2005 Project Abstract
For the Period Ending June 30, 2008

PROJECT TITLE: Effects of Land Retirement on the Minnesota River
PROJECT MANAGER: Victoria Christensen
AFFILIATION: U.S. Geological Survey
MAILING ADDRESS: 2280 Woodale Dr.
CITY/STATE/ZIP: Mounds View, MN 55112
PHONE: 701-277-0682
FAX: 763-783-3103
E-MAIL: vglenn@usgs.gov
WEBSITE:
FUNDING SOURCE: Minnesota Environment and Natural Resources Trust Fund
LEGAL CITATION: ML 2005, First Special Session, [Chap.1], Art. 2, Sec.[10], Subd. 7(c).
APPROPRIATION AMOUNT: **$** 300,000

Overall Project Outcome and Results

Three watersheds in the Minnesota River basin were selected to study effects of agricultural land retirement on stream quality. Site selections were based on similarities in hydrology, land use, soil type, and other characteristics and differences in land retirement percentages. Water samples were collected from 2005-2007 and analyzed for field measurements, nutrients, and sediment. Streamflow and continuous water-quality data were collected and disseminated (http://waterdata.usgs.gov/nwis/mn/rt). Biological sampling was conducted in August 2006 and 2007. The South Branch Rush River (representing little to no land retirement) had substantially higher nitrogen concentrations (mean=14.3 mg/L) than Chetomba Creek (mean= 11.3 mg/L) and West Fork Beaver Creek (mean=8.5 mg/L), watersheds with more riparian land retirement. Total phosphorus was highest (mean=0.26 mg/L) in West Fork Beaver Creek and lower in Chetomba Creek (mean=0.15 mg/L) and South Branch Rush River (mean=0.16 mg/L). A second monitoring site was established in Chetomba basin, downstream from substantial riparian land retirement. Nitrite plus nitrate, total nitrogen, and total phosphorus were lower for the downstream monitoring site, which may indicate that water-quality improved due to land retirement. Fish data indicate better resource quality for West Fork Beaver Creek than other streams likely due to several factors including habitat quality, food resources, and dissolved oxygen characteristics. Index of biotic integrity scores increased as local land-retirement percentages (50-and 100-ft buffers) increased. Information from this study can be used to evaluate land retirement programs for improving water quality.

Additional work will continue at these sites under another USGS/BWSR project funded through LCCMR and USGS (ML2007, [Chap. HF 293], Sec. [2], Subd. 5(c)). Biological data collected from these watersheds will be compared to existing data collected across the Minnesota River basin and GIS coverages of land retirement, allowing the results from this study to extend to other sites in the Minnesota River basin and address the relation of retired land characteristics and biological integrity.

Project Results Use and Dissemination

The streamflow and continuous, in-stream water-quality data for Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River was disseminated to the public in real-time through the USGS National Water Information Website at http://waterdata.usgs.gov/nwis/mn/rt. In addition, the following products or presentations were given:

1. A poster presentation, *Effects of Land Retirement on Three Streams in the Minnesota River Basin*, was given to attendees of the Minnesota Water 2006 and Annual Water Resources Joint Conference at the Earl Brown Center, Brooklyn Center, Minn. On October 24-25, 2006 by Chad R. Anderson, Victoria G. Christensen, and Kathy E. Lee.
2. An informal presentation was held on July 11, 2007 at the Muetzel Farm in the Minnesota River basin to discuss the project with LCCMR, BWSR, local agencies and land owners. Jim Stark,

USGS, provided to attendees a hand-out on how we are collecting the data, preliminary results, and analysis.

3. The presentation, *Effects of Agricultural Land Retirement on Quality of Streams of the Minnesota River Basin*, was given and an abstract published for the Soil and Water Conservation Society, Rocky Mountain Rendezvous II on July 25, 2007 by V.G.Christensen and K.E. Lee.
4. A presentation was given at the 2008 AWRA Summer Specialty Conference in Virginia Beach, Virginia on July 1, 2008. A proceedings paper also was published and provided to LCCMR (Christensen, V.G., and Lee, K.E., 2008, Effects of Agricultural Land Retirement in the Minnesota River Basin, *in* proceedings of the American Water Resources Summer Specialty Conference, June 30-July 2, 2008, Virginia Beach, VA, 6 p.).

Future presentations scheduled include a field tour in Olivia, Minn. hosted by the Board of Water and Soil Resources and the Renville Soil and Water Conservation District on August 27, 2008. A hand-out will be prepared and an informal presentation will be prepared. Additionally, an abstract has been accepted for a presentation at the Minnesota Water 2008 and Annual Water Resources Joint Conference in October 2008. The focus of this presentation will be the benefits of continuous water-quality monitoring.

LCMR 2005 Work Program Final Report

Date of Report: August 15, 2008
LCCMR 2005 Work Program Final Report
Date of Work program Approval: June 14, 2005
Project Completion Date: June 30, 2008

I. PROJECT TITLE: Effects of Land Retirement on the Minnesota River

Project Manager: Victoria Christensen
Affiliation: USGS Minnesota Science Center
Mailing Address: 2280 Woodale Dr.
City / State / Zip: Mounds View, MN 55112
Telephone Number: (701) 277-0682
E-mail Address: vglenn@usgs.gov
FAX Number: (763) 783-3103
Web Page address:

Location: Minnesota River Basin

Total Biennial LCMR Project Budget:

LCMR Appropriation:	$ 300,000
Minus Amount Spent:	$ 300,000
Equal Balance:	$ 0
Matching Funds	$ 281,711

Legal Citation: ML 2005, First Special Session, [Chap.1], Art. 2, Sec.[10], Subd. 7(c).

Appropriation Language: 7(c) Effects of Land Retirements on the Minnesota River $300,000. $150,000 the first year and $150,000 the second year are from the trust fund to the Board of Water and Soil Resources for a cooperative agreement with the U.S. Geological Survey to evaluate effects of retired or set-aside agricultural lands on the water quality and aquatic habitat of streams in the Minnesota River Basin in order to enhance prioritization of future land retirements. This appropriation must be matched by an equal amount of non-state money. This appropriation is available until June 30, 2008, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

II. and III FINAL PROJECT SUMMARY: Three watersheds in the Minnesota River basin were selected to study effects of agricultural land retirement on stream quality. Site selections were based on similarities in hydrology, land use, soil type, and other characteristics; and differences in land retirement percentages. Water samples were collected from 2005-2007 and analyzed for field measurements, nutrients, and sediment. Streamflow and continuous water-quality data were collected and disseminated (http://waterdata.usgs.gov/nwis/mn/rt). Biological sampling was conducted in August 2006 and 2007. The South Branch Rush River (representing little to no land retirement) had substantially higher nitrogen concentrations (mean=14.3 mg/L) than Chetomba Creek (mean= 11.3 mg/L) and West Fork Beaver Creek (mean=8.5 mg/L), watersheds with more riparian land retirement. Total phosphorus was highest (mean=0.26 mg/L) in West Fork Beaver Creek and lower in Chetomba Creek (mean=0.15 mg/L) and South Branch Rush River (mean=0.16 mg/L). A second monitoring site was established in Chetomba basin, downstream from substantial riparian land retirement. Nitrite plus nitrate, total nitrogen, and total phosphorus were lower for the downstream monitoring site, which may indicate that water-quality improved due to land retirement. Fish data indicate better resource quality for West Fork Beaver Creek than other streams likely due to several factors including habitat quality, food resources, and dissolved oxygen characteristics. Index of biotic integrity scores increased as local land-retirement percentages (50-and 100-ft buffers) increased. Information from this study can be used to evaluate land retirement programs for improving water quality.

