Potential Benefits of Perpetual Easements on Phosphorus Reduction in Minnesota

Research addendum-post peer review

Legislative Citizens Commission on Minnesota Resources

Project Number: 5i

Project Leaders:

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PROJECT SUMMARY

This study will examine limited-duration and perpetual easements and their effectiveness at reducing phosphorus transport to streams. The U.S. Geological Survey (USGS), Minnesota Board of Water and Soil Resources (BWSR), and the Hawk Creek Watershed Project (HCWP) will work collaboratively to examine West Fork Beaver Creek watershed in Renville County, which has the largest number of Re-Invest In Minnesota (RIM) land retirement contracts in the state. The project builds on previous Environmental and Natural Resources Trust Fund (ENTRF) projects that demonstrated numerous benefits related to land retirement, including reductions in nitrogen concentrations and improvements in fish quality.

PROBLEM

Most studies of management practices are not long enough to evaluate reductions in phosphorus. Failure to show phosphorus reductions may reduce support for land retirement programs. It is up important that scientists and resource managers to demonstrate that immediate reductions in phosphorus may not always be expected. Recent ENRTF projects (ML 2005 Subd. 7(c) and ML 2007 Subd. 5(c)) studied the impacts of agricultural land retirement programs on stream water quality and biotic integrity at sites in the Minnesota River Basin. The projects demonstrated that land retirement programs are a positive influence on stream quality, resulting in lower nitrogen concentrations and better fish quality. However, these studies did not demonstrate a relation between **phosphorus** and **amount** of land retirement.

West Fork Beaver Creek is an important local resource and has a high profile among recreational users, especially kayakers. The high resource quality, visibility to Minnesota recreationists, and on-going data collection in the watershed, make it ideal for this investigation. The HCWP has noted that phosphorus concentrations have decreased in West Fork Beaver Creek over the past 10 years, coinciding with the commencement of land retirement through the Reinvest in Minnesota (RIM) program and Conservation Reserve Enhancement Program (CREP). Renville County, which includes most of the West Fork Beaver Basin, has the greatest number of acres enrolled in the RIM program in the State of Minnesota, for the longest duration (most of the easements in Renville County are perpetual).

State and local agencies would like to establish why previous research comparing retired land across basins showed no relation to total phosphorus, whereas the West Fork Beaver Creek has had decreases in total phosphorus over time, since the implementation of the RIM and CREP programs. Therefore, the hypothesis of this research is that reductions in stream phosphorus concentrations are related to the **length of time** that the surrounding land has been in retirement. In other words, a comparison of the average age of land retirement contracts per year in the West Fork Beaver Creek watershed will be inversely related to annual phosphorus concentrations in the West Fork Beaver Creek watershed.

Confirming this hypothesis would be important to BWSR management decisions and policy of prioritizing perpetual easements over limited duration easements and may encourage more participation. This also will be useful to BWSR management for setting priorities and providing for responsible use of taxpayer dollars.

BACKGROUND

The West Fork Beaver Creek watershed (fig. 1) located primarily in Renville County lies within the Midwest Corn Belt, one of the most productive and intensively managed agricultural regions in the world. Current agricultural practices use large quantities of chemical fertilizers to maintain productivity. The West Fork Beaver Creek watershed is 84.8 percent cultivated crops (data from National Land Cover Database, 2001; U.S. Geological Survey, 2003) and 60.4 percent of Renville County is treated with fertilizer (U.S. Department of Agriculture, 2002). The nutrients in these fertilizers have the potential for deleterious effects on stream quality.

Two previous USGS and ENTRF funded projects examined the effects of agricultural land retirement. The first of these projects (ML 2005 Subd. 7(c)), examined water-quality and biological characteristics in three streams in the Minnesota River Basin during 2006-08 (Christensen and others, 2009). One of these three streams was the West Fork Beaver Creek. Through the course of this study, samples were collected and analyzed by the USGS, with additional samples collected by the HCWP. Continuous real-time water-quality monitoring was used in addition to water-quality sampling, physical habitat characterization, benthic algae collection, invertebrate and fish collection, and a survey of biomass accumulation. This study gave a detailed assessment of the basins and, in general, showed that total nitrogen concentration, suspended sediment concentration, chlorophyll-*a* concentration, and fish resource quality improved with increasing land retirement percent. For these three basins, the 2006-08 data showed no relation between land retirement percent and total phosphorus.

