Prepared in cooperation with the Minnesota Board of Water and Soil Resources

Assessment of Conservation Easements, Total Phosphorus, and Total Suspended Solids in West Fork Beaver Creek, Minnesota, 1999–2012

Scientific Investigations Report 2014–5002

U.S. Department of the Interior
U.S. Geological Survey

Cover. West Fork Beaver Creek (U.S. Geological Survey site 0531656290) looking downstream, August 9, 2012. Photograph by Kristen Kieta, U.S. Geological Survey.

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By Victoria G. Christensen and Kristen A. Kieta

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Application rate	
pounds per acre per year [(lb/acre)/yr]	1.121	kilograms per hectare per year [(kg/ha)/yr]

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Water year is the 12-month period, October 1 through September 30, and is designated by the calendar year in which it ends.

Abbreviations

CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
GIS	geographical information system
n	number of samples
NWQL	National Water Quality Laboratory
p-value	probability value
®	registered trademark
RIM	Reinvest in Minnesota
RPD	relative percentage difference
SSC	suspended-sediment concentration
TSS	total suspended solids
USGS	U.S. Geological Survey
WMA	Wildlife Management Area
WRP	Wetland Reserve Program

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Assessment of Conservation Easements, Total Phosphorus, and Total Suspended Solids in West Fork Beaver Creek, Minnesota, 1999–2012

By Victoria G.Christensen and Kristen A. Kieta

Abstract

This study examined conservation easements and their effectiveness at reducing phosphorus and solids transport to streams. The U.S. Geological Survey cooperated with the Minnesota Board of Water and Soil Resources and worked collaboratively with the Hawk Creek Watershed Project to examine the West Fork Beaver Creek Basin in Renville County, which has the largest number of Reinvest In Minnesota land retirement contracts in the State (as of 2013). Among all conservation easement programs, a total of 24,218 acres of agricultural land were retired throughout Renville County, and 2,718 acres were retired in the West Fork Beaver Creek Basin from 1987 through 2012. Total land retirement increased steadily from 1987 until 2000. In 2000, land retirement increased sharply because of the Minnesota River Conservation Reserve Enhancement Program, then leveled off when the program ended in 2002.

Streamflow data were collected during 1999 through 2011, and total phosphorus and total suspended solids data were collected during 1999 through 2012. During this period, the highest peak streamflow of 1,320 cubic feet per second was in March 2010. Total phosphorus and total suspended solids are constituents that tend to increase with increases in streamflow. Annual flow-weighted mean total-phosphorus concentrations ranged from 0.140 to 0.759 milligrams per liter, and annual flow-weighted mean total suspended solids concentrations ranged from 21.3 to 217 milligrams per liter. Annual flow-weighted mean total phosphorus and total suspended solids concentrations decreased steadily during the first 4 years of water-quality sample collection. A downward trend in flow-weighted mean total-phosphorus concentrations was significant from 1999 through 2008; however, flow-weighted total-phosphorus concentrations increased substantially in 2009, and the total phosphorus trend was no longer significant. The high annual flow-weighted mean concentrations for total phosphorus and total suspended solids in 2009 were affected by outlier concentrations documented in March 2009.

Agricultural land-retirement data only were available through 2008; therefore, it was not possible to compare total phosphorus and total suspended solids concentrations to agricultural land-retirement data for 2009–11. A downward trend in annual flow-weighted mean total-phosphorus concentrations was related significantly to annual land retirement for 1999–2008. The relation between annual flow-weighted mean total suspended solids concentration and annual land retirement was not statistically significant for 1999–2008. If land-retirement data had been available for 2009–11, it is possible that the relation between total phosphorus and land retirement would no longer be evident because of the marked increase in flow-weighted concentrations during 2009. Alternatively, the increase in annual flow-weighted mean total-phosphorus concentrations during 2009–11 may be because of other factors, including industrial discharges, increases in drain tile installation, changes in land use including decreases in agricultural land retirement after 2008, increases in erosion, increases in phosphorus applications to fields, or unknown causes. Inclusion of land-retirement effects in agency planning along with other factors adds perspective with regard to the broader picture of interdependent systems and allows agencies to make informed decisions on the benefits of perpetual easements compared to limited duration easements.

Introduction

Agriculture is the primary contributor of nutrients and sediment to many areas in the United States (Kroger and others, 2012). With the assumption that retiring agricultural land reduces erosion and improves water quality, agricultural land is retired through programs such as the Conservation Reserve Program (CRP), the Conservation Reserve Enhancement Program (CREP), the Wetland Reserve Program (WRP), and, in Minnesota, the Reinvest in Minnesota (RIM) program (Sullivan and others, 2004). A common goal of conservation easements or agricultural land retirement is to reduce sediment and nutrient transport to streams. Most easements purchased by the State of Minnesota are perpetual (forever), whereas some lands are enrolled under limited duration easements (Minnesota Board of Water and Soil Resources, 2013c).

The relative importance of agricultural land retirement to water quality and aquatic-community responses across 82 sites in the Minnesota River Basin was studied for data collected in 2001–03 (Christensen and others, 2011). The 2001–03 study examined water-quality, fish, invertebrate, and physical habitat data collected during the same sampling season. Multivariate statistical models indicated that other environmental factors (such as drainage basin area) commonly were correlated to aquatic-community response, as were in-stream factors (for example, substrate type). The results indicated that a higher percentage of agricultural land retirement was related significantly to decreased nitrogen and improved fish quality, as measured by the index of biotic integrity and other metrics; however, fish quality was affected by a combination of basin, riparian, and in-stream factors. No relation was evident between agricultural land retirement and total-phosphorus concentration.

Christensen and others (2009) examined water-quality and biological characteristics in three streams in the Minnesota River Basin, including the West Fork Beaver Creek, during 2005–08. Continuous, real-time, water-quality monitoring data were collected in addition to discrete water-quality samples, physical habitat characteristics, benthic algae, invertebrate, fish, and biomass accumulation data. The 2005–08 study gave a detailed assessment of the basins and, in general, indicated that total nitrogen concentration, suspended-sediment concentration, chlorophyll-*a* concentration, and fish-resource quality improved with an increasing percentage of land retirement. No relation between percentage of land retirement and total-phosphorus concentration was evident in the 2005–08 study.

The U.S. Geological Survey (USGS), Minnesota Board of Water and Soil Resources, Hawk Creek Watershed Project, and the Minnesota Pollution Control Agency have cooperated on these water-quality monitoring studies, which demonstrated that conservation easement programs have a positive effect on stream quality, resulting in lower nitrogen concentrations and better fish quality as indicated by biotic integrity scores (Christensen and others, 2009; 2011); however, these studies did not demonstrate a relation between the amount of land retirement and phosphorus concentrations. These studies were 3 years in duration, which may not be long enough to evaluate phosphorus reductions.

State and local agencies wanted to establish why previous research comparing total-phosphorus concentrations to agricultural land retirement across basins determined no relation on a spatial scale, whereas data collected by the Hawk Creek Watershed Project in West Fork Beaver Creek has indicated decreases in total-phosphorus concentrations since 1999 (Cory Netland, Hawk Creek Watershed Project, written commun., 2009). Therefore, the USGS cooperated with the Minnesota Board of Water and Soil Resources and worked collaboratively with the Hawk Creek Watershed Project to examine total phosphorus and total dissolved solids concentrations in the West Fork Beaver Creek Basin in Renville County, which has the largest number of land-retirement contracts for Reinvest In Minnesota in the State (as of 2013; Minnesota Board of Water and Soil Resources, 2013a).

