropping or structural practices that could reduce erosion.

Most soils in the watershed can be highly productive for growing corn, soybeans, and wheat crops. Poor natural drainage and frequently saturated soil water conditions in the root zone have caused farmers to install buried subsurface drainage systems (tiles) on most cropland. A range of conservation tillage practices is employed in the region; common features include crop residue left in the field and no moldboard or chisel plowing in most or all years. Conservation tillage practices usually comprise chisel plowing in the fall and cultivating with disking in the spring. Climatic conditions and farmer preferences sometimes result in all tillage operations being conducted in the late winter and spring. The most common crop rotations are corn–soybeans–corn–soybeans–

**Figure 18.1**  
 Rock Creek Watershed, Ohio, land use and stream networks.



**Legend**

- Agricultural land
- Forest
- Rangeland
- Water
- Urban



Scale: 1:200,000

wheat and corn–soybeans–soybeans–wheat. Soybeans and wheat are commonly grown under conservation tillage, but corn typically receives more extensive tillage, although not complete inversion. Livestock production has declined in the watershed since the 1980s; there is very little livestock in the watershed today. Any manure applied in the watershed is in a dry form.

The basin receives an average of 958 mm  $y^{-1}$  (37.7 in  $yr^{-1}$ ) of precipitation (Tiffin weather station, 1975 to 2007) with the majority typically occurring in the spring, early summer, and fall. Base flow represents about 16% of streamflow (hydrograph separation by the Web-based Hydrograph Analysis Tool, WHAT [<http://cobweb.ecn.purdue.edu/~what/>], for Rock Creek period of record, using recursive digital filter for perennial stream with hard rock aquifer). These streams are very flashy.

## Water Quality Information

Eutrophication and hypoxia in Lake Erie are due to excessive sediment and nutrient loading, with significant contributions from agricultural nonpoint sources (Forster and Rausch 2002; Richards et al. 2008; Richards et al. 2002; Richards and Baker 2002; Moog and Whiting 2002; Calhoun et al. 2002). The Rock Creek monitoring station began operation in 1982 in

response to the need to understand nonpoint source sediment and nutrient loading to Lake Erie, especially P, which is the limiting nutrient in the lake. This 26-year record contains data from 12,635 samples.

Constituents of concern are suspended sediment, P, and N delivered from cropland to major tributaries in the western Lake Erie area. Efforts toward water quality remediation have focused on P. It was assumed that N can be fixed by cyanobacteria, and therefore, cannot be controlled.

Water quality is monitored at a single station at the outlet of Rock Creek 0.8 km (0.5 mi) from the confluence with the Sandusky River, collocated with the US Geological Survey (USGS) gage for Rock Creek (USGS 04197170), thus sampling the water quality for the watershed as a whole. Because monitoring occurs only at the watershed outlet, the lack of internal site-specific water quality monitoring relative to land treatment that is occurring throughout the watershed is an acknowledged gap in project data. The length and detail of the water quality monitoring record, however, offsets the lack of spatial resolution.

The Rock Creek water quality monitoring station has been in continuous operation since 1982. A refrigerated autosampler takes three samples per day from a sink within the station, into which water from the creek is pumped continuously by a submerged pump in the creek. All samples collected during periods of storm runoff are analyzed, whereas one sample per day collected during low flow is analyzed. Samples are analyzed for suspended solids, TP, SRP,  $\text{NO}_3\text{-N}$ , TKN, dissolved reactive silica), and major anions. Qualitative and quantitative biological sampling is carried out periodically by staff and by the Ohio Environmental Protection Agency.

Data are kept in Datatrieve databases on the NCWQR VAX mainframe and in Microsoft Excel files on various computers. Data are also in STORET (STORAGE and RETRIEVAL), though the complete dataset is not available there. Data can be accessed from the National Center for Water Quality Research Web site (Heidelberg University 2011).

Water quality trend analyses for Rock Creek were first done as part of the Lake Erie Agricultural Systems for Environmental Quality (LEASEQ) study, which revealed significant downward trends in flow and suspended solids, TP, SRP,  $\text{NO}_3\text{-N}$ , and TKN concentrations. The LEASEQ study was a collaboration of investigators from Heidelberg University, The Ohio State University, and Case Western Reserve University. It investigated the relationships between water quality and agricultural practices in the Maumee and Sandusky basins in north-west Ohio for the period of 1975 and 1995.

A major finding of the Rock Creek NIFA–CEAP was that these trends continued through 2008 for sediment and TP, but SRP concentrations have increased sharply over the last 13 years.