The second USGS and ENTRF funded study (ML 2007 Subd. 5(c)) examined the relative importance of agricultural land-retirement on water quality and aquatic-community responses across 82 sites in the Minnesota River Basin. In this study, chemical and biological data

collected by the Minnesota Pollution Control Agency were used. Each site had one sample for water quality, fish, invertebrate, and physical habitat data collected during the same season. Three Geographic Information System (GIS) layers, National Land Cover database (NLCD), State Soil Geographic database (STATSGO), and number of acres in land retirement programs also were used in the analysis. In order to assess the interrelation among physical and chemical factors on stream conditions, multivariate analysis of co-variance (MANCOVA) and analysis of co-variance (ANCOVA) models were performed. MANCOVA and ANCOVA models indicated that other environmental factors (such as watershed area) commonly were correlated to aquatic-community response, as were in-stream factors (for example, substrate type). The results indicated that although agricultural land retirement was significantly related to fish quality, a combination of watershed, riparian and in-stream factors act together to influence index of biotic integrity scores. There was no relation between total phosphorus concentration and agricultural land retirement *on a spatial scale* (Christensen and others, in review).

Neither study showed a relation between total phosphorus and retired land on a spatial scale. This lack of relation, combined with decreasing total phosphorus concentration data from the Hawk Creek Watershed Project has lead to the hypothesis that total phosphorus and retired land are related *on a temporal scale*.

A review of recent research (Meals and others, 2010) has shown that phosphorus may lag behind other water-quality improvements when a management practice (such as land retirement) has been adopted. Although some reduction in concentrations may occur soon after implementation of a management practice, full benefits may not be seen for as many as 10 years. This is especially true for projects where plant communities need time to become established (Meals and others, 2010; Newbold and others, 2008). In addition, where soil phosphorus levels are high, it may take many years for the dissolved phosphorus

concentrations to be reduced (McCollum, 1991; Zhang and others, 2004; Sharpley and others, 2007). Therefore, because some areas of the Minnesota River Basin have high soil phosphorus concentrations and because land retirement takes time for the plants to become fully established, delays in total phosphorus reduction should be expected.

OBJECTIVES AND SCOPE

The objective of this study is to determine if the age of land retirement is related to changes in total phosphorus concentrations in the West Fork Beaver Creek watershed. GIS data analysis will cover the West Fork Beaver Creek basin. Samples will be collected at the site location indicated in figure 1 (USGS site id# 0531656290) in 2011 and 2012. Statistical analyses will include HCWP data and USGS data from 1999-2012.

STUDY AREA AND SETTING

The West Fork Beaver Creek is part of the Minnesota River Basin. The Minnesota River Basin is located primarily within south-central Minnesota in an area characterized by dissected till plains, undulating till plains, lake plains, and glacial moraines (Stark and others, 1996). The West Fork Beaver Creek watershed is part of the till plains and drumlins physiographic province (Payne, 1994). The terrain is generally flat and the rocks are easily erodible.

Agriculture has a major effect on water quality in the Minnesota River Basin (Battaglin and Goolsby, 1999). Intensive use of agricultural chemicals has resulted in nonpoint-source contamination of surface water throughout the basin. Agricultural activities, such as channelization and the installation of tile drains, also have changed local hydrologic conditions.

The drainage area of West Fork Beaver Creek is approximately 247 square kilometers (km^2) at the current Hawk Creek Watershed Project sampling location (fig. 1). This also is the location where the USGS sampled in 2006-08. Land use in the West Fork Beaver Creek watershed is 84.8% cultivated crops, 1.6% pasture or hay, 1.1% forest or shrub, 6.7% open water, and 5.7% developed or barren land (from the National Land Cover Dataset 2001, U.S. Geological Survey, 2003).