Additional work will continue at these sites under another USGS/BWSR project funded through LCCMR and USGS (ML2007, [Chap. HF 293], Sec. [2], Subd. 5(c)). Biological data collected from these watersheds will be compared to existing data collected across the Minnesota River basin and GIS coverages of land retirement, allowing the results from this study to extend to other sites in the Minnesota River basin and address the relation of retired land characteristics and biotic integrity.

IV. OUTLINE OF PROJECT RESULTS: Minnesota Governor Tim Pawlenty has requested funds for retiring an additional 100,000 acres of agricultural lands (currently 200,000 acres are included) to improve water quality and aquatic biology in Minnesota's streams and rivers. There are no existing state or federal programs to evaluate the effects of land retirement (for example, the Conservation Reserve Enhancement Program, CREP), or large-scale best-management practices (BMPs), on water quality and aquatic biology. Furthermore, the efficacy of prioritizing retired lands near streams is unknown. There have been several previous analyses of the effects of small-scale agricultural BMPs, such as crop-residue management and conservation tillage. Whereas field-scale agricultural BMPs and agricultural practice changes have shown promise in reducing non-point sources, a basin-scale analysis of current land-use practices was needed. This effort complements existing small-scale studies and provides a holistic evaluation on a watershed scale. This cohesive analysis, which addresses the effects of land retirement and effective locations for retired lands in a watershed, complements studies of small-scale agricultural practices and provides the basis for evaluating the combined effects of large and small-scale programs intended to improve environmental water quality.

During 2006-2007, streamflow was collected continuously in the Chetomba Creek basin, West Fork Beaver Creek basin, and South Branch Rush River basin. Streamflow during 2006 was higher for all sites than in 2007, which was a very low-flow year. Continuous in-stream water-quality data also were collected during 2006-2007. In-stream parameters included temperature, dissolved oxygen, pH, specific conductance, and turbidity. Fifty-five samples were collected and analyzed for nitrite plus nitrate, total nitrogen, total phosphorus, and other nutrients. Generally, nitrogen concentrations decreased with increasing land retirement percentages. Additional results of these chemical analyses are given in the attached progress report. Twenty-three samples were collected and analyzed for chlorophyll-a. Chlorophyll-a was substantially higher at West Fork Beaver Creek than at other sites. Fish and aquatic biological samples were collected in the three basins. IBI scores were calculated from this data and results indicate that IBI scores increase with increasing local (50- and 100-ft buffers) land retirement percentages.

There were some changes in project expenditures from the original budget detail (attachment A). The most substantial difference was that more funds were spent on the collection of in-stream water-quality parameters, whereas fewer funds were spent on manual sample collection and analysis. There is a rich data set available from the continuous water-quality monitors, resulting in substantial dissolved oxygen data that will be used for metabolism analysis. A paper including stream metabolism will be published at a later date, using the remaining matching funds provided by the USGS.

A progress report was prepared (attached) that quantifies the effects of agricultural land-retirement programs on reductions in non-point nutrient and sediment inputs and changes in aquatic ecosystem integrity. Data from this analysis can be used by others to calibrate and verify current water-quality models. Data also can be used to verify information provided by local agencies, through the interagency e*LINK* Program, to estimate the success of non-point pollution control programs. In addition, the establishment of sampling sites with automated samplers and streamflow gages can provide the infrastructure for future evaluations of BMPs in these watersheds.

Result 1: Selection of sites and streamgaging

Description: The effectiveness of land-retirement in improving stream-water quality and aquatic biological conditions is expected to be significantly related to how close retired lands are to streams and by the erodibility of soils in a watershed. As originally proposed, this study involved selection, study, and instrumentation of six watersheds from combinations of three levels of land-retirement acreages and two soil-runoff conditions. Watersheds were to be classified into three groups: 1) those with large proportions of the lands in retirement adjacent to streams, 2) those with a large proportion of upland lands in land retirement, and 3) those with little or no retirement acreage. The influence of soil runoff, on inputs to nutrients and sediment delivered to streams was to be tested in areas with both high and low runoff potential.

The revised study design required a reduction in scope as a result of lower funding. The revised design focused on three watersheds with fine-grained (heavy) soils that make up most of the Minnesota River watershed. A follow-up study, in subsequent years, could focus on watersheds with soils of different texture and therefore runoff characteristics. In addition, this revised study design places additional emphasis on assessing and understanding the significance of biological conditions and physical characteristics of the stream channels in the watersheds being studied. Results from previous studies were used to co-locate the selected basins in areas where historical data exist. These previous studies include the Minnesota River Assessment Project (MRAP) and biological reconnaissance studies conducted by the USGS and MPCA. By using data from previous studies in the historical evaluations of conditions in the watersheds, investigators were able to gain insight on changes in historical stream quality and aquatic biological conditions.

Watersheds were monitored for suspended sediment, nutrients, aquatic biological conditions, and habitat conditions. Some samples were collected during runoff events when the majority of sediment is being transported and to more accurately determine loads of nutrients and sediment. The ecosystem approach of this study includes detailed water chemistry along with physical, hydrologic, and biological (invertebrates and fish) components. The results can be linked to e*LINK* (Board of Water and Soil Resources) calculations. The project was leveraged with a current USGS project that analyzes landscapes data in the Midwest by providing ancillary information needed to select appropriate watersheds.

The approach depended on our ability to identify retired lands within individual watersheds that fit the design criteria outlined in the preceding paragraph. The original sampling design was altered in 2006, by adding a secondary site in Chetomba Creek basin (Judicial Ditch No. 1), co-located with a sampling and streamgaging site operated by the Hawk Creek Watershed Project. In addition, it was difficult to find basins with substantial upland land retirement that fit the design criteria. Therefore, analyses of watersheds were based on a range of the total amount of retired land in a watershed, in addition to proximity of retired land to streams.

The design was based on existing GIS data as well as Minnesota Board of Water and Soil Resources data, STATSGO data (U.S. Department of Agriculture, 1991), consultation with the U.S. Fish and Wildlife Service, the USDA Natural Resources Conservation Service, Minnesota Department of Agriculture, local soil and water districts and direct observation. Each watershed had a gaging station with automated water samplers. A total of three watersheds were studied.