Purpose and Scope

The purposes of this report are to (1) describe the compilation and analyses of agricultural land retirement, total phosphorus, and total suspended solids (TSS) data collected during 1999–2012 from West Fork Beaver Creek; and (2) assess any trends in total phosphorus and TSS concentrations with time that would correspond to the length of time land has been retired through conservation easements. This report provides information for local agencies to aid in setting priorities and prioritizing perpetual and limited duration easements.

Background

The West Fork Beaver Creek Basin (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 (Porter and others, 2001). Current (2013) agricultural practices use large quantities of chemical fertilizers (Battaglin and Goolsby, 1999) and pesticides (Fuglie, 1999) to increase yields. The West Fork Beaver Creek watershed is 84.8 percent cultivated crops (data from 2001 National Land Cover Database, Homer and others, 2007), and 60.4 percent of Renville County is treated with fertilizer (Sullivan and others, 2004). Subsurface tile drains also are used extensively in this region to quickly drain away unwanted moisture from the fields (Perry, 2012). The combination of fertilizers, herbicides, pesticides, and artificial drainage have the potential for deleterious effects on stream quality.

Several Federal and State programs are designed to encourage agricultural land retirement through conservation easements, and four of these programs are responsible for most of retired land in the West Fork Beaver Creek Basin—CRP, CREP, WRP, and RIM. Perpetual and limited duration easements are created through RIM and CREP, whereas CRP contracts are 10–15 years, and WRP easements can be for 30 years or in perpetuity (Minnesota Board of Water and Soil Resources, 2013c). In Minnesota, a partnership between the Board of Water and Soil Resources and the Natural Resources Conservation Service has created RIM/WRP where perpetual wetland easements are created.

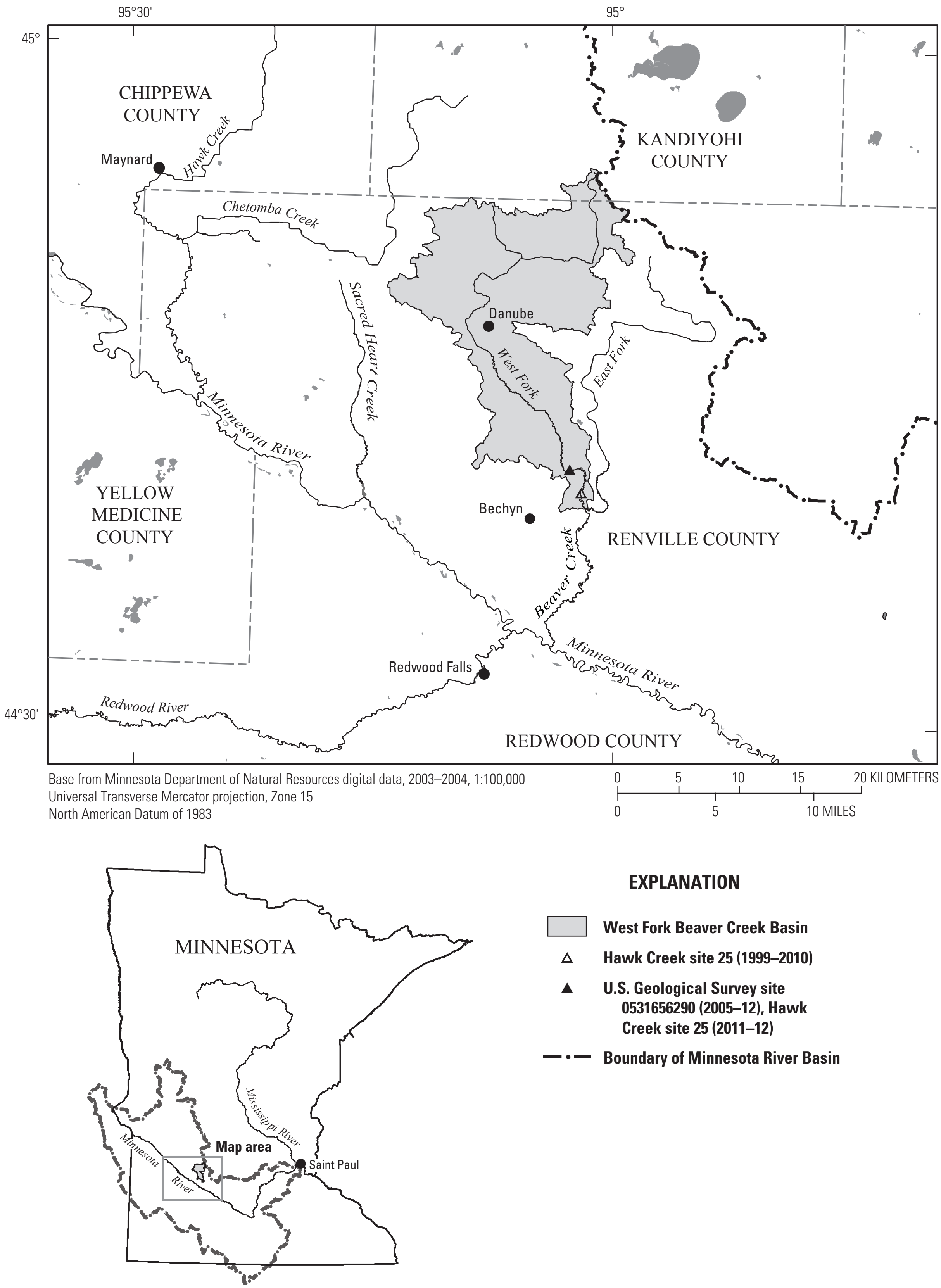

Figure 1. West Fork Beaver Creek, Minnesota River Basin, Minnesota.

A review of recent research revealed that reductions in phosphorus and sediment concentrations may lag behind other water-quality improvements when a management practice (such as a conservation easement) has been adopted (Meals and others, 2010). 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 (Newbold and others, 2008; Meals and others, 2010). In addition, where soil phosphorus levels are high, it may take many years for dissolved phosphorus concentrations to be reduced (McCollum, 1991; Zhang and others, 2004; Sharpley and others, 2007). Consequently, total phosphorus reduction may be delayed because it takes time for plants to become fully established after land is retired.

Study Area and Setting

West Fork Beaver Creek is part of the Minnesota River Basin (fig. 1). 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 Basin, which constitutes the study area, is part of the till plains and drumlins physiographic province (Payne, 1994). The terrain of the watershed generally is flat, and the rocks are easily erodible.

Local geology likely has a substantial effect on phosphorus concentrations in water. Soil phosphorus concentrations in the Minnesota River Basin are lower than the surrounding Mississippi and St. Croix River Basins (not shown in fig. 1); however, phosphorus loads in the Minnesota River Basin can be as much as five times higher (Montcrief and others, 1997). The Minnesota River carries a higher load of suspended soil particles, including particulate phosphorus, than the Mississippi and St. Croix Rivers because of the type of glacial material and native vegetation; the Mississippi and St. Croix Rivers are forested, whereas the Minnesota River was characterized by prairie vegetation (Montcrief and others, 1997) prior to agricultural expansion.

Agriculture has a substantial 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. Although native levels of soil phosphorus are medium to low in the Minnesota River Basin, manure and fertilizer have been applied to most fields to support crop production (Montcrief and others, 1997). Other agricultural activities, such as channelization and tile drain installation, also have changed local hydrologic conditions.

The West Fork Beaver Creek Basin is approximately 92.2 square miles (mi^2) at the current Hawk Creek Watershed Project sampling location (U.S. Geological Survey site 0531656290; fig. 1). Land use in the West Fork Beaver Creek Basin is 84.8 percent cultivated crops, 1.6 percent pasture or hay, 1.1 percent forest or shrub, 6.7 percent open water, and 5.7 percent developed or barren land (from the National Land Cover Dataset 2001; Homer and others, 2007).