## Land Treatment

Numerous conservation efforts have taken place in the region over the last several decades based on standard USDA NRCS practices to control erosion. The USDA NRCS staff worked with farmers interested in being early adopters of conservation tillage. Practices included conservation tillage, no-tillage, and grassed waterways. Producers were motivated to change practices due to the advantages of conservation of tillage; water quality is not immediately important to them because Lake Erie is too far away to be the determining reality for the producers. There was no targeted approach, however, to reducing sediment or nutrients. Fortunately, in the past 30 years, most producers have moved to minimum or no-tillage for soybeans and wheat. Corn receives more extensive tillage. Other conservation practices include Conservation Reserve Enhancement

Program (CREP) and CRP funding to add buffers and take land out of production. In addition to conservation practice implementation, both farm acreage and animal numbers in the watershed have decreased in the last several decades.

Fertility management has been an important practice; however, there has been an increase in soil test P even though fertilizer P rates have declined. Most of the soil samples are within the agronomic range for P. Nonetheless, most producers could reduce their P fertilization without loss of yield. Grid sampling and precision application of fertilizers are only used by a few innovative farmers. As tillage practices have changed, so too has the timing of fertilization. Typically, fertilizer is added in the fall after wheat harvest; often sufficient fertilizer is added to replace nutrients removed in the wheat crop and to support successive corn and soybean crops. The wheat straw is flailed, and then the fertilizer is topdressed. Depending on the tillage choice, the fertilizer may or may not be worked into the soil. When corn is planted, starter P and all N is applied. No fertilizer is applied to the soybeans, and removal rates of P are applied to the wheat as is a topdressing of N in the spring. Typically, the soil is tilled for the corn, and all other crops are planted and managed with no-tillage. There has been a shift from spring fertilization to fall fertilization.

There was no concurrent monitoring of land treatment practices as water quality data were collected. Therefore, conservation practice data could not be attributed spatially. The Rock Creek NIFA–CEAP linked water quality trends and land use and agricultural trends to infer cause and effect through trend analysis. The prior LEASEQ study found that conservation choices were generally rather inefficient. The majority of conservation funds were spent on less cost-effective choices. There was poor correlation between areas with high soil erosion rates and areas that attracted large funding. For the Rock Creek NIFA–CEAP, primary data on conservation tillage were collected by on-the-ground measurements (e.g., point-intercept and photographic techniques of measuring crop residue) correlated with a supervised classification of Landsat 5 Thematic Mapper imagery.

Recent history of conservation practices is available from the Seneca County USDA NRCS and USDA Farm Service Agency office since 1984. The project determined the number of acres under different tillage levels: <30% cover, 30% to 90% cover, and >90% cover. Project personnel calculated the amount of N and P fertilizer, and manure N and P based on animal units and standard coefficients. However, there is little animal agriculture in this basin.

Data on watershed-wide agricultural trends were obtained from the National Agricultural Statistical Service, Conservation Technology Information Center, and the Ohio Department of Agriculture. Considerable effort was made to collect data on crop type using interpretation of satellite imagery. However, significant difficulties in distinguishing among crop types were encountered.

## Water Quality Response

Improvements in the mass balance of P inputs and outputs from the watersheds between 1975 and 1995 have been documented. Water quality trend analyses for Rock Creek, conducted as part of the LEASEQ study, revealed significant (~30% to 50%) downward trends in flow and in suspended solids, TP, SRP, NO<sub>3</sub>-N, and TKN concentrations. Trend analysis of daily water quality and flow data documented significant trends. Analysis of concentration-flow relationships indicated that the observed changes were not due to weather but reflected genuine

decreases in sediment and nutrient concentrations due to management changes in the watersheds. Declining TP led to an initial reduction in algal blooms in Lake Erie.

Project results showed that water quality trends include improved conditions (lower sediment and nutrient loads) and that these trends result from intentional changes in the use of the land. On the basis of the nature, timing, and magnitude of the water quality changes, project investigators have previously determined that they could have been caused by changes in the management practices, primarily conservation tillage and improved fertilizer management. Within the last 10 years, flow has increased (table 18.1). Since 1995, there has been an increase of SRP. As SRP has increased, algal blooms have also increased in extent and severity.