Summary Budget Information for Result 1:	**LCMR Budget**	$ 105,943
	Minus Amount Spent	$ 104,826
	Balance	$ 1,117
	Matching Funds	$ 113,858

Completion Date: September, 2007

Final Report Summary: Sites were selected and streamgaging equipment was installed at 3 sites. A problem that was encountered during the site selection process was that current CRP data was not available in a GIS coverage. Additionally, there was not a site to represent primarily upland set-aside conditions because only two basins had substantial amounts (Hawk, LeSueur) and these two basins do not have similar hydrologic conditions (i.e. many upland lakes in Hawk) and have other complicating factors (i.e. wastewater discharge into Hawk Creek). Sites selected for this project are: Chetomba Creek near Renville (05314510); West Fork Beaver Creek at 320 St. near Bechyn (053165290); and South Branch Rush River at Co. Rd. 63 near Norseland (05326189). In addition, streamflow is being monitored by Hawk Creek Watershed Project at a fourth site (Judicial Ditch 1 at County Road 17 near Maynard, site 05313930).

Current CRP data was acquired from the FSA in 2007. This data has been used to calculate the percentage of land in CRP and other set-aside programs for each basin. In addition, GIS coverages were created which quantify the amount of land retired within 50-, 100-, 200-, and 300-ft of the stream—identified as critical buffer distances (Emmons and Olivier, 2001).

Streamflow was variable during 2006 and 2007. Several storm events occurred in the 3 basins during the study period; however, 2007 was a very low flow year. Streamflow can have a significant effect on water-quality (discussed under Result 2). Dissemination of data from the USGS sites is available to the public at http://waterdata.usgs.gov/mn/nwis/rt by clicking on the streamflow table and selecting one of the three sites. Additional flow data will be collected during 2008 (partially funded under ML2007, [Chap. HF 293], Sec. [2], Subd. 5(c)).

Result 2: Water quality and aquatic biological monitoring

Description: During the major runoff months of April through August (2006 and 2007), two types of water-quality samples and habitat, invertebrate and fish information were collected at each site. Water-quality data consisted of routine samples and samples collected during high-flow runoff. Water-quality measurements included in-stream continuous parameters, such as dissolved oxygen and manually collected water-quality samples. Water quality samples were analyzed for nutrients, chlorophyll-a, and suspended sediment. During storm runoff events, some of the samples were collected with automatic samplers.

Summary Budget Information for Result 2:	**LCMR Budget**	**$** 126,225
	Minus Amount Spent	**$** 133,783
	Balance	**$** - 7,558
	Matching Funds	**$** 122,074

Completion Date: September, 2007

Final Report Summary: The first set of water-quality samples were collected in October 2005 (Water Year 2006) at the 3 USGS sites and the Hawk Creek Watershed Project site. The water samples were analyzed for major ions, nutrients, wastewater compounds, organic carbon, chlorophyll, suspended solids, suspended sediment concentration, and field parameters (dissolved oxygen, turbidity, pH, temperature, and specific conductance). All results from the National Water Quality Laboratory have been released and are on file at the USGS office. Results of the nutrient sampling are described here briefly. The South Branch Rush River (representing little to no land retirement) had substantially higher nitrogen concentrations (mean=14.3 mg/L) than Chetomba Creek (mean= 11.3 mg/L) and West Fork Beaver Creek (mean=8.5 mg/L), watersheds with more riparian land retirement. Total phosphorus was highest (mean=0.26 mg/L) in West Fork Beaver Creek and lower in Chetomba Creek (mean=0.15 mg/L) and South Branch Rush River (mean=0.16 mg/L).

Routine samples also were collected at the Hawk Creek Watershed site in the Chetomba basin. Initial results show some nutrient concentrations are lower at the downstream Chetomba site. The area between these two sites has a substantial amount of riparian CRP.

Autosamplers were installed at Chetomba, West Fork Beaver, and South Branch Rush sites in March 2006. Auto samples were collected during at least 3 precipitation events during spring 2006 and 2007. The autosampler occasionally malfunctioned; at these times a field crew collected manual samples. Precipitation events have been more significant at some sites than at others, making comparisons difficult.

Biological sampling at the 3 USGS sites was conducted in August of 2006 and 2007. Sampling included fish identification, physical habitat characterization, benthic macroinvertebrate and periphyton collections, measurements of dissolved oxygen, and phytoplankton chlorophyll *a*.

Some additional dissolved oxygen, nutrient, and biological data were collected from the West Fork Beaver and South Branch Rush River as part of a USEPA/USGS project. This additional data will be available for analysis at no cost to this USGS/BWSR/LCCMR project and may provide some insight into the relation between daily dissolved oxygen fluctuation and chlorophyll-a concentrations in a nutrient-rich environment. Water-quality monitors continue to be maintained and data from selected USGS sites are available on-line at http://waterdata.usgs.gov/mn/nwis/rt.

Result 3: Data analysis, synthesis, and report writing

Description: Data generated by this effort are available to be used by others for calibration and verification of simulations of changes in water quality resulting from changes in land-use activities. The data may also be used to verify the algorithms used by local units of government in reporting to document the success of individual non-point pollution control programs through *eLINK*. The establishment of fully instrumented sampling sites with automated samplers and streamflow gages also can provide the infrastructure for future evaluations of other BMPs in watersheds. This resulted in a progress report that identified the benefits of watershed-level land-use programs to reduce non-point source nutrient and sediment inputs and improve stream habitat. The final report (which will be published in September 2009, after another year of data is collected) will compare sediment and nutrients and aquatic biological conditions in small watersheds with differing set-aside lands.

Summary Budget Information for Result 3:	**LCMR Budget**	$ 67,832
	Minus amount spent	$ 61,391
	Balance	$ 6,441
	Matching Funds	$ 45,779

Completion Date: June 30, 2008

Final Report Summary: The streamflow and continuous water-quality data from the 3 selected sites is being disseminated through the USGS website (http://waterdata.usgs.gov/nwis/mn/rt). In addition, the following in products were prepared or presentations given:

1. Presentation of results to date was provided to USGS cooperators and others interested in nutrient studies at the USGS Nutrient work group meeting in May 2006
2. A poster presentation, *Effects of Land Retirement on Three Streams in the Minnesota River Basin*, was given to attendees of the Minnesota Water 2006 and Annual Water Resources Joint Conference at the Earl Brown Center, Brooklyn Center, Minn. on October 24-25, 2006 by Chad R. Anderson, Victoria G. Christensen, and Kathy E. Lee.
3. An informal presentation was held on July 11, 2007 at the Muetzel Farm in the Minnesota River basin to discuss the project with LCCMR, BWSR, local agencies and land owners. Jim Stark, USGS, provided to attendees a hand-out on how data was collected, preliminary results, and analysis.
4. The presentation, *Effects of Agricultural Land Retirement on Quality of Streams of the Minnesota River Basin*, was given and an abstract published for the Soil and Water Conservation Society, Rocky Mountain Rendezvous II on July 25, 2007 by V.G.Christensen and K.E. Lee.
5. A presentation was given at the 2008 AWRA Summer Specialty Conference in Virginia Beach, Virginia on July 1, 2008. A proceedings paper also was published and provided to LCCMR (Christensen, V.G., and Lee, K.E., 2008, Effects of Agricultural Land Retirement in the Minnesota River Basin, *in* proceedings of the American Water Resources Summer Specialty Conference, June 30-July 2, 2008, Virginia Beach, VA, 6 p.).