APPROACH

Activity 1: Collect water samples and evaluate existing data from multiple sources and time periods.

The West Fork Beaver Creek has been the site of several recent research studies and monitoring efforts. Something that often is overlooked in studies that use existing data is an evaluation of the field and laboratory techniques and methods used. To provide sound results and address the hypothesis effectively, an evaluation of the differences in techniques is critical. Without this type of quality-control data, the water-quality of West Fork Beaver Creek cannot be interpreted adequately because errors associated with the sample data are unknown.

In addition to the regular sampling occurring at West Fork Beaver Creek, the HCWP will assist the U.S. Geological Survey in the collection of environmental and quality-assurance samples during 2011-12. Field values for water temperature, specific conductance, pH, and dissolved oxygen will be recorded at the time of sampling. Samples will be sent to the Minnesota Valley Testing Lab and the U.S. Geological Survey National Water Quality Laboratory for nutrient analyses. Minnesota Valley Testing Laboratory will analyze using EPA 365.1 (total phosphorus), SM 4500 NorgB/NH3E (Total Kjeldahl nitrogen), and EPA 353.2 (nitrite plus nitrate).

Most samples will be collected using equal-width increment techniques (EWI; Wilde and Radke, 1998). These EWI samples will be composited in a churn splitter. Split replicate samples will be collected from the churn and sent to the two labs. The purpose of the split replicate samples is to minimize any differences from sampling techniques in order to determine differences associated with the labs. Replicate error for the study period (2011-2012) will be calculated using relative percentage differences (see Christensen and others, 2009). An additional grab sample will be collected from the centroid of flow. This will provide a comparison between grab and EWI methods.

Historical continuous streamflow data and periodic total phosphorus data will be obtained from the HCWP. Protocols and methods of the Minnesota Valley Testing Lab will be reviewed in order compare to historical phosphorus values. Historical reference sample data (for example, USGS round-robin data) for low level nutrients will be obtained from the labs. If comparable historical reference sample data is not available, low level nutrient samples for the USGS round-robin program (Ludke and Woodworth, 1997) will be sent to Minnesota Valley Testing Laboratory to determine whether there are differences in bias or variability between labs. The HCWP used a third laboratory for some of the historical total phosphorus analyses. The USGS will obtain the data and quality-assurance information from this third lab in order to determine if the data are of acceptable quality to include in the analysis. The collection activities may be adjusted to send a third split replicate sample to this lab for quality-control purposes.

The environmental samples will provide a longer data set in which to assess the effects of land retirement and the quality-control samples will offer continued assurance that the data sets are comparable. The relative percentage difference (error) will be used to evaluate approximately 10 years of existing data. The outcome of Activity 1 will be a quality-assured data set for use in Activity 2.

Table 1. Proposed sampling schedule

Date[1]	Collector	Sample type	QA sample type	Laboratory	Constituents	No. of samples
7-15-11	USGS	ewi	Environmental+blank	NWQL	Field properties, nutrients	2
	USGS	ewi	Split replicate (lab replicate)	MVTL	Field properties, nutrients	1
	HCWP	grab	Environmental	MVTL	nutrients	1
8-1-11	HWCP	grab	Environmental+field replicate	MVTL	Field properties, nutrients	2
7-15-12	USGS	ewi	Environmental+blank	NWQL	Field properties, nutrients	2
	USGS	ewi	Split replicate (lab replicate)	MVTL	Field properties, nutrients	1
	HCWP	grab	Environmental	MVTL	nutrients	1
8-1-12	HWCP	grab	Environmental+field replicate	MVTL	Field properties, nutrients	2

[1]sampling dates are approximate. These samples are in addition to those collected by HWCP under other grants.

Activity 2: Perform geographic spatial analysis of historical RIM participation, summarize documentation and statistical analysis of landscape patterns of RIM participation, and write a final report

Land retirement history will be compared to existing U.S. Geological Survey and Hawk Creek Watershed Project phosphorus data from West Fork Beaver Creek. Land retirement history will be determined from RIM, CREP, and CRP contract data to determine length of time acres have been enrolled in the programs. The length of time will be based on the contract expiration date provided for each contract as part of the metadata associated with the GIS coverage. The West Fork Beaver Creek watershed provides a unique opportunity to do this type of evaluation because very few acres have been taken out of land retirement and many of the contracts are perpetual easements.