Industrial sources potentially affecting water quality in the West Fork Beaver Creek Basin include a sugar beet processing plant and wastewater treatment from the city of Danube (population 505; U.S. Census Bureau, 2010). The city of Danube uses a lagoon system located near West Fork Beaver Creek, approximately 10.3 miles (mi) upstream from the sampling site. The sugar beet processing plant holds a discharge permit for nearby Sacred Heart Creek; however, the plant has been fined previously, including fines in 1980, 1995, 1998, 1999, 2002, 2006, and 2013, for allowing untreated or partially treated wastewater to escape into CD 37 (Sam Brungardt, Minnesota Pollution Control Agency, written commun., August 20, 2013; Minnesota Pollution Control Agency, 2006, 2013), which flows into West Fork Beaver Creek approximately 12.4 mi upstream from the sampling site.

Methods

Methods for sample collection and methods for calculations and statistical analyses are described in this section. Quality assurance was an important aspect of this project because there were multiple data sources, therefore quality assurance for the water-quality samples also is described in this section.

Sample Collection

Water samples were collected from West Fork Beaver Creek during 1999–2012 by personnel from the Hawk Creek Watershed Project and USGS. Samples generally were collected every 2 weeks and during storm events. The USGS samples were collected at West Fork Beaver Creek at 320th Street near Bechyn, Minnesota (USGS site 0531656290; fig. 1) during water years 2005–08 and 2011–12; a water year is a 12-month period, October 1 through September 30, and is designated by the calendar year in which it ends. Personnel from the Hawk Creek Watershed Project collected water samples during 1999–2010 about 1 mi downstream at the next road crossing at West Fork Beaver Creek at County Road 4 (fig. 1), then moved their sampling site to the USGS site for collection of the 2011–12 samples because of road and bridge work. The Hawk Creek Watershed Project site is designated as site 25 at both locations.

Field values for water temperature, specific conductance, pH, and dissolved oxygen were recorded at the time of sampling according to methods described in the USGS National Field Manual (Wilde, 1998). Hawk Creek Watershed Project personnel collected water samples using a single vertical. The USGS personnel collected water samples using equal-width increment techniques (U.S. Geological Survey, 2006) with the exception of two single vertical samples that were collected during low-flow conditions. Suspended-sediment samples were collected using methods described by Edwards and Glysson (1999).

Streamflow Data Collection

During water years 2006–08, streamflow was measured at both sites for comparison (fig. 2). Discrete and continuous streamflow measurements made by USGS personnel at site 0531656290 during water years 2006–08 (U.S. Geological Survey, 2013) followed standard methods for measurement and computation of streamflow (Turnipseed and Sauer, 2010); continuous streamflow measurements made by personnel from the Minnesota Pollution Control Agency or Minnesota Department of Natural Resources at both sites during 1999–2011 followed methods described by the Minnesota Department of Natural Resources (Minnesota Department of Natural Resources, 2013a). No substantial inflows (except for a few tile drain outlets) exist between the two sites; therefore, no adjustments were made for the data collected at the USGS site 0531656290 and West Fork Beaver Creek at County Road 4. Streamflow and water-quality data from the two sites were combined for the analyses in this report. Where streamflow data from more than one source existed, USGS data were used. The combined streamflow dataset used in this report is provided in appendix table 1–1.

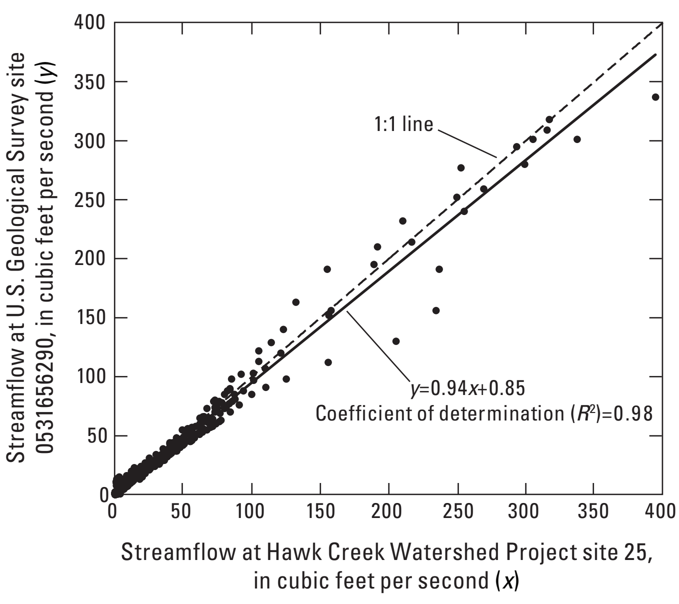

Figure 2. Comparison of streamflow at two data collection sites on West Fork Beaver Creek, water years 2006–08.

Laboratory Analysis

Samples collected by the Hawk Creek Watershed Project were sent to Era Laboratories, Duluth, Minnesota, during 1999–2009 and to the Minnesota Valley Testing Laboratory in New Ulm, Minn., during 2010–12. Samples collected by the USGS were sent to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, and to the USGS sediment laboratories in Iowa City, Iowa, and Louisville, Kentucky. Samples sent to Era Laboratories were analyzed for total phosphorus using EPA 365.3 (U.S. Environmental Protection Agency, 1983) and for total suspended solids using USGS I-3765-85 (Guy, 1969). Samples sent to the Minnesota Valley Testing Laboratory were analyzed for total phosphorus using EPA 365.1 (U.S. Environmental Protection Agency, 1993a) and for total suspended solids using USGS I-3765-85 (Guy, 1969). Samples sent to the NWQL were analyzed for total phosphorus using EPA 365.1 (U.S. Environmental Protection Agency, 1993a) and for total suspended solids using methods described by Fishman (1993) and Patton and Kryskalla (2011). Samples were analyzed for suspended-sediment concentration (SSC) at the USGS Sediment Laboratories in Iowa City, Iowa (2005–11), and Louisville, Ky. (2012), by using methods described by Guy (1969).

Calculations and Statistical Analyses

Although current (2013) conservation lands data are available on an aggregate (for example, county) level, agricultural land-retirement metadata (for example, information on a basin or sub-basin level) were only available through 2008. Land-retirement history was determined from RIM, WRP, CREP, CRP, and Wildlife Management Area (WMA) contracts. For limited duration easements, the age of the retired land (length of time it has been enrolled) was based on the contract expiration date provided for each contract as part of the 2009 (CRP), 2010 (RIM, WRP, and CREP), and 2013 (WMA) metadata associated with geographic information system (GIS) coverages obtained from the Farm Services Agency (St. Paul, Minn.) and Minnesota Board of Water and Soil Resources (2013d). However, because only aggregate data was available for 2009–13, the land retirement analysis was only completed through 2008. Total acres per year were calculated based on contract expiration dates. Average age of land retirement was then determined from the summation of acres enrolled per year multiplied by the length of enrollment:

$$\text{Average age of land retired in yearX} = \frac{\sum_{yearX}^{1987}\left(\text{Acres retired in yearX} \times L\right)}{\text{Total retired acres in yearX}} \qquad (1)$$

where L is length of enrollment, in years; and the summation in the numerator represents acres retired each year from 1987 through *yearX*, in acre years.

For example, the average age of land retirement for 1990 (*yearX*) was computed from the summation of land added in 1989 multiplied by 1 year, the land added in 1988 multiplied by 2 years, and so on as in the following example for 1990:

1987=77.97 acres×3 years old=233.91 acre years,
1988=94.37 acres×2 years old=188.74 acre years,
1989=51.27 acres×1 years old=51.27 acre years,
1990=31.36 acres×0 years old=0 acre years, and
Total retired acres in 1990=254.97 acres.