Future presentations scheduled include a field tour in Olivia, Minn. hosted by the Board of Water and Soil Resources and the Renville Soil and Water Conservation District on August 27, 2008. A hand-out will be prepared and an informal presentation will be prepared. Additionally, an abstract has been accepted for a presentation at the Minnesota Water 2008 and Annual Water Resources Joint Conference in October 2008. The focus of this presentation will be the benefits of continuous water-quality monitoring. The final report, submitted with this Work Plan is an unpublished progress report. This report is for LCCMR review, not to be cited or released to the public. The information from this project will then be combined with the enhancement funded under the 2007 Trust Fund (Legal Citation: ML 2007, [Chap. HF 293], Sec. [2], Subd. 5(c)) into a published report. The report is scheduled for publication in September 2009.

V. TOTAL LCMR PROJECT BUDGET:

All Results: Personnel: $	**186,712**
All Results: Equipment: $	**53,568**
All Results: Development: $	0
All Results: Acquisition: $	0
All Results: Other: $	**59,720**

TOTAL LCMR PROJECT BUDGET: $ 300,000

Explanation of Capital Expenditures Greater Than $3,500: No single capital expenditure over $3,500. The cost of a stage sensor is $3495 (model H350XL/355). One stage sensor will be purchased for each of the three sites.

VI. Past, Present, and Future Spending: Some data analysis and report writing will continue with USGS matching funds. A presentation and paper is being prepared for the Minnesota Water 2008 Conference. Future publications include a USGS Scientific Investigations Report, which includes the data collected through the LCCMR/USGS/BWSR project (ML 2007, [Chap. HF 293], Sec.[2], Subd. 5(c)).

VII. OTHER FUNDS & PARTNERS:

A. Project Partners: The USGS, Minnesota Board of Water and Soil Resources, and others, were partners in the effort. The USGS will provide project design, management and evaluation, equipment, personnel, and half of the costs (Federal matching funds) for this project, through a joint funding agreement with the Board of Soil and Water Resources (Board). The Board and other agencies will provide in-kind support and may provide supplemental funding. The Hawk Creek Watershed Project is providing data and assistance for the Judicial Ditch 1 and Chetomba Creek sites. The Rush River CWP Project has agreed to provide data and assistance in the collection of rainfall event samples.

B. Other Funds being Spent during the Project Period: Because this project is a good fit with local and national science priorities of the USGS, federal matching funds were available to be provided for this effort.

C. Required Match (if applicable): $300,000 in Federal matching funds. These matching funds will provide for personnel expense for science support staff, administrative staff, facilities costs, cost center and bureau assessments and indirect costs.

Detail is provided in Attachment A.

D. Past Spending: none

E. Time: The project will required three years to complete. The first year was consumed with site selection and gage and sampling equipment installation.

Sampling commenced in fall of 2005. The sites were sampled through September of 2007.

VIII. DISSEMINATION: Products of this study will be publicly available. A USGS Scientific Investigations Report will be completed at the end of the project (combined with the results from the project enhancement and due September 30, 2009). Real-time streamflow and water-quality information are available on the World Wide Web at URL http://waterdata.usgs.gov/nwis.

IX. LOCATION: Minnesota River basin

X. REPORTING REQUIREMENTS: Periodic work program progress reports were submitted every six months beginning in December 2005, and ending with this final work program report.

XI. RESEARCH PROJECTS: A provisional report (unpublished) is attached. This report has not yet received approval for publication from the USGS. The report is subject to revision and should not be referenced or released.

Attachment A: Budget Detail for 2005 Projects

Proposal Title: Effect of Land Retirement on the Minnesota River *Proposal # (A-01)*

Project Manager Name: Jim Stark/Victoria Christensen

LCMR Requested Dollars: $ *300,000 with an equivalent amount from Federal matching funds*

1) **See list of non-eligible expenses, do not include any of these items in your budget sheet**
2) **Remove any budget item lines not applicable**

2005 LCMR Proposal Budget	Result 1 Budget:	Amount Spent *(6/30/08)*	Balance *(6/30/08)*	Result 2 Budget:	Amount Spent *(6/30/08)*	Balance *(6/30/08)*	Result 3 Budget:	Amount Spent *6/30/08)*	Balance *(6/30/08)*	TOTAL FOR BUDGET ITEM
Effects of Land Retirement on the Minnesota River	*Selection of sites and streamgaging*			*Water quality and aquatic biological monitoring*			*Data Analysis, Synthesis and Reporting*			
BUDGET ITEM										
PERSONNEL: Staff Expenses, wages, salaries – Project Chief	$17,000	$17,000	$0	$0	$0	$0	$50,000	$45,359	$4,641	$67,000
PERSONNEL: Staff Expenses, wages, salaries – Support Staff				$0	$0	$0	$4,267	$4,267	$0	$4,267
PERSONNEL: Staff Expenses, wages, salaries – Geographer	$18,275	$18,275	$0	$0	$0	$0	$1,175	$1,175	$0	$19,450
PERSONNEL: Staff Expenses, wages, salaries – Support Hydrologist/Aquatic Biologist	$2,000	$2,000	$0	$24,080	$24,080	$0	$6,500	$6,500	$0	$32,580
PERSONNEL: Staff Expenses, wages, salaries – Hydrologic Technician/Student Help				$16,425	$16,425	$0			$0	$16,425
PERSONNEL: Staff Expenses, wages, salaries – Hydrologic Technician	$2,400	$2,400	$0	$5,790	$5,790	$0	$0		$0	$8,190
PERSONNEL: Staff Expenses, wages, salaries – Hydrologic Technician	$32,500	$31,383	$1,117	$6,300	$6,300	$0	$0		$0	$38,800
Equipment / Tools:Gage house and equipment	$10,215	$10,215	$0	$0	$0	$0			$0	$10,215
Equipment/Tools: stage sensor and DCP	$19,053	$19,053	$0			$0			$0	$19,053
Equipment/Tools: WQ monitor rental				$24,300	$29,376	-$5,076			$0	$24,300
Printing			$0	$0		$0	$1,800		$1,800	$1,800
WQ monitor supplies (standards, etc)				$2,754	$15,701	-$12,947			$0	$2,754
Automated sampler rental				$5,508	$2,203	$3,305			$0	$5,508
Lab supplies for integrated sampling				$2,500	$2,500	$0			$0	$2,500
Supplies for automated sampling				$982	$982	$0			$0	$982
Supplies for biological sampling				$110	$278	-$168			$0	$110
Travel expenses in Minnesota	$4,500	$4,500	$0	$4,738	$9,456	-$4,718	$3,090	$3,090	$0	$12,328
Travel outside Minnesota	$0		$0	$0		$0	$1,000	$1,000	$0	$1,000
Analytical costs			$0	$32,738	$17,973	$14,765			$0	$32,738
Postage/Fedex/sample transport				$0	$2,719	-$2,719				$0
COLUMN TOTAL	$105,943	$104,826	$1,117	$126,225	$133,783	-$7,558	$67,832	$61,391	$6,441	$300,000