Analysis of data from the larger Sandusky Watershed suggested that the greatest decreases are associated with summer and fall and with low flow conditions, whereas the smallest decreases are associated with the spring and with high flow conditions. Regression analysis was used to evaluate trends in water quality (sediment and nutrients) and in agricultural management (number and size of farms, farm acreage, crops, tillage, buffers, fertilizer management, etc.). Data were typically log-transformed prior to analysis because most environmental data are approximately log-normally distributed. Constituent concentrations were adjusted to reduce short-term variability due to correlations with flow using a LOWESS fit of log-concentration versus log-flow. Analyses were performed using daily data; prior experience indicates that this approach is more powerful than analyzing data aggregated to monthly or annual intervals. Autocorrelation is important at the daily time step, and the t-test values used to determine significance must be adjusted to account for the loss of information due to this autocorrelation. Trend analyses done in this fashion assumed a linear change in log-concentration over time. Further insights can be gained by examining plots of constituent concentrations as a function of time, with a superimposed LOWESS fit, that is responsive to changes in the rates of change over time but does not permit statistical significance testing. This kind of plot is particularly useful in comparing the timing of water quality changes with that of practice implementation.

Large rain events in Water Year 2007 (October 1, 2006, to September 30, 2007) caused the greatest discharge observed since monitoring on the Maumee and Sandusky rivers began (Richards et al. 2010). As a consequence of the record high discharge, TP, SRP, TKN, and chloride loads were the highest ever recorded. A warm, wet fall and early winter exacerbated the record-setting rainfall at the Tiffin weather station (Sandusky Watershed), which reduced producers' ability to complete field work, including fall fertilization. Likewise, the same con-

**Table 18.1**

Percent changes in values of water quality parameters at Rock Creek, Ohio, per decade, before and after 1995.

Parameter	Before 1995	After 1995	Parameter	Before 1995	After 1995
Flow	-17	+32	SS	-12	-32
TP	-27	+12	SRP	-45	+306
NO <sub>3</sub> -N	-12	+17	SRP/TP	-27	+301

Notes: SS = suspended sediment. TP = total phosphorus. NO<sub>3</sub>-N = nitrate-nitrogen. SRP = soluble reactive phosphorus.

sequences occurred with the nearly largest rainfall at the Toledo station (Maumee Watershed). Nitrate, particulate P, and suspended solid loads were not the largest ever recorded; nitrate loads ranked 5th (Sandusky) and 8th (Maumee) out of 33, particulate P loads ranked 2nd (Sandusky) and 4th (Maumee), and suspended sediment loads ranked 10th (Sandusky) and 9th (Maumee). These losses represent a significant cost to the producers in replacement fertilizer—more than US\$85 million or US\$166 ha<sup>-1</sup> (US\$67 ac<sup>-1</sup>). Successes in reducing TP and sediment in these watersheds due to large increases in conservation tillage were apparent during the record-setting rainfall as particulate P and sediment losses did not constitute the greatest loads ever recorded. However, large hydrologic events in interaction with agricultural management activities (such as broadcast fertilization due to the conservation tillage system) can greatly affect total nutrient losses, as seen by the record-setting losses of TP, SRP, TKN, and chloride, even when conservation practices have been implemented.

## Model Application

Monitoring data were only available at the watershed outlet, and therefore, modeling was used to directly discriminate effects of multiple practices and landscape effects at the watershed scale. A well-developed, properly calibrated and validated model was thought to be the best resource to assess these complex issues. Only a model could apply different practices to different regions of the same landscape and compare outcomes. That is, only a model could perform multiple management experiments with the same watershed over the same time period.

Climate conditions were represented in the AnnAGNPS by data from a single weather station; no spatially distributed climate inputs were attempted. Soils data were from the Soil Survey Geographic (SSURGO) database. Land use and management characteristics were evaluated using multispectral, multitemporal analyses of satellite imagery. There were several theses written where students tried to calibrate Landsat Thematic Mapper maps to determine tillage types and crops, but the results were less than ideal because different students made different decisions in developing their classifications. There was no attempt to obtain spatial data developed from USDA NRCS records.

Conservation practices were represented using default values in AnnAGNPS database. The model was calibrated for flow using autocalibration routines, but successful calibration was not achieved for sediment or nutrients. Efforts to model the impact of conservation practices were based on hypothetical combinations of practices, not actual conservation practices installed in the watershed.

The initial goal of the project modeling effort was to build an AnnAGNPS model of the Rock Creek Watershed with cells corresponding to fields and other management units. However, a series of personnel changes and inherent shortcomings of the AnnAGNPS model presented major challenges to achievement of this goal. The work was subcontracted to the University of Toledo which developed the AnnAGNPS model, but the contract expired before they could run the model to confirm different conservation practice scenarios. Initially, familiarity with the AnnAGNPS model was a major consideration for its selection. Also, AnnAGNPS cannot simulate tile drainage, grassed waterways, fields, or changes in tillage during a run. Changes in land use and land management required recalibration of the model. The model significantly overpredicted sediment (by 100%) and N (by 30%) loads.