Substituting the above values into equation 1 yields the following:

Average age of land retired in 1990 = (233.91+188.74+51.27+0)/254.97 = 1.86 years.

Flow-weighted mean concentrations were calculated to account for the differences in streamflow conditions during sample collection. The water-quality samples collected at different streamflows are weighted differently when calculating the mean concentration. Flow-weighted mean total-phosphorus concentration and flow-weighted mean TSS concentrations were calculated using the following equation:

$$FWMC = \frac{\sum C \times Q}{\sum Q} \quad (2)$$

where

FWMC is the flow-weighted mean concentration, in milligrams per liter;

C is either total phosphorus or total suspended solids concentration, in milligrams per liter; and

Q is streamflow, in cubic feet per second.

Flow-weighted mean concentrations for 1999–2011 were compared to FLUX32 output (U.S. Army Corps of Engineers, 2013). Hawk Creek Watershed Project used FLUX for data collected during 1989–2011 to determine flow-weighted mean concentrations (Stephanie Klamm and Jordan Austin, Hawk Creek Watershed Project, written commun., November 11, 2011, and November 2, 2012). The comparison between the two methods served as a quality-assurance check of the two datasets. The flow-weighted mean concentrations determined from equation 2 and FLUX generally were similar, except when extreme streamflow occurred. In the analyses that follow, results from equation 2 are used.

Statistical analyses were completed using a significance value of 0.05. The probability (*p*-value) is provided for all statistical analyses in this report. An analysis was considered to be statistically significant for *p*-values less than or equal to the significance value of 0.05. Trends in flow-weighted mean concentrations of total phosphorus and TSS were analyzed for 1999–2011 (period for which streamflow data were available), and trends between flow-weighted mean concentrations and agricultural land-retirement data were analyzed for 1999–2008 (period for which land-retirement data were available).

Flow-weighted mean concentrations and retired-land age data (calculated with equation 1) were compared with Spearman's correlations, which is an appropriate statistical test due to the monotonic or nonlinearity of the hydrologic variables (Helsel and Hirsch, 1992). Phosphorus application rates were assumed to be constant during the 1999–2012 field seasons. Samples collected during 2012 were used for quality assurance, but are not included in the statistical analyses because 2012 streamflow data were not available. Continuous streamflow data collected by the Minnesota Pollution Control Agency or Minnesota Department of Natural Resources from 1999 to 2005 and 2009 to 2011 (Minnesota Department of Natural Resources, 2013a) and continuous streamflow data collected by the USGS from 2005 to 2008 (U.S. Geological Survey, 2013) were used as input. Kendall's tau (Helsel and Hirsch, 1992) was used to determine if significant trends (*p*-value less than 0.05) in the data existed.

Quality Assurance

The West Fork Beaver Creek has been the site of several recent research studies and monitoring efforts. An evaluation of the differences in sample collection techniques was critical to provide sound results. Hawk Creek Watershed Project personnel assisted USGS personnel with quality-assurance sample collection during 2012. Two types of replicate samples were collected, field replicates and laboratory replicates. Field replicates were collected using USGS and Hawk Creek Watershed Project field methods during 2012, but analyzed for nutrients using the same laboratory (table 1). Field replicates were meant to compare the two types of field collection methods between agencies. Personnel from Hawk Creek Watershed Project collected a grab sample from the centroid of flow, whereas USGS personnel collected a composite

Table 1. Summary of relative percent differences between collection techniques for field replicate water samples collected from West Fork Beaver Creek at 320th Street near Bechyn, Minnesota.

[USGS, U.S. Geological Survey; HCWP, Hawk Creek Watershed Project; RPD, relative percent difference; mg/L, milligrams per liter; <, less than]

Constituent	USGS sample[1]	HCWP sample[1]	RPD[2]
Ammonia, filtered, mg/L as nitrogen	<0.01	0.015	100
Nitrite plus nitrate, filtered, mg/L as nitrogen	<0.04	<0.04	0
Nitrite, filtered, mg/L as nitrogen	0.001	0.001	0
Orthophosphate, filtered, mg/L as phosphorus	0.05	0.048	10
Phosphorus, unfiltered, mg/L as phosphorus	1.41	1.61	13

[1]USGS sample was collected by USGS personnel using standard USGS protocol (equal-width increment). HCWP sample was collected by HCWP personnel using HCWP standard protocol (single point grab sample). Both samples were sent to the USGS National Water Quality Laboratory for analysis.

[2]For the case in which one of the values was not detected (<), one-half the detection limit was used to calculate the RPD.

sample with equal width increment methods (U.S. Geological Survey, 2006). Laboratory replicate samples were collected using the same field methods and personnel, and split from the same sample. In addition to the analytical methods for total phosphorus, TSS, and suspended sediment listed above, ammonia was determined using SM 4500 NH3B, E (American Public Health Association, 1999), nitrite plus nitrate was determined using EPA 353.2 (U.S. Environmental Protection Agency, 1993b), total Kjeldahl nitrogen was determined using SM 4500 NorgB/NH3E (American Public Health Association, 1999), and soluble orthophosphorus was determined using EPA 365.1 (U.S. Environmental Protection Agency, 1993a). Laboratory replicate sample sets were sent to the Minnesota Valley Testing Laboratory and the NWQL for analyses (table 2).

Table 2. Relative percent differences for laboratory replicate water samples collected from West Fork Beaver Creek at 320th Street near Bechyn, Minnesota.

[NWQL, U.S. Geological Survey National Water Quality Laboratory; MVTL, Minnesota Valley Testing Laboratory; RPD, relative percent difference; mg/L, milligrams per liter; <, less than]

Constituent	NWQL[1]	MVTL[1]	RPD
Ammonia, filtered, mg/L as nitrogen	<0.01	<0.16	0
Nitrite plus nitrate, filtered, mg/L as nitrogen	<0.04	<0.2	0
Orthophosphate, filtered, mg/L as phosphorus	0.049	0.044	11
Phosphorus, unfiltered, mg/L as phosphorus	0.248	0.209	17

[1]Both samples were collected by U.S. Geological Survey personnel using depth- and width-integrating techniques.

Replicate error between samples was calculated using relative percentage differences (RPDs; see Christensen and others, 2009). RPD was calculated using the following equation:

$$RPD = [|sample\ 2 - sample\ 1|/((sample\ 1 + sample\ 2)/2)] \times 100 \quad (3)$$

where *sample 1* and *sample 2* are concentrations of the first and second replicate samples, respectively (Christensen and others, 2011). For the cases in which one of the values was not detected, one-half the detection level was used to calculate the RPD. The objective for precision of replicate samples is a maximum RPD of 20 percent according to Taylor (1987).

With the exception of ammonia, differences between concentrations in water samples collected by USGS and Hawk Creek Watershed Project personnel were less than or equal to 20 percent (table 1), with a median RPD of 10 percent. The results indicate that caution should be used for the interpretation of ammonia concentrations; however, for the remainder of the nutrients, samples collected at the centroid of the stream are a fairly good approximation of conditions across the stream.

Differences in analytical results between the two laboratories ranged from 0 to 17 percent (table 2) with a median RPD of 5.5 percent. The results of this comparison indicated analytical results from the two laboratories could be combined into one dataset.