Other project costs to be covered by the USGS:

Personnel: Support Staff (Distributed Direct)	$45,555	$46,672	-$1,117	$40,199	$53,892	-$13,693	$23,066	$24,400	-$1,334	$108,820
Personnel: Project Chief							$0	$4,641	-$4,641	
Facilities	$10,594	$10,594	$0	$9,349	$10,571	-$1,222	$6,357	$1,869	$4,488	$26,300
Cost Center Assessment	$40,523	$40,523	$0	$35,758	$41,435	-$5,677	$24,314	$12,128	$12,186	$100,595
Bureau Assessment	$24,314	$16,069	$8,245	$25,383	$16,176	$9,207	$14,588	$2,741	$11,847	$64,285
TOTAL USGS COSTS	$120,986	$113,858	$7,128	$110,689	$122,074	-$11,385	$68,325	$45,779	$22,546	$300,000
TOTAL PROJECT COST	$226,929	$218,684	$8,245	$236,914	$255,857	-$18,943	$136,157	$152,949	-$16,792	$600,000

EFFECTS OF AGRICULTURAL LAND RETIREMENT IN THE MINNESOTA RIVER BASIN

Victoria G. Christensen and Kathy E. Lee*
U.S. Geological Survey
2280 Woodale Drive
Mounds View, Minnesota 55112
Phone 701-277-0682
Fax 701-281-5018

ABSTRACT: The effects of agricultural land retirement on nutrient concentrations and biological conditions of three streams in the Minnesota River Basin were assessed using data collected during 2005-2007. The Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins, which range in size from 52,500 to 96,031 acres, have similar geologic and hydrologic settings, but differ with respect to the amount, type, and location of retired land. Preliminary results show that nitrite plus nitrate concentrations were highest (mean=13.4 milligrams per liter [mg/L]) in South Branch Rush River, the subbasin with little to no land retirement, and lower in Chetomba Creek (mean=10.9 mg/L) and West Fork Beaver Creek (mean=7.8 mg/L), subbasins with more riparian or upland land retirement. Fish data indicate better resource quality for the West Fork Beaver Creek than other streams likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics. Index of biotic integrity (IBI) scores increased as local land retirement percentages (50- and 100-ft buffers) increased. Data and analysis from this study can be used to evaluate the success of agricultural best management practices (BMPs) and land retirement programs for improving stream quality.
KEY TERMS: Minnesota River Basin, agricultural land retirement, CRP, nutrients, physical habitat, IBI scores.

INTRODUCTION

Streams in the Minnesota River Basin (fig. 1) are being studied to determine the effect of agricultural land retirement on stream quality. Agricultural land commonly is retired, or taken out of production and planted with native grasses, on the basis of field-scale research that shows land retirement leads to improved water quality. However, little information exists regarding watershed-scale effects of land retirement. To provide information for this goal, the Legislative-Citizen Commission on Minnesota Resources and the Minnesota Board of Water and Soil Resources cooperated with the U.S. Geological Survey (USGS) to compare water quality and biological conditions across three streams with varying degrees and location of land retirement.

The objectives of the study are to characterize and compare streamflow, water quality, and biological conditions in the Minnesota River Basin and to compare spatial and temporal variability in water quality and biological conditions to the amount and location of agricultural land retirement. The purpose of this paper is to provide an overview of nutrient concentrations and biological conditions within the Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins.

The Minnesota River originates near the western border of Minnesota, flows southeast to Mankato (fig. 1), and then turns northeast to join the Mississippi River at St. Paul, Minn. (Ojakangas and Matsch, 1982). The basin lies 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).

Study Area

Data collection sites established for this study include USGS stream-gaging stations located on Chetomba Creek (site 1, fig. 1), West Fork Beaver Creek (site 3), and South Branch Rush River (site 6). The three subbasins differ with respect to the amount and location of land retirement (table 1), but have similar

* Respectively, Hydrologist, U.S. Geological Survey, 2280 Woodale Drive, Mounds View, Minn., 55112, Phone: 701-277-0682, vglenn@usgs.gov and Hydrologist, U.S. Geological Survey, 2280 Woodale Drive, Mounds View, MN, 55112, Phone: 763-783-3100, klee@usgs.gov

geologic and hydrologic settings. A second site was selected in the Chetomba Creek subbasin, Judicial Ditch No. 1 (site 2, fig. 1). Chetomba Creek was re-routed through Judicial Ditch No. 1 in the 1970s, making this site downstream from the Chetomba Creek site 1. The intervening drainage area between these two sites has few tributary ditches or streams and substantial land retirement (table 1). Secondary sites were established on West Fork Beaver Creek (site 4, fig. 1) and South Branch Rush River (site 5) for instream comparisons; however, these two sites did not have sufficient data to include here.