Due to these shortcomings and the personnel changes mentioned, the project switched to the Soil Water Assessment Tool (SWAT). While SWAT uses many of the same input files and has some of the same limitations, it was judged more suitable to the project needs, and the new modeler on the team had substantial prior experience with this model. However, work with SWAT started at the project end. Because of the difficulties with AnnAGNPS described above, the initial hypotheses stated in project objectives based on AnnAGNPS modeling were not tested in the Rock Creek Project.

Currently, a new faculty member is working with SWAT and is calibrating and validating the model. However, because the project is now completed, any modeling results will be available postproject.

## Socioeconomic Analysis

A survey of farmers was conducted to evaluate awareness of and attitudes about conservation practices, adoption of conservation practices, and use of farm support agencies. In addition the census collected reasons for participation or nonparticipation, economic consequences of conservation practices, and the farmers' socioeconomic profiles. Of the farmers who returned the survey, almost 50% had fewer than 40.5 ha (100 ac). Nearly 40% of farmland owners rent farmland to operators, rather than farming it themselves; 67% of farmers finished high school; and about 18% had an undergraduate or graduate degree. Of the farmers surveyed, 46% also worked off the farm. There was one hog operation in the watershed and some beef cattle, but there were only, on average, 52 cows per farm.

There was a considerable amount of uncertainty about water quality, water quality impairments, and causes, although most farmers surveyed thought water quality was important and that water quality was reasonably good. Approximately 30% of those surveyed did not know how much of a problem different contaminants might cause for their water supply.

Results of the survey suggest that most watershed farmers use reduced tillage to protect against erosion (72%) and regularly conduct soil tests (68%). It was suggested that farmers use soil test data primarily for the pH results to assess the need for lime application, rather than for nutrient management purposes. There was almost no animal livestock in the watershed; therefore, producers did not work with Soil and Water Conservation Districts on nutrient management. Most farmers thought that their coop was making nutrient management plans. A large percentage of farmers stated that they used grassed waterways, filter strips, and/or windbreaks to reduce erosion and soil loss (80%) and participated in recycling events for disposal of accepted items (82%).

Profitability, out-of-pocket expenses, concern about yield losses, personal views of the practice, yield, and environmental benefit were all extremely important in farmers' decision making on the use of new practices—more than 73% of the farmers used these criteria for making decisions. Other factors important for making decisions about new management practices included lack of government funds to cover cost share, possible environmental damage, ease of use, personal views about farming, time needed to learn new skills, concern that the practice will interfere with farming practices, and lack of equipment. Clearly producers used multiple factors when considering the introduction of new practices into their farming systems.

## Outreach

Outreach objectives for the Rock Creek NIFA–CEAP were to provide information about the effectiveness of specific conservation practices to extension personnel, producers in the watershed, and The Sandusky River Watershed Coalition.

Ohio State University extension personnel developed a farmer survey that was mailed to all producers (~180) or farmers in the watershed, with a 40% return rate. They developed a newsletter for the producers that discussed the results of the survey. Extension also held a field day to focus on conservation practices identified through the survey and then sent producers a follow-up survey to see if the outreach had any benefit. The primary outreach communication was through the newsletters and field day conducted by the watershed team. Most of the information communicated was from the producer survey or from local or regional agricultural and environmental professionals, rather than strictly from project results.

The Sandusky River Watershed Coalition, one of the most active and successful in Ohio, is currently revising its watershed plans at the 11-digit hydrologic unit code level with the support of the NCWQR. They are also working with fertilizer dealers on a separate project that has soil test results from different depths and is indicating stratification of P due to conservation tillage. They have started showing producers and dealers that US\$14 million for P and US\$71 million for N are being lost into Lake Erie from the Maumee and Sandusky rivers (~US\$166 ha<sup>-1</sup> [~US\$67 ac<sup>-1</sup>]). This really increased awareness of what these losses mean to producers. The results of this project were of great interest and utility to them.

## Rock Creek Watershed National Institute of Food and Agriculture–Conservation Effects Assessment Project Publications

This project's results have been published in numerous journal articles and other publications. The list of these publications is provided below.