The quality-assurance plan included certain activities to maintain the integrity of the samples. All samples were collected using decontaminated equipment. All clean collection jars, bottles, and containers were pre-packaged. Sampling equipment was checked before field work commenced. Pre-field preparation ensured that all equipment was in good working condition and that all necessary containers, supplies, and materials were available for all activities. Field blanks were collected throughout the study to assess sample contamination, and field blanks collected before 2011 are described in Christensen and others (2009). A field blank sample collected on August 4, 2011 (table 3) did not have detectable concentrations of 6 of the 7 constituents. Ammonia, the only exception, was detected at a concentration of 0.016 milligrams per liter (mg/L). This concentration, however, was less than the minimum reporting level, which is the smallest measured concentration of a constituent that may be reliably reported by using a given analytical method (Timme, 1995).

Twelve duplicate samples for comparison of SSC and TSS were collected during water years 2005–08. Suspended sediment concentration and TSS concentrations were correlated (p-value=0.001); however, SSC was 14 times TSS, due in part to one outlier at high flow. The larger SSC than TSS is consistent with a study of over 14,000 samples collected across the U.S., which is likely due to the differences in analytical methods for TSS and SSC (Glysson and Gray, 2002). Due to the large difference between SSC and TSS at West Fork Beaver Creek, especially at high concentrations, only TSS results are included in the analyses of this report.

Table 3. Field-blank sample concentrations in water samples collected from West Fork Beaver Creek at 320th Street near Bechyn, Minnesota, on August 4, 2011.

[MDL, method detection limit; MRL, minimum reporting level; mg/L, milligrams per liter; <, less than; N, nitrogen]

Constituent	Value	MDL	MRL
Ammonia, filtered, mg/L as nitrogen	0.016	0.010	0.02
Nitrite plus nitrate, filtered, mg/L as nitrogen	<0.020	0.02	0.04
Nitrite, filtered, mg/L as nitrogen	<0.001	0.001	0.002
Total nitrogen (nitrate+nitrite+ammonia+ organic-N), unfiltered, mg/L	<0.05	0.05	0.1
Orthophosphate, filtered, mg/L as phosphorus	<0.004	0.004	0.008
Phosphorus, unfiltered, mg/L as phosphorus	<0.004	0.004	0.008
Suspended solids, unfiltered, mg/L	<15	15	15

Conservation Easements, Total Phosphorus, and Total Suspended Solids

Landscape Patterns of Conservation Easements

The conservation program CREP, the perpetual easement program in which agricultural land was enrolled from February 1998 to September 2002, was responsible for 1,403 acres of retired land in the West Fork Beaver Creek Basin and 10,375 acres across Renville County (Minnesota Board of Water and Soil Resources, 2013d). The CREP targeted habitat restoration and water quality in the Minnesota River Basin and thus, nearly all of the 42 CREP contracts in the West Fork Beaver Creek Basin were for land concentrated directly adjacent to Minnesota River tributaries. Land not directly adjacent to a stream was designated for wetland restoration. Using GIS metadata from the Farm Services Agency (St. Paul, Minn.) and Minnesota Board of Water and Soil Resources (2013d), the amount of total land retired each year within the West Fork Beaver Creek Basin was calculated (fig. 3). However, because only aggregate conservation land data is available for years 2009–13, total retired land calculations were made based on the 2009 (CRP), 2010 (RIM, CREP, WRP), and 2013 (WMA) metadata from 1987 through 2008.

The CRP, CREP, RIM, and WRP programs account for a total of 24,218 acres of retired land throughout Renville County, and 2,718 acres in the West Fork Beaver Creek Basin from 1987 through 2012 (Minnesota Board of Water and Soil Resources, 2013d). In addition to private land in the CRP, CREP, and RIM programs, some public land was converted to WMAs in 1999 (108 acres) and 2008 (81 acres) (Minnesota Department of Natural Resources, 2013b). Total land retirement increased steadily from 1987 until 2000. In 2000, land retirement increased substantially because of the Minnesota River CREP (Minnesota Board of Water and Soil Resources, 2013b). In 2002, the total land retirement leveled off because the next CREP did not include the Minnesota River Basin (or Renville County).

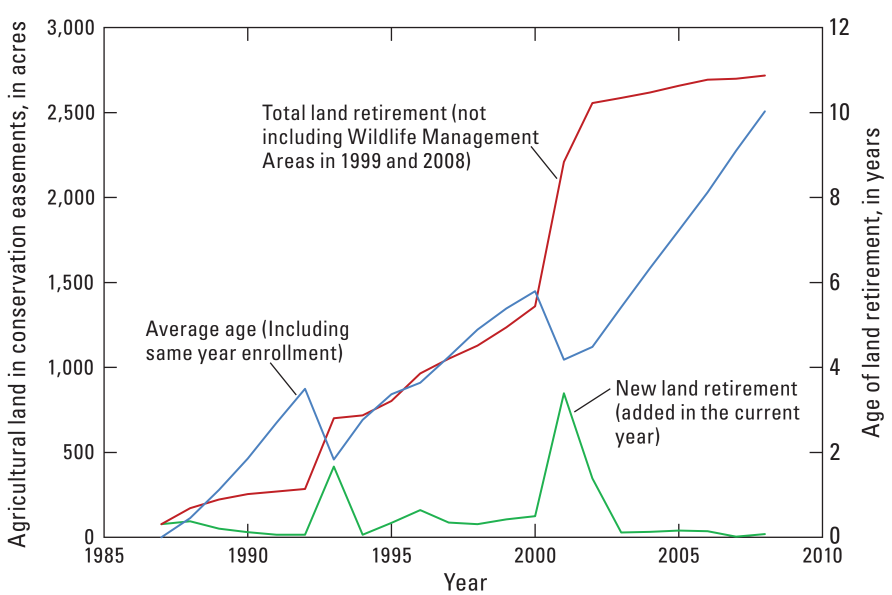

Figure 3. Total acres and average age of agricultural land retirement, West Fork Beaver Creek, Minnesota, 1987–2008.

Streamflow, Total Phosphorus, and Total Suspended Solids

Streamflow was measured continuously during the open-water season from 1999 through 2011 by personnel from the Hawk Creek Watershed Project at site 25 (fig. 4). During water years 2006–08, streamflow was measured continuously, including winter months (fig. 4), by USGS personnel at site 0531656290 (U.S. Geological Survey, 2013). Mean annual streamflow ranged from 12.2 cubic feet per second (ft^3/s) (2008) to 153 ft^3/s (2011). Maximum streamflow typically occurred in the spring (May or June), with 2010 having the highest peak streamflow of 1,320 ft^3/s. Peak streamflows in 2010 and 2011 were as much as 878 ft^3/s greater than the peak streamflows for the remainder of the record (1999–2009; fig. 4).

Measured total-phosphorus concentrations ranged from 0.008 (August 9, 2005) to 1.09 (March 24, 2009) during 1999–2011 [number of samples (n)=323; fig. 4*A*]. All measured total phosphorus data are available in appendix table 1–1. Annual flow-weighted mean concentrations ranged from 0.140 mg/L (2003) to 0.759 mg/L (2009). Annual flow-weighted mean total-phosphorus concentrations steadily decreased during the first few years after water-quality sample collection commenced (fig. 5). A downward trend in annual flow-weighted mean total-phosphorus concentrations was significant from 1999 through 2008 (Kendall's tau=-0.511, *p*-value=0.046); however, flow-weighted total-phosphorus concentration increased substantially in 2009 (fig. 5*A*), and the total-phosphorus trend was no longer significant. The annual flow-weighted mean total-phosphorus concentration for 2009 appears to be affected substantially by two outlier concentrations occurring on two consecutive days, March 23 and 24, 2009 (fig. 4*A*); however, even when the two values are removed from the dataset, the annual flow-weighted mean total-phosphorus concentration remained high in 2009 and the downward trend was no longer significant.