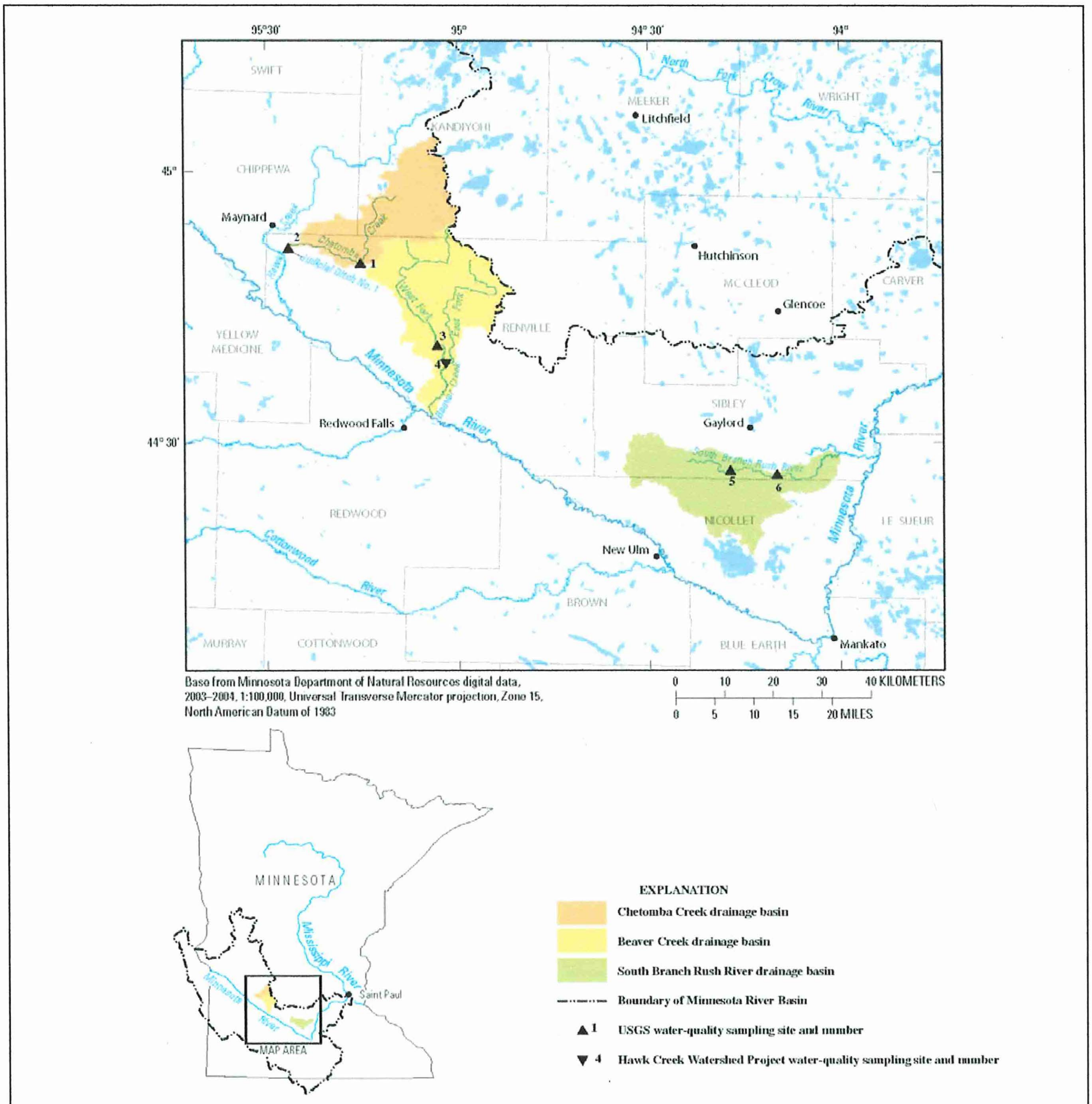


Figure 1. Sampling sites in Chetomba Creek, Beaver Creek, and South Branch Rush River subbasins, Minnesota River Basin, south-central Minnesota.

Table 1. Percentage of land retirement in selected subbasins of the Minnesota River Basin, 2005-2007.
[Percentage land retirement for Judicial Ditch No. 1 is for intervening drainage area only; ft, feet]

Site name	Site number	Drainage area (acres)	Percentage Land Retirement				
			Basin	300-ft buffer[1]	200-ft buffer[1]	100-ft buffer[1]	50-ft buffer[1]
Chetomba Creek	1	74,476	3.1	3.9	4.3	5.1	5.7
Judicial Ditch No. 1	2	96,031	6.3	9.4	11.3	15.3	18.7
West Fork Beaver Creek	3	58,974	3.7	6.2	7.5	9.5	10.4
South Branch Rush River	6	52,915	1.5	2.7	3.2	5.1	7.6

[1] The buffers are defined by the percentage of retired land within 300, 200, 100, and 50 feet on either side of the stream.

Agriculture has a major influence on water quality in the Minnesota River Basin (Battaglin and Goolsby, 1999; Kroening and others, 2003). Intensive use of agricultural chemicals has resulted in nonpoint-source contamination of surface water throughout the basin. Because of the poorly drained soils and resulting low infiltration rates in much of the Minnesota River Basin, ditches and tile drains are used to help drain the water from agricultural fields. This type of drainage may reduce flood damage to the fields and may draw oxygen into the soil. However, tile drains also provide a direct path for surface water and any associated contaminants to reach drainage ditches and streams (Wilson and others, 1997). Ditch and tile systems direct excess soil water to surface water without the longer residence time of ground-water storage.

Stream conditions are influenced by interactions among physical and chemical factors at differing spatial scales. However, loss of riparian vegetation and natural land cover in the Minnesota River Basin has reduced habitat, modified hydrologic conditions, and changed water quality (Stark and others, 1996). Two important factors that influence physical, chemical, and biological conditions are local and watershed-wide land-cover characteristics. Retired land cover may be important to water quality, aquatic habitat, instream temperature, and reduction of sediment and overland runoff.

METHODS

An objective of this study was to characterize effects of retired lands on the water quality and biological conditions of streams in the Minnesota River Basin that could be used to evaluate the success of agricultural best management practices and land retirement programs for improving stream quality. Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins were selected after considering a set of parameters (for example, slope, basin size, and absence of in-line lakes). The selection required minimizing the differences in these parameters, while maximizing differences in percentages of land retirements.

Land retirement data were obtained in 2007 from the Farm Services Agency (FSA, St. Paul. Minn.) and included a geographic information system (GIS) coverage of land with Conservation Reserve Program (CRP) contracts. Land retirement data also were obtained from the Conservation Reserve Enhancement Program (CREP), Re-invest in Minnesota (RIM) program, and some smaller amounts of retired agricultural land in other programs including Pheasants Forever, Wildlife Management Areas, and U.S. Fish and Wildlife Service Waterfowl Production Areas.

Water-quality samples were collected manually according to methods described in the USGS National Field Manual (Wilde and others, 1998) using depth- and width-integrating techniques with the exception of samples collected with automated sampling equipment and occasional grab samples. Nutrient samples were analyzed (Patton and Kryskalla, 2003) at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Water-quality samples were collected between October 2005 and September 2007 and were classified as either *event*, which refers to samples collected during rainfall events, or *routine*, which are samples collected during monthly maintenance trips. Most event samples were collected with an autosampler, except for a few cases when the autosamplers malfunctioned. In these situations, a grab (single point) sample was collected if field personnel were onsite. Quality assurance was assessed with field blanks and replicate samples. No detectable concentrations of nitrite plus nitrate, total nitrogen, or total phosphorus were present in blank samples. The median analytical variation between duplicate analyses of nitrite plus nitrate, total nitrogen, and total phosphorus was less than 1 percent.

Periphyton and phytoplankton samples were collected at each stream during 2007 and sent to the USGS NWQL for analyses of chlorophyll-a using fluorometric methods (Arar and Collins, 1997). Fish were collected during August and September 2006-2007 at each stream by electrofishing equipment (pulsed DC), conducted according to protocols established for the USGS's National Water-Quality Assessment Program (Moulton and others, 2002). Briefly, backpack electrofishing gear was used to make two collection passes within the reach. Sampling time was recorded to normalize catch per unit of effort. Index of biotic integrity (IBI) scores were used to measure fish community response and community health. The IBI was calculated following Bailey and others (1993) using 12 metrics related to the composition and structure of the fish community. The sum of the metric scores is the IBI score, which ranges from 12 to 60 (greater number indicates better aquatic resource quality). Physical habitat was characterized at each stream location at the time of fish collections following Fitzpatrick and others (1998).