Stream conditions, including total phosphorus concentrations, are influenced by interactions among many physical and chemical factors. Therefore, in addition to comparing phosphorus to the length of time land has been in retirement, other watershed, riparian, and in-stream factors will be summarized and considered. A journal article recently approved by the USGS for publication (Christensen, and others, in review, Journal of Environmental Quality) examined 82 watersheds in the Minnesota River Basin and the relation of phosphorus and other stream conditions to environmental factors. A similar approach will be used for this study. This will allow agencies and land managers to put land retirement into perspective with regard to the broader picture of interdependent systems.

Flow-weighted total phosphorus concentrations and retired land age data will be compared with linear regression techniques. A metric may be developed to assign an incremental effect to the retired land age data. Subsequently, multiple regression or other multivariate techniques will be performed in order to determine the relative importance of other independent variables, including distance of retired land from the stream. Other independent variables may include row

crop percentage and a variable for seasonality. In addition, an attempt will be made to obtain accurate annual phosphorus application rates to include in the analysis. Results will be presented on the year by year (or other time increment) basis in order to measure the strength of the association between the variables. Computation of loads may be completed using the S-loadest feature in SPLUS® (Tibco, Inc., 2008) or the FLUX program (U.S. Army Corps of Engineers). Continuous streamflow data (currently collected by the Minnesota Pollution Control Agency at the same West Fork Beaver site) will be used as input.

All sample data collected will be archived in the U.S. Geological Survey's NWIS database. Data storage and retrieval will be accomplished initially using Microsoft Access®, SPLUS®, Arc Info®, Arc View®, and (or) Arc/GIS computer software.

QUALITY ASSURANCE PLAN

The quality-control data was discussed previously under Activity 1, which is primarily a quality-control activity. In addition to the split replicates and blanks discussed in the methods section, the quality-assurance plan includes certain activities to maintain the integrity of the samples. All samples will be collected using decontaminated equipment. All clean collection jars, bottles, and containers will be pre-packaged. Sampling equipment will be checked prior to field work. Pre-field preparation ensures that all equipment is in good working condition and that all necessary containers, supplies, and materials are available for all activities. The USGS has standardized procedures for the collection and processing of water-quality samples. Data interpretation will be reviewed by the project leaders as results become available.

PRODUCTS

A geographic spatial analysis of historical RIM participation will be completed, documentation and statistical analysis of landscape patterns of RIM participation will be summarized, and a final report will be written by the USGS. This peer-reviewed report will document phosphorus reduction or changes in the West Fork Beaver Creek and the history of land retirement in the RIM programs in the basin and submitted as a journal article. The report will be the basis for outreach activities including presentations to BWSR and local governments, fact sheets, and workshops in order to explain results of participation the RIM program.

ARCHIVAL PLAN

Data archival for this project will follow procedures and guidelines of the National Water Quality Assessment Program. Water quality will be archived in USGS National Water Information Systems databases. Archival procedures and reviews will follow those used by the USGS Minnesota Water Science Center.

TIMELINE

Outcomes – Activity 1	**Completion Date**
1. Evaluate Minnesota Valley Testing Lab performance standards	*9-30-2011*
2. Collect samples and analyze for phosphorus and other nutrients	*9-30-2012*
Outcomes – Activity 2	**Completion Date**
1. Database of RIM acres and analysis of years in program	*6-30-2012*
2. Statistical interpretation of RIM and phosphorus concentrations	*12-30-2012*
3. Draft report provided to the LCCMR quantifying benefits of easements	*3-30-2013*

RELEVANCE AND BENEFITS

Data from the study will be used to assess the relation between phosphorus and length of time land has been in retirement. The combination of advanced technology such as remote sensing, geographic information systems, and computer science is widely recognized as an effective approach to assess the potential effects of complex natural and anthropogenic forces on the structure and function of water-quality and ecological resources at various temporal and geographical scales. This project benefits from using mostly existing data. The analysis of the effect of agricultural land retirement practices may provide valuable information for other Minnesota River watersheds. Because it is part of the Hawk Creek Watershed Project area, the effort can take advantage of cost sharing.