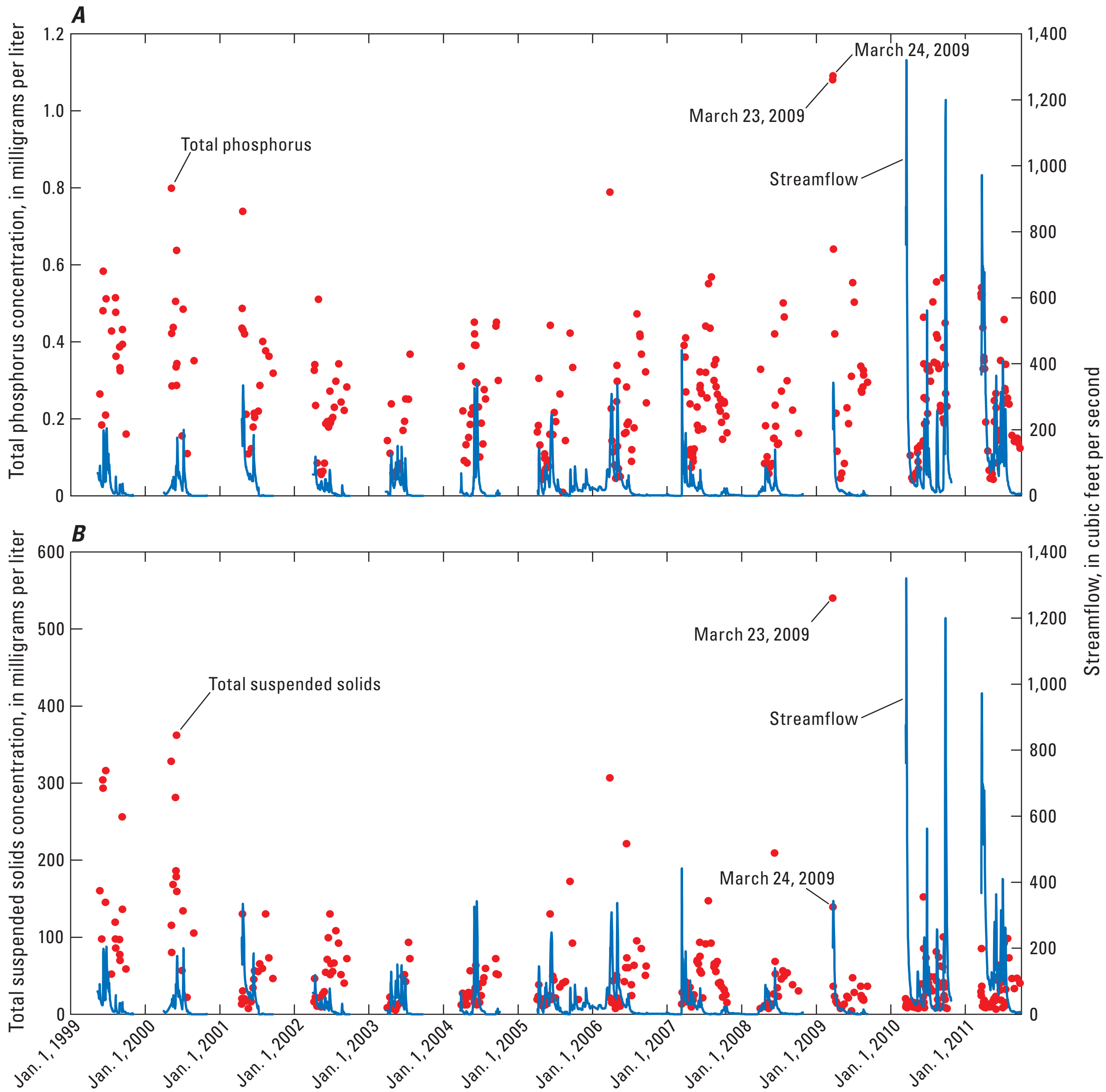

Figure 4. Streamflow and *A*, total-phosphorus concentrations and *B*, total suspended solids concentrations at West Fork Beaver Creek, Minnesota, 1999–2011.

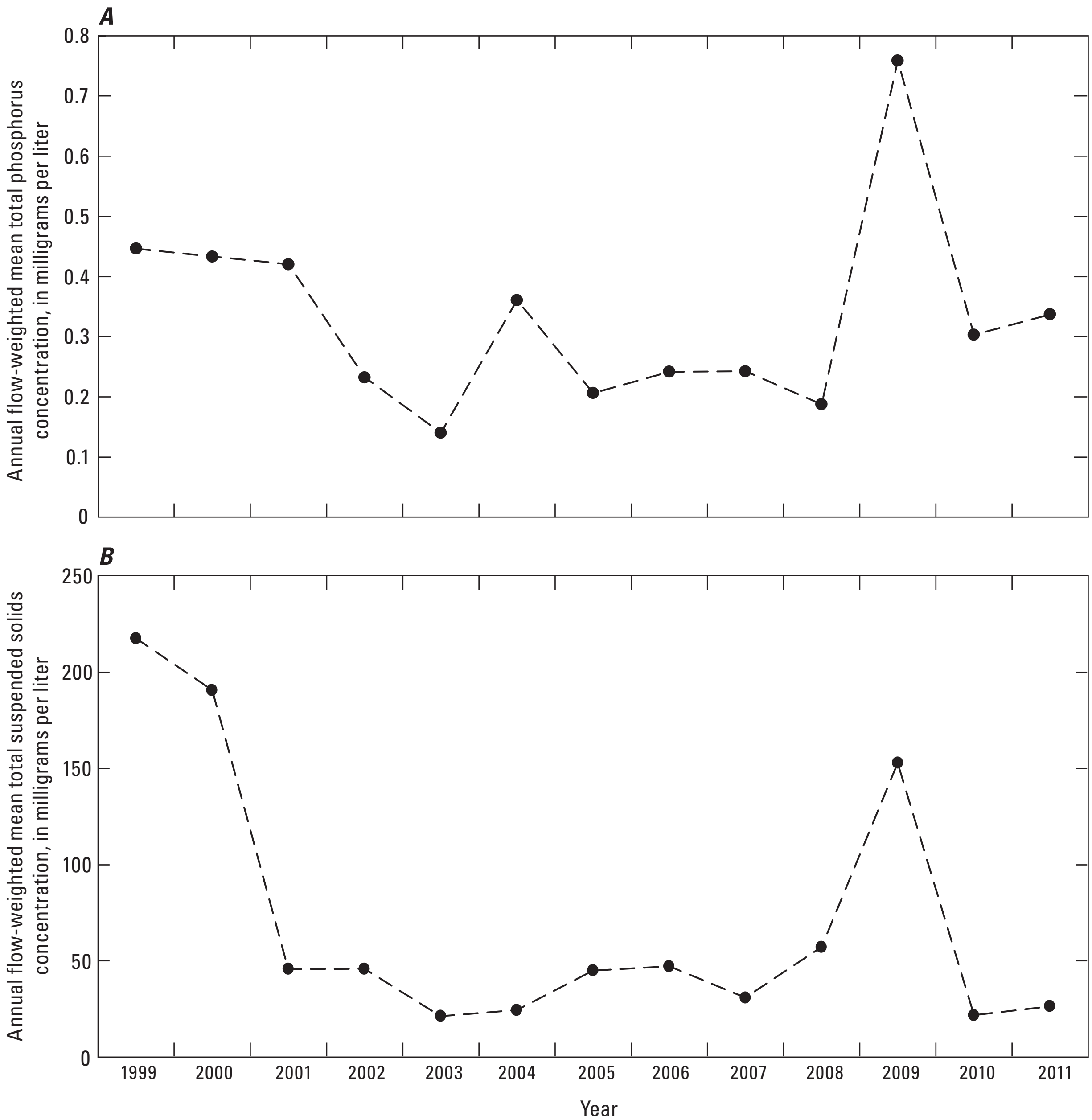

Figure 5. Annual flow-weighted mean concentrations, West Fork Beaver Creek, Minnesota, 1999–2011. *A*, total phosphorus, and *B*, total suspended solids.