RESULTS AND DISCUSSION

Nitrite plus nitrate concentrations (table 2) were highest in South Branch Rush River, the subbasin with little to no land retirement, and lower in Chetomba Creek and West Fork Beaver Creek, subbasins with more riparian or upland land retirement. Nitrite plus nitrate and total nitrogen (table 2) decreased with increasing retired land percentage (table 1). Total phosphorus concentrations were lowest in Judicial Ditch No. 1 and highest in West Fork Beaver Creek. Judicial Ditch No. 1, which is downstream from a substantial amount of retired land (table 1), had lower nutrient concentrations than the upstream Chetomba Creek site. This may indicate that the retired land between the Chetomba Creek site and the Judicial Ditch site leads to improved water quality.

Table 2. Average chlorophyll-a and nutrient concentrations at selected streams in the Minnesota River Basin, 2005-2007.

[All nutrient concentrations are in milligrams per liter; chy-a, chlorophyll-a concentrations in micrograms per liter; number in parentheses is number of samples; --, not applicable]

Site name (site number, table 1)	Chy-a	Nitrite plus nitrate			Total nitrogen			Total phosphorus		
		Routine	Event	Total	Routine	Event	Total	Routine	Event	Total
Chetomba Creek (1)	13.7(6)	9.6(11)	15.9(3)	10.9(14)	10.3(10)	17.4(3)	11.9(13)	0.13(11)	0.23(3)	0.15(14)
Judicial Ditch No. 1 (2)	6.08(5)	8.2(8)	--(0)	8.2(8)	7.5(8)	--(0)	7.5(8)	0.10(8)	--(0)	0.10(8)
West Fork Beaver Creek (3)	19.1(6)	6.1(12)	13.0(4)	7.8(16)	6.7(12)	14.0(4)	8.5(16)	0.21(12)	0.39(4)	0.26(16)
South Branch Rush River (6)	15.1(6)	10.0(11)	19.5(6)	13.4(17)	11.3(11)	19.8(6)	14.3(17)	0.14(11)	0.19(6)	0.16(17)

Physical characteristics varied among streams and among years (table 3). Stream reach volume and habitat composition changed between 2006 and 2007 due to flow conditions. During 2006, stream widths and depths generally were greater than in 2007, leaving less habitat volume in 2007. Chetomba Creek had the greatest overall reach volume during both years. The dominant types of instream cover at Chetomba Creek and South Branch Rush River were macrophyte/macroalgal cover and overhanging vegetation. West Fork Beaver Creek had little or no macrophyte/macroalgal cover; rather the instream cover consisted of overhanging vegetation and woody debris. The bottom substrate at Chetomba Creek, and South Branch Rush River was primarily sand and gravel. At West Fork Beaver Creek the bottom substrate tended toward finer silt and clay.

There were 21 species of fish within five families collected among all sites and time periods. The majority of fish were in the Cyprinidae family (12), followed by two taxa each of the remaining families (Cataostomidae, Centarchidae, Gasterosteidae, Ictaluridae, and Percidae). Most of the fish collected were invertivores, planktivores, or detritivores, and five of the taxa were classified as tolerant fish. At Chetomba Creek, fathead minnows, creek chubs, and bigmouth shiners composed most (more than 50 percent) of the abundance during 2006 and creek chubs composed most of the abundance during 2007. At West Fork Beaver Creek, common shiner and bluntnose minnows (*Pimephales notatus*) composed most of the abundance during both years. At South Branch Rush River, fathead minnows and bluntnose minnows composed most of the abundance in 2006, whereas creek chubs composed most of the abundance during 2007.

Table 3. Summary of physical habitat and biological characteristics at selected streams in the Minnesota River Basin, 2006-2007.

[m, meters; m², square meters; m³, cubic meters; mm, millimeters; >, greater than]

	Chetomba Creek		West Fork Beaver Creek		South Branch Rush River	
Site number (fig. 1)	1		3		6	
Collection year	2006	2007	2006	2007	2006	2007
Reach length (m)	150	150	150	150	150	150
Average wetted channel width (m)	6.2	4.9	4.6	3.9	4.2	2.6
Average depth (m)	0.17	0.14	0.15	0.16	0.10	0.08
Average velocity (m)	0.04	0.03	0.06	0.02	0.08	0.008
Reach volume (m³)	158	103	104	94	63	31
Reach area (m²)	930	735	690	585	630	390
			Instream habitat cover			
Macrophyte/macroalgal cover (percent)[1]	98	44	1.8	0.0	22	22
Overhanging vegetation (percent)	75	22	16	15	38	18
Woody debris (percent)	0	0	26	6	0	0
			Bottom substrate composition			
Silt, clay, and organic detritus (percent)	0	2	70	89	0	0
Sand > 0.062 – 2 mm (percent)	0	18	15	4	13	60
Fine gravel > 2 – 16 mm (percent)	77	55	6	7	78	40
Coarse gravel > 16 – 32 mm (percent)	23	24	6	0	9	0
			Fish characteristics			
Number of fish species collected	8	9	13	15	16	11
Percent of fish classified as tolerant[2]	56	41	8	11	33	78
Index of biotic integrity (IBI) scores[2]	14	20	30	28	19	23

[1]Percentage of measurements where selected cover was present (out of 55 measurements)

[2]Bailey and others (1993) was used for fish tolerance classification and IBI calculations; Bailey and others (1993) rates streams with IBI scores of 50-60 as "excellent," 40-49 as "good," 30-39 as "fair," 20-29 as "poor," and 12-20 as "very poor."

IBI scores indicated poor quality at all streams during both sampling periods except the West Fork Beaver Creek had a rating of "fair" during 2006. IBI scores generally decrease with increasing physical and chemical perturbations such as poor water quality, poor instream habitat, and migration barriers (Karr and others, 1987). Two of the metrics that influenced the overall IBI score, species richness (the number of fish taxa collected) and percent tolerant fish, show that West Fork Beaver Creek had a moderate number of fish species and the smallest percentage of tolerant species, whereas South Branch Rush River had a moderate number of fish species and a high percentage of tolerant species.

In this study, IBI scores increased as the local land retirement percentages (50- and 100-ft buffers) increased. The relation was not as clear with retired land percentages at greater buffer distances. In addition to low percentages of retired land, the Chetomba Creek site has very little instream habitat diversity with the exception of very dense macrophyte and macroalgae mats that may not provide good habitat due to increased dissolved-oxygen variability. Number of fish species collected indicates better resource quality for the West Fork Beaver Creek than other streams likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics. The greater IBI score at West Fork Beaver Creek compared to Chetomba Creek and South Branch Rush River coincides with greater percentages of retired land and diversity of physical habitat cover types. The substrate at West Fork Beaver Creek was primarily silt and clay which is not preferable for many fish and invertebrate species but a lack of extensive macroalgae cover may lead to more stable dissolved oxygen conditions within the stream.