### Publications

- Richards, R.P. 2007. Report on a roundtable discussion about realistic expectations for agricultural BMPs. *In* Environmental Benefits of Conservation on Cropland: The Status of our Knowledge, ed. M. Schnepf and C. Cox. Ankeny, IA: Soil and Water Conservation Society.
- Richards, R.P., D.B. Baker, and J.P. Crumrine. 2006. Detecting water quality responses to land management changes: Why is it so difficult? *In* Proceedings: Innovations in Reducing Nonpoint Source Pollution: Methods, Policies, Programs, and Measurement, November 28-30, 2006, 81-91. Rivers Institute at Hanover College, Hanover, Indiana.
- Richards, R.P., D.B. Baker, and J.P. Crumrine. 2009. Improved water quality in Ohio tributaries to Lake Erie: A consequence of conservation practices. *Journal of Soil and Water Conservation* 64(3):200-211, doi:10.2489/jswc.64.3.200.
- Richards, R.P., D.B. Baker, J.P. Crumrine, J.W. Kramer, E. Ewing, and B.J. Merryfield. 2008. Thirty-year trends in suspended sediment in seven Lake Erie tributaries. *Journal of Environmental Quality* 37:1894-1908.
- Richards, R.P., D.B. Baker, J.P. Crumrine, and A.M. Stearns. 2010. Unusually large loads in 2007 from the Maumee and Sandusky Rivers, tributaries to Lake Erie. *Journal of Soil and Water Conservation* 65(6):450-462, doi:10.2489/jswc.65.6.450.

## Presentations

- Czajkowski, K., J. Jowett, R.P. Richards, and J. Coss. 2006. Development of a GIS for the Rock Creek Watershed, including remote sensing techniques. PowerPoint presentation. Ohio Geographically Referenced Information Program seminar, Columbus, OH.
- Jowett, J., K. Czajkowski, R.P. Richards, and J. Coss. 2006. Land use and water quality trends in Rock Creek Watershed (Seneca Co., OH). PowerPoint presentation. East Lakes Division, Association of American Geographers, Toledo, OH.
- Richards, R.P. 2005. USDA-NIFA CEAP Rock Creek Project: Plans and early results. PowerPoint presentation. USDA CEAP Project Meeting, USDA-CEAP Meeting, Fort Wayne, IN, July 27, 2005.
- Richards, R.P. 2005. USDA-NIFA CEAP Rock Creek Project: Plans and early results. PowerPoint presentation. USDA CEAP Project Meeting, Columbus, OH, November 4, 2005.
- Richards, R.P. 2006. Detecting water quality responses to land management changes: Why is it so difficult? PowerPoint presentation. CEAP Symposium, Columbus, OH, March 1, 2006.
- Richards, R.P., and D.B. Baker. 2007. Thirty-year trends in phosphorus in Lake Erie tributaries: What's happening and why? PowerPoint presentation. Cleveland State Biological, Geological, and Environmental Sciences Department Seminar, Cleveland, OH, April 20, 2007.
- Richards R.P., D.B. Baker, J. Coss, J. Crumrine, K. Czajkowski, J. Kramer, R. McCall, and J. Stafford. 2006. The Rock Creek (Ohio) Conservation Effects Assessment Project: Plans and preliminary results. Poster. 2006 Water Conference, San Antonio, TX.
- Richards, R.P., D.B. Baker, and J.P. Crumrine. 2007. Increased dissolved phosphorus loading to Lake Erie from agricultural watersheds. PowerPoint presentation. Great Lakes Protection Fund Workshop, Tiffin, OH, December 18, 2007.

## Theses

- Jowett, J.H. 2006. Identification of Conservation Tillage Practices in Rock Creek Watershed Seneca County, Ohio, Utilizing Landsat 5 Thematic Mapper Imagery. MS thesis, University of Toledo.
- Yao, L. 2005. Evaluating the Effect of Minimum Noise Fraction Transformation (MNF) in Crop Classification using Multi-Temporal Landsat Images. MS thesis, University of Toledo.

## Project Web Site

Heidelberg University. Tributary Data Download. <http://www.heidelberg.edu/academiclife/distinctive/ncwqr/data>.

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Funding of US\$547,000 for this project was provided by the USDA NIFA-CEAP (Award No. 2004-51130-02252).

## Project Personnel

Pete Richards (chemical limnologist) was project investigator at Heidelberg University. Coproject investigators included Kevin Czajkowski (Director of the Geographic Information Science and Applied Geographics Lab at the University of Toledo) and Joe Bonnell (research scientist, Water Quality Extension) at The Ohio State University. Other participants included Rem Confesor (Heidelberg University), David Dean, Jeff Jowett, James Coss, and Ling Yao (all formerly with the University of Toledo), and Jim Stafford (formerly with USDA NRCS, Columbus, Ohio).

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