Measured TSS concentrations ranged from 4.0 (June 23, 2009) to 540 mg/L (March 23, 2009) between 1999 and 2011 (n=325; fig. 4*B*). Annual flow-weighted mean TSS concentrations (fig. 5*B*) ranged from 21.3 mg/L (2003) to 217 mg/L (1999). Similar to total phosphorus, annual flow-weighted mean TSS concentrations also appeared to decrease during the first few years after 1999. The high annual flow-weighted mean TSS concentration during 2009 (fig. 5*B*) appears to be affected substantially by one measurement made on March 23, 2009 (540 mg/L). The TSS concentration on March 24, 2009 (139 mg/L) is substantially less than the concentration for the previous day (fig. 4*B*). This is typical of sediment transport, in that most of the sediment is transported at the beginning of a storm or runoff event (Landers and Strum, 2013). Unlike the trend in total-phosphorus concentration, which was not significant when the outliers in 2009 were removed, the downward trend in annual flow-weighted mean TSS concentration was significant when both March 23 and March 24, 2009, values were removed from the analysis.

Annual flow-weighted mean total phosphorus and TSS concentrations were compared to the amount of agricultural land retired through conservation easement programs for 1999–2008 (fig. 6). Total phosphorus and TSS are constituents that tend to increase with increases in streamflow. Although streamflow increased from 1999–2011, the trend in streamflow was not statistically significant (*p*-value=0.430); however, land retirement by year was related statistically to a decrease in annual flow-weighted total-phosphorus concentration (Spearman's rho=-0.636, *p*-value=0.024). The relation between total land retirement by year and TSS concentrations was not statistically significant (Spearman's rho=-0.479, *p*-value=0.081).

Because agricultural land-retirement data were only available through 2008, it was not possible to compare total phosphorus and TSS concentrations to land retirement for 2009–11; however, if land-retirement data had been available, it is possible that the relation between these constituents and land retirement would no longer be evident because of the marked increase in flow-weighted concentrations during 2009 (fig. 5). Alternatively, the increase in flow-weighted total-phosphorus concentrations in 2009–11 may be due to one or more of the following reasons:

1. Discharges from the sugar beet plant or other industrial sources,
2. Increase in tile drain installation and subsequent increase in runoff to the stream,
3. Decrease in agricultural land retirement after 2008 or other change in land use,
4. Increase in streamflow causing increased erosion,
5. Increase in phosphorus application to fields, or
6. No correlation or unknown cause.

Given that annual flow-weighted mean TSS concentration trends were not the same as annual flow-weighted mean total-phosphorus concentration trends (fig. 5*A*), it is possible that phosphorus is not associated with sediment and the increased concentrations may be due to a point source or phosphorus application to fields.

Stream conditions, including total-phosphorus concentrations, are affected by interactions among many physical and chemical factors. Other watershed, riparian, and in-stream factors were summarized and considered in a recent study of the Minnesota River Basin (Christensen and others, 2011). Given that the results of this study indicate that land-retirement programs may improve stream water quality as inferred by significant decreases in total-phosphorus concentrations, consideration of agricultural land retirement along with other factors may allow agencies and land managers to put land retirement into perspective with regard to the broader picture of interdependent systems.

The West Fork Beaver Creek Basin provided a unique opportunity for evaluation because very few acres have been taken out of land retirement (as of 2013; U.S. Department of Agriculture, Farm Services Agency, 2013) and many of the contracts are perpetual easements. These conservation easements are intended to permanently protect, restore, and manage natural resources on public and private lands (Minnesota Board of Water and Soil Resources, 2013c). Most conservation easements in the RIM program are perpetual, whereas others are enrolled under limited duration easements. Short-term studies may not indicate immediate phosphorus reduction. Failure to indicate immediate phosphorus reductions may unjustifiably reduce support for land-retirement programs. As such, it is important that scientists and resource managers understand that immediate reductions in phosphorus may not always be expected. By providing a long-term dataset and analyses, the Federal and State agencies can make informed decisions on the benefits of perpetual easements in comparison to limited duration easements. This study, coupled with previous studies, shows that land retirement has positive effects on water quality and condition. However, for total phosphorus, the benefits may take more time to develop and the results can be confounded by point discharges and other factors, making frequent sampling essential.

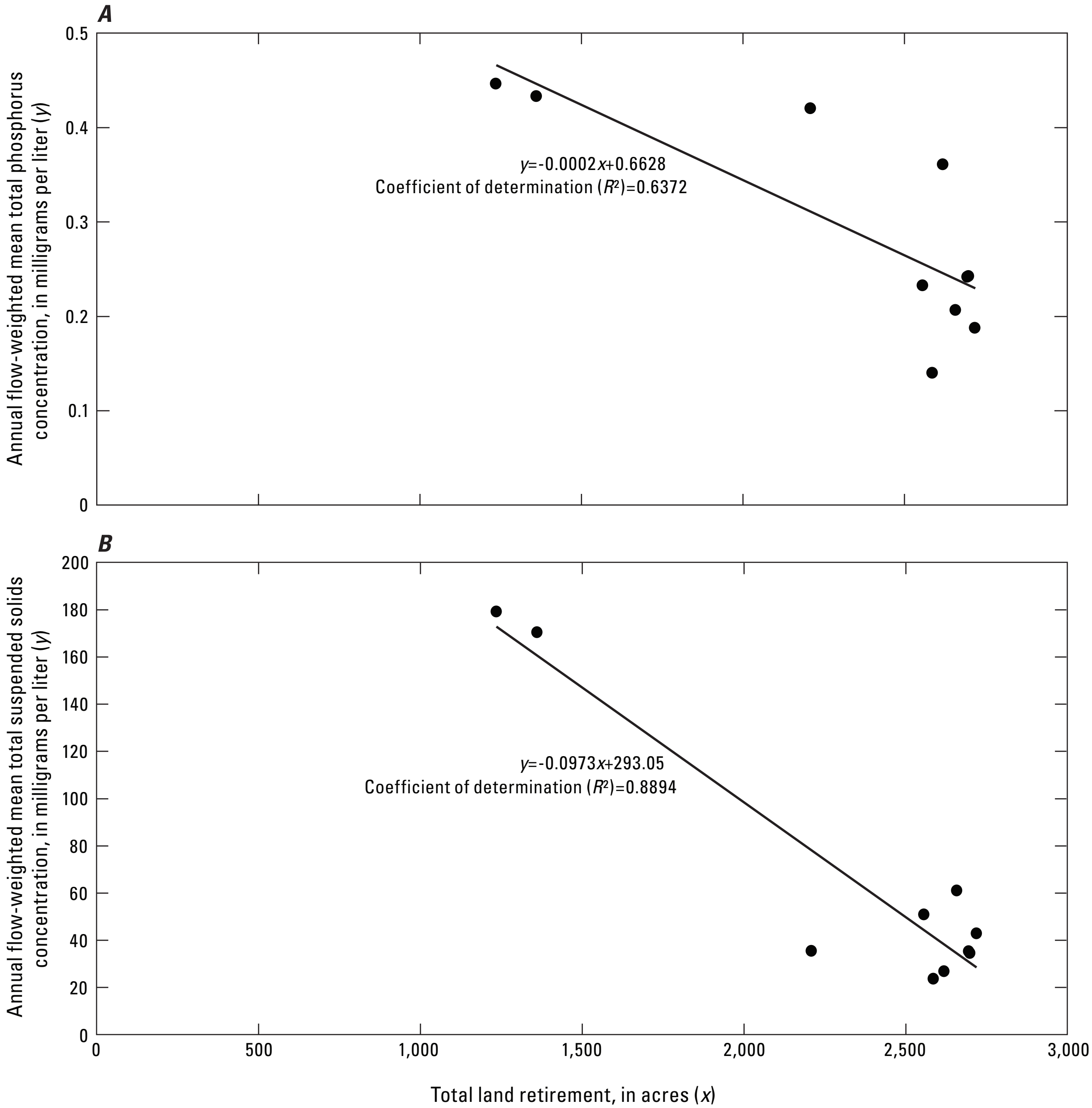

Figure 6. Relation between annual flow-weighted mean concentrations and number of acres in conservation easement programs, West Fork Beaver Creek, Minnesota, 1999–2008. *A*, Total phosphorus, and *B*, total suspended solids.