CONCLUSION

Retired land is assumed to improve water quality and aquatic resource quality by reducing surface runoff and reducing agricultural chemical entry into streams. In this study, both nitrogen and phosphorus concentrations were lowest in the subbasin with the highest retired land percentage. Nitrogen concentrations were highest in the subbasin with little to no land retirement. IBI scores increased as local land retirement percentages (50- and 100-ft buffers) increased likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics.

REFERENCES

Arar, E. J., and Collins G. B., 1997, U. S. Environmental Protection Agency Method 445.0, In Vitro Determination of Chlorophyll a and Pheophytin a in Marine and Freshwater Algae by Fluorescence, Revision 1.2. Cincinnati, Ohio, U.S. Environmental Protection Agency, National Exposure Research Laboratory, Office of Research and Development, 22 p.

Bailey, P.A., Enblom, J.W., Hanson, S.R., Renard, P.A., and Konrad Schmidt, 1993. A Fish Community Analysis of the Minnesota River Basin. Minnesota Pollution Control Agency, St. Paul, Minnesota, variously paged.

Battaglin, W.A., and D.A. Goolsby, 1999. Spatial Data in Geographic Information System Format on Agricultural Chemical Use, Land Use and Cropping Practices in the United States. U.S. Geological Survey Water-Resources Investigations Report 94-4176.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and M.E. Gurtz, 1998. Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program. U.S. Geological Survey Water-Resources Investigations Report 98-4052, 67 p.

Gray, J.R., Glysson, G.D., Turcios, L.M., and G.E. Schwartz, 2000, Comparability of Suspended-sediment Concentration and Total Suspended Solids Data. U.S. Geological Survey Water-Resources Investigations Report 00-4191, 14 p.

Guy, H.P., and V.W. Norman, 1970. Field Methods for Measurement of Fluvial Sediment. U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2, 59 p.

Karr, J.R., Yant, P.R. Fausch, K.D., and I.J. Schlosser, 1987. Spatial and Temporal Variability of the Index of Biotic Integrity in Three Midwestern Streams. Transactions of the American Fisheries Society 116: 1-11.

Kroening, S.E., Lee, K.E., and R.M. Goldstein, 2003. Water-quality Assessment of Part of the Upper Mississippi River Basin Study Unit, Minnesota and Wisconsin—Nutrients, Chlorophyll a, Phytoplankton, and Suspended Sediment in Streams, 1996-1998. U.S. Geological Survey Water-Resources Investigations Report 2002-4287, 34 p.

Moulton, S.R., II, Kennen, J.G., Goldstein, R.M., and J.A. Hambrook, 2002. Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment Program. U.S. Geological Survey Open-File Report 02-150, 75 p.

Ojakangas, R.W., and C.L. Matsch, 1982. Minnesota's Geology. University of Minnesota Press, Minneapolis, 255 p.

Patton, C.J. and J.R. Kryskalla, 2003, Methods of Analysis by the U. S. Geological Survey National Water Quality Laboratory—Evaluation of Alkaline Persulfate Digestion as an Alternate to Kjeldahl Digestion for Determination of Total and Dissolved Nitrogen and Phosphorus in Water. U.S. Geological Survey Water-Resources Investigations Report 03-4174, 33 p.

Stark, J.R., Andrews, W.J., Fallon, J.D., Fong, A.L., Goldstein, R.M., Hanson, P.E., and S.E. Kroening, 1996. Water-quality Assessment of Part of the Upper Mississippi River Basin, Minnesota and Wisconsin—Environmental Setting and Study Design. U.S. Geological Survey Water Resources Investigations Report 96-4098, 62 p.

Wilde, F.D., and D.B. Radke, eds., 1998. National Field Manual for the Collection of Water-quality Data. U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, variously paged.

Wilson, B., Burt, E., Oduro, P., Headrick, M., AbuLaban, A., Brown, J., and E. Brooks, 1997. Minnesota River Surface Tile Inlet Research—Modeling Component. Final Report to the Legislative Commission on Minnesota Resources, St. Paul.

PROVISIONAL DRAFT Subject to Revision DO NOT QUOTE OR RELEASE

USGS
science for a changing world

Minnesota Board of Water & Soil Resources

Prepared in Cooperation with Minnesota Board of Water and Soil Resources with funding from the Minnesota Environment and Natural Resources Trust Fund

Water Quality and Biological Responses to Agricultural Land Retirement in Streams of the Minnesota River Basin, 2006-07

By Victoria G. Christensen, Kathy E. Lee, Christopher A. Sanocki, and Eric H. Mohring

Progress Report

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

Contents

Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
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 Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

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

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Water Quality and Biological Response to Agricultural Land Retirement in Streams of the Minnesota River Basin, 2006-07

By V.G. Christensen, K.E. Lee, C.A. Sanocki, and E.H. Mohring

Abstract

The effects of agricultural land retirement on nutrient concentrations and biological conditions of three streams in the Minnesota River basin were assessed using data collected during 2006-2007. The Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River subbasins, which range in size from 52,500 to 96,031 acres, have similar geologic and hydrologic settings, but differ with respect to the amount, type, and location of retired land. Preliminary results show that nitrogen concentrations were highest (mean=14.3 milligrams per liter [mg/L]) in South Branch Rush River, the subbasin with little to no land retirement, and lower in Chetomba Creek (mean=11.9 mg/L) and West Fork Beaver Creek (mean=8.5 mg/L), subbasins with more riparian or upland land retirement. Total phosphorus concentrations were not directly related to differing land retirement percentage with average concentrations at West Fork Beaver Creek of 0.26 mg/L, compared with 0.15 mg/L at the Chetomba Creek site and 0.16 mg/L at the South Branch Rush River site. Fish data indicate better resource quality for the West Fork Beaver Creek than other streams likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics. Index of biotic integrity (IBI) scores increased as local land retirement percentages (50- and 100- ft buffers) increased. Data and analysis from this study can be used to evaluate the success of agricultural best management practices (BMPs) and land retirement programs for improving stream quality.

Introduction

The Minnesota River basin (fig. 1) located primarily in the state of Minnesota, is part of the Midwest Corn Belt, one of the most productive and intensively managed agricultural regions in the world. Current (2008) agricultural practices use large quantities of chemical fertilizers and pesticides to maintain productivity. Most of the Midwest Corn Belt receives annual fertilizer application in excess of

7.4 and 2.9 tons per mi^2 for nitrogen and phosphorus, respectively (Battaglin and Goolsby, 1999). These agrichemicals have the potential for deleterious effects on stream quality.