PERSONNEL

This project will include a team of scientists from the USGS. Part-time staff from the USGS Minnesota Water Science Center will include: project lead, water-quality specialist, GIS specialists, hydrologic technicians and students. A student may be hired to complete a geographic analysis of the land retirement programs.

PROJECT BUDGET

LCCMR 2011-2012 Detailed Project Budget

IV. TOTAL TRUST FUND REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
-	-
Contracts: USGS - Hydrologist, 20%FTE, 30% fringe, 3 years	$64,896
USGS - GIS Student, 30%FTE, 30% fringe, 3 years	$39,424
USGS - Hydrologic Technician, 5%FTE, 30% fringe, 2 years	$8,112
USGS - GIS specialist & water-quality specialist, 5%FTE, 30% fringe, 1 year	$6,354

Contracts: Minnesota Valley Testing, Nutrient analysis and sample shipping costs (contract through Hawk Creek Watershed Project)	$1,000
Contracts: USGS National Water-Quality Lab	$ 494
Contracts: USGS publishing network, editing, printing, illustrations	$4,000
Equipment/Tools/Supplies: Sample bottles, analytical blank water, filters, preservatives, ice	$400
Travel: Travel to sampling site. $0.55 per mile, no per diem	$220
Additional Budget Items: Fedex of samples to National Water Quality Laboratory	$100
TOTAL ENVIRONMENT & NATURAL RESOURCES TRUST FUND $ REQUEST	$125,000

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ USGS 40/60 matching funds	$84,000	Pending
Other State $ Being Applied to Project During Project Period:	0.00	
In-kind Services During Project Period: BWSR hydrologist, project oversight, communications, presentations, report writing	$20,000	
Remaining $ from previous ENRTF Appropriation	0.00	
Funding history: ML 2005, First Special Session, [Chap.1], Art. 2, Sec. [10], Subd. 7(c) and ML 2007, [Chap. HF 293], Sec.[2]. Subd. 5(c).	$575,000	

USGS FY Estimates

	FY2011	FY2012	FY2013[1]	Total
LCCMR Share	$20,000	$80,000	$25,000	$125,000
USGS share	$13,440	$52,500	$18,060	$84,000
Total Project Costs	$33,440	$132,500	$43,060	209,000

[1]It is anticipated that funds in USGS FY 2013 will be spent prior to Dec. 31, 2012.

SAFETY

Job hazard analysis (JHA) provided as an attachment.

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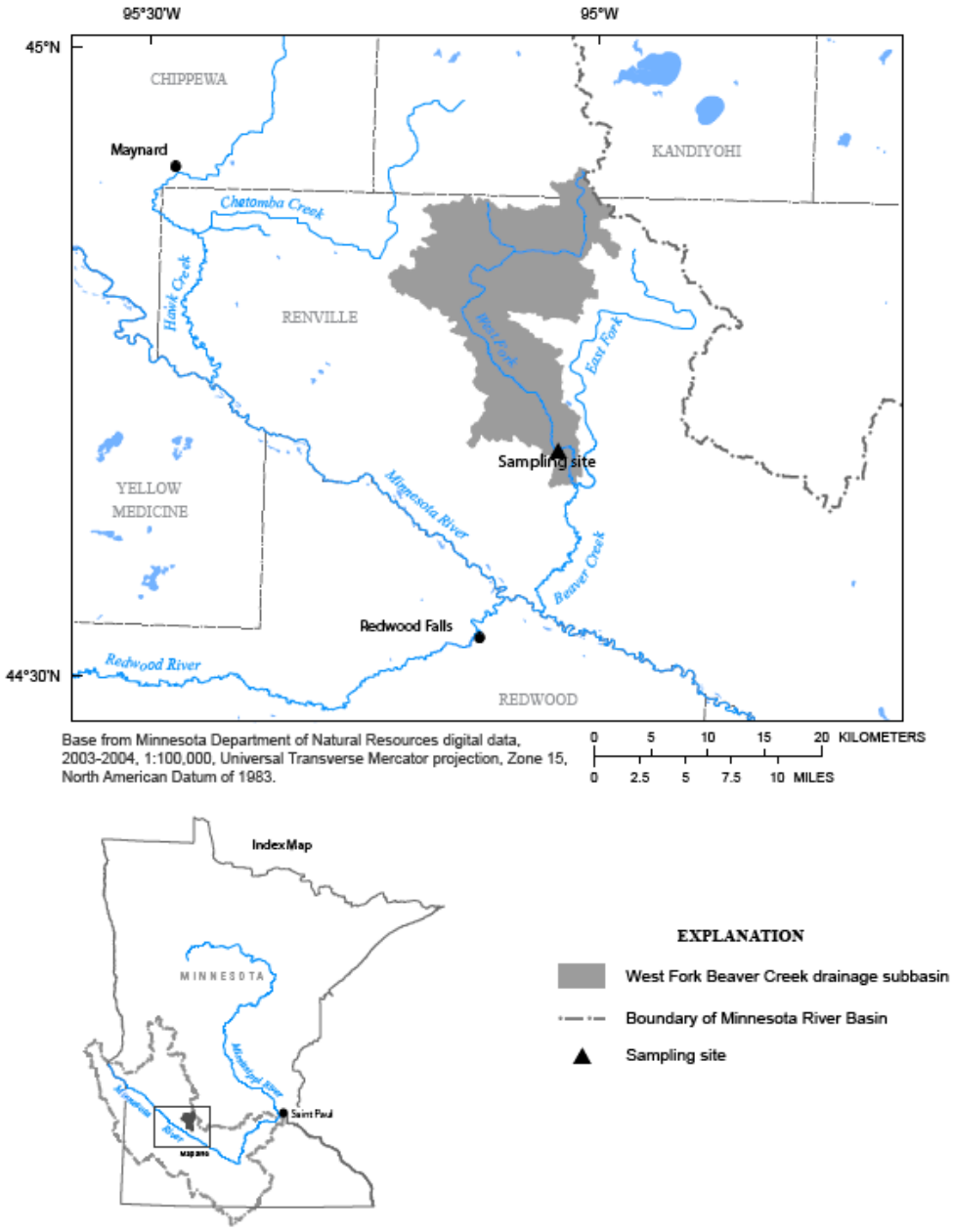

Figure 1. West Fork Beaver Creek study area and sampling site in the Minnesota River Basin.

Attachment 1: **Summary of Peer Review of Research Proposal**

Peer Review

A draft of the proposal was provided for peer review. This version of the proposal presented above includes the recommendations of the reviewers below. The proposal was subject of a peer review, by the following personnel, in September, 2010:

- Don Hansen, Supervisory Hydrologist, USGS MN Water Science Center
- Dr. Richard Kiesling, Water-Quality Specialist, USGS MN Water Science Center
- James Stark, Director, USGS MN Water Science Center
- Geoff Delin, USGS Regional Ground Water Specialist
- Dave Mueller, USGS Regional Water Quality Specialist (pre-proposal and full proposal comments are attached)
- Dave Lorenz, USGS MN WSC Surface Water Specialist

Stark made comments at the preproposal stage and has no comments at this time. Delin has no comments at this time.

Suggestions and recommendations of this group were as follows:

1. Some suggestions for clarification were made using track changes. –Hansen
2. Objectives and scope: the reviewer believes that the first objective was an approach, not an objective. Suggested deleting Objective 1 or moving it to the approach section.
3. On p. 7 MN Valley Testing lab will be evaluated? The USGS has a protocol for outside labs that are evaluated. Reviewer suggests that since there are only 4 samples going to MVTL, the word “compare” be used instead of “evaluated”.
4. Products: should specify report type (ie Journal article or SIR).
5. You might need to track changes in agricultural practice on the lands still under cultivation in the study area because ag practices affect soil erosion under the USLE models, soil particles are a transport vector for total P in runoff.
6. Clarify which nutrients will be analyzed—full suite? How will this compare to historic data.
7. For activity 2 add ag practice evaluation here as well as other structural features that might confound the relation (change in buffer location and size, etc.).
8. The following comments are from Dave Mueller based on the preproposal only: Thanks for sending the LCCMR proposal. It is considered a USGS pre-proposal under the recommendations from the recent GW-WQ technical review recommendations, so I'm providing comments that Vicki can consider in preparing the full proposal. The study approach appears very good from the short LCCMR document. I think using historical data with QC collected by the project is an excellent idea. The most important QC will be to determine

whether there are differences in bias or variability between labs or over time in the historical database. If more than 1 lab has been used, paired comparison samples should be sent to each lab to determine whether there are any current differences. These paired samples should be as similar as possible, so I suggest split replicates after sample collection. Bias can best be determined by comparing lab results for reference samples to known concentrations. It should be possible to obtain historical reference-sample data (such as from the USGS round-robin program) from the lab or labs. These can be added to the QC data that will be collected during the project, and might provide the best information for evaluating potential effects of lab analytic procedures over time. This type of information is used in the BQS Lab Evaluation Process, and the graphs developed for that process could be useful for your analysis as well. The GIS analysis should consider not only the length of time that land has been retired, but also the distance of retired lands to streams. Phosphorus tends to move with sediment, so lands that are far from a stream channel will have less effect on P-loading than lands adjacent to the channel. The final proposal should include some discussion about how changes in phosphorus will be evaluated. For example, will you have enough data to calibrate a LOADEST or similar model for one or more sites. Changes in the watershed are best evaluated by trends in flow-adjusted concentration, which can be extracted from a LOADEST model using coefficients on the time terms. These coefficients indicate whether changes in P mobilization and transport within the watershed have resulted in a shift in the flow-concentration relation over time.

9. Dave Lorenz comments: I reviewed the phosphorus reduction proposal. I do have one minor comment and one major comment. The minor comment pertains to the Objectives and Scope section. There is no scope statement. The major comment is about the lack of details in Activity 2: It is not clear in the Activity 2 section how the hypothesis proposed in the Problem section will be tested. The language of the problem section and the second objective requires a concise statement of the test designed to establish that hypothesis. The second paragraph in Activity 2 can help understand the processes, but does not address 'proving' the hypothesis. I cannot determine if a single basin will be used or multiple basins. If a single basin, then how does one transfer the information to other basins? How do you propose to account for any changes in P application rates? How do you account for changes in retired lands?

The full proposal was approved by the USGS Central Region on November 2, 2010. Comments were provided by

- Dave Mueller, Central Region Water-Quality Specialist
- Ron Kuzniar, Central Region Safety Officer
- Woody Woodward, Central Region Science Coordinator for Water
- Keith Lucey, Central Region Report Specialist
- Jeff Stoner, Midwest Area Science Officer

Suggestions and recommendations of this group were as follows:

1. Dave Mueller: The QC aspect of this study is excellent. The WSC incorporated all of my comments from review of the pre-prosposal. The information obtained from the QC samples can be used to ensure that changes in measured P concentration over time are more than could be expected simply due to differences in labs or analytical methods. The proposal can be approved as is, but Dave reiterates the importance of 2 pre-proposal comments: 1. The GIS analysis should consider the distance of retired lands to the streams and 2. Changes are best evaluated by trends in flow-adjusted concentrations.
2. Ron Kuzniar: Proposal Job Hazard Analysis in incomplete. Requests a new JHA.
3. Woody Woodward: No additional comments.
4. Keith Lucey: Several editorial comments were made using track changes. Also, two USGS colleague reviewers will be required for the journal article proposed.
5. Jeff Stoner: Minnesota should be added to the title of this proposal as this is not intended as a national (universal) study. This is a good example of building off a successful interpretive study.

Incorporating Peer Review Suggestions into Work Plan

All peer review suggestions were addressed and changes were made to this version of the proposal. The comments by Ron Kuzniar on the Job Hazard Analysis will be addressed on a separate document (JHA) in consulation with Ron.