Summary

Agriculture is a primary contributor of nutrients and sediment in many areas of the United States. With the assumption that retiring agricultural land reduces erosion and improves water quality, agricultural land is retired through a variety of conservation easement programs. One of the goals of a conservation easement is to reduce sediment and nutrient transport to streams. The U.S. Geological Survey, Minnesota Board of Water and Soil Resources, Hawk Creek Watershed Project, and the Minnesota Pollution Control Agency cooperated on monitoring studies of varying duration and drainage basin size to investigate the effects of conservation easements on water quality in Minnesota River watersheds, including the West Fork Beaver Creek. The West Fork Beaver Creek Basin 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 increase crop yields. The nutrients in these fertilizers have the potential for deleterious effects on stream quality. Previous studies demonstrated that conservation easement programs have a positive effect on stream quality, resulting in lower nitrogen concentrations and better fish community metrics; however, these studies did not demonstrate a relation between phosphorus concentrations and amount of land retirement.

State and local agencies wanted to establish why previous research comparing total-phosphorus concentrations to agricultural land retirement across basins determined no relation on a spatial scale, whereas data collected by the Hawk Creek Watershed Project in West Fork Beaver Creek indicated decreases in total-phosphorus concentrations since the implementation of the Reinvest in Minnesota (RIM) and Conservation Reserve Enhancement (CREP) programs. Thus, the USGS cooperated with the Minnesota Board of Water and Soil Resources and worked collaboratively with the Hawk Creek Watershed Project to examine total phosphorus and total dissolved solids concentrations in the West Fork Beaver Creek Basin in Renville County, which has the largest number of land-retirement contracts for RIM in the State (as of 2013). This report describes the compilation and an analysis of agricultural land retirement, total phosphorus, and total suspended solids data collected during 1999–2012 from West Fork Beaver Creek, and describes any trends in total phosphorus and TSS concentrations with time that would correspond to the length of time land has been retired. This report provides information for local agencies to aid in setting priorities and prioritizing perpetual and limited duration easements.

Industrial sources potentially affecting water quality in the West Fork Beaver Creek Basin include a sugar beet processing plant and wastewater treatment from the city of Danube. The city of Danube uses a lagoon system located near the West Fork Beaver Creek, approximately 10.3 miles upstream from the sampling site. The sugar beet processing plant holds a discharge permit for nearby Sacred Heart Creek; however, the plant has been fined previously, including fines in 1980, 1995, 1998, 1999, 2002, 2006, and 2013, for allowing untreated or partially treated wastewater to escape into CD 37, which flows into West Fork Beaver Creek approximately 12.4 miles upstream from the sampling site.

Water samples were collected during 1999–2012 by personnel from the Hawk Creek Watershed Project and U.S. Geological Survey. Samples were analyzed for total phosphorus and total suspended solids concentrations. Land-retirement history was determined from conservation easement contracts. The age of the retired land (length of time it has been enrolled) was based on the contract expiration date provided for each contract as part of the 2009, 2010, and 2013 metadata associated with geographic information system coverages.

Among all conservation easement programs, a total of 24,218 acres of land was retired throughout Renville County, and 2,718 acres were retired in the West Fork Beaver Creek Basin from 1987 through 2012. Total land retirement increased steadily from 1987 until 2000. In 2000, land retirement increased substantially because of the CREP for the Minnesota River. In 2002, the total land retirement leveled off when the Minnesota River CREP ended.

Streamflow was measured continuously during the open-water season from 1999 through 2011. Mean annual streamflow ranged from 12.2 cubic feet per second (ft^3/s) in 2008 to 153 ft^3/s in 2011. Maximum streamflow typically occurred in the spring, with 2010 having the highest peak streamflow of 1,320 ft^3/s. Peak streamflows in 2010 and 2011 were substantially greater than the peak streamflows for the remainder of the record (1999–2009).

Annual flow-weighted mean total-phosphorus concentrations ranged from 0.140 to 0.759 milligrams per liter. Annual flow-weighted mean total suspended solids concentrations ranged from 21.3 to 217 milligrams per liter.

Total phosphorus and total suspended solids steadily decreased during the first 4 years after water-quality data collection began in 1999. A downward trend in annual flow-weighted mean total-phosphorus concentration was significant from 1999 through 2008; however, flow-weighted total-phosphorus concentrations increased substantially in 2009 and the total phosphorus trend was no longer significant. The high annual flow-weighted mean concentrations for total phosphorus and total suspended solids in 2009 appear to be heavily affected by outlier concentrations occurring in March 2009.

The annual flow-weighted mean concentrations for total phosphorus and total suspended solids were compared to the amount of agricultural land retired through conservation easement programs. A downward trend in annual flow-weighted mean total-phosphorus concentrations was related significantly to annual land retirement for 1999–2008. The relation between annual flow-weighted mean total suspended solids concentration and total land retirement by year was not statistically significant.

Because agricultural land-retirement data were only available through 2008, it was not possible to compare total phosphorus and total suspended solids concentrations to land retirement for 2009–11; however, if land-retirement data had been available for that period, it is possible that the relation between these constituents and land retirement would no longer be evident because of the marked increase in flow-weighted concentrations during 2009. Alternatively, the increase in annual flow-weighted mean total-phosphorus concentrations during 2009–11 may be due to other factors, including discharges from industrial sources, increases in drain tile installation, changes in land use including decreases in agricultural land retirement after 2008, increases in erosion, increases in phosphorus applications to fields, or unknown causes.

Stream conditions, including total-phosphorus concentrations, are affected by interactions among many physical and chemical factors. Considering agricultural land retirement along with other factors may allow agencies to put land retirement into perspective with regard to the broader picture of interdependent systems.

The West Fork Beaver Creek Basin provided a unique study opportunity because very few acres had been taken out of land retirement in favor of crops (as of 2013) and many of the contracts are perpetual easements. These conservation easements are intended to permanently protect, restore, and manage natural resources on public and private lands. Long-term datasets and analyses are valuable for aiding Federal and State agencies in making informed decisions on the benefits of perpetual easements compared to limited duration easements.

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Appendix

Streamflow, total phosphorus, and total suspended solids data collected from West Fork Beaver Creek during 1999–2011 are presented in table 1–1, which is a Microsoft® Excel spreadsheet. The Excel file is available for download at *http://pubs.usgs.gov/sir/2014/5002/*.

Table 1–1. Streamflow, total phosphorus, and total suspended solids data collected from West Fork Beaver Creek at 320th Street near Bechyn and at County Road 4, Minnesota, 1999–2011.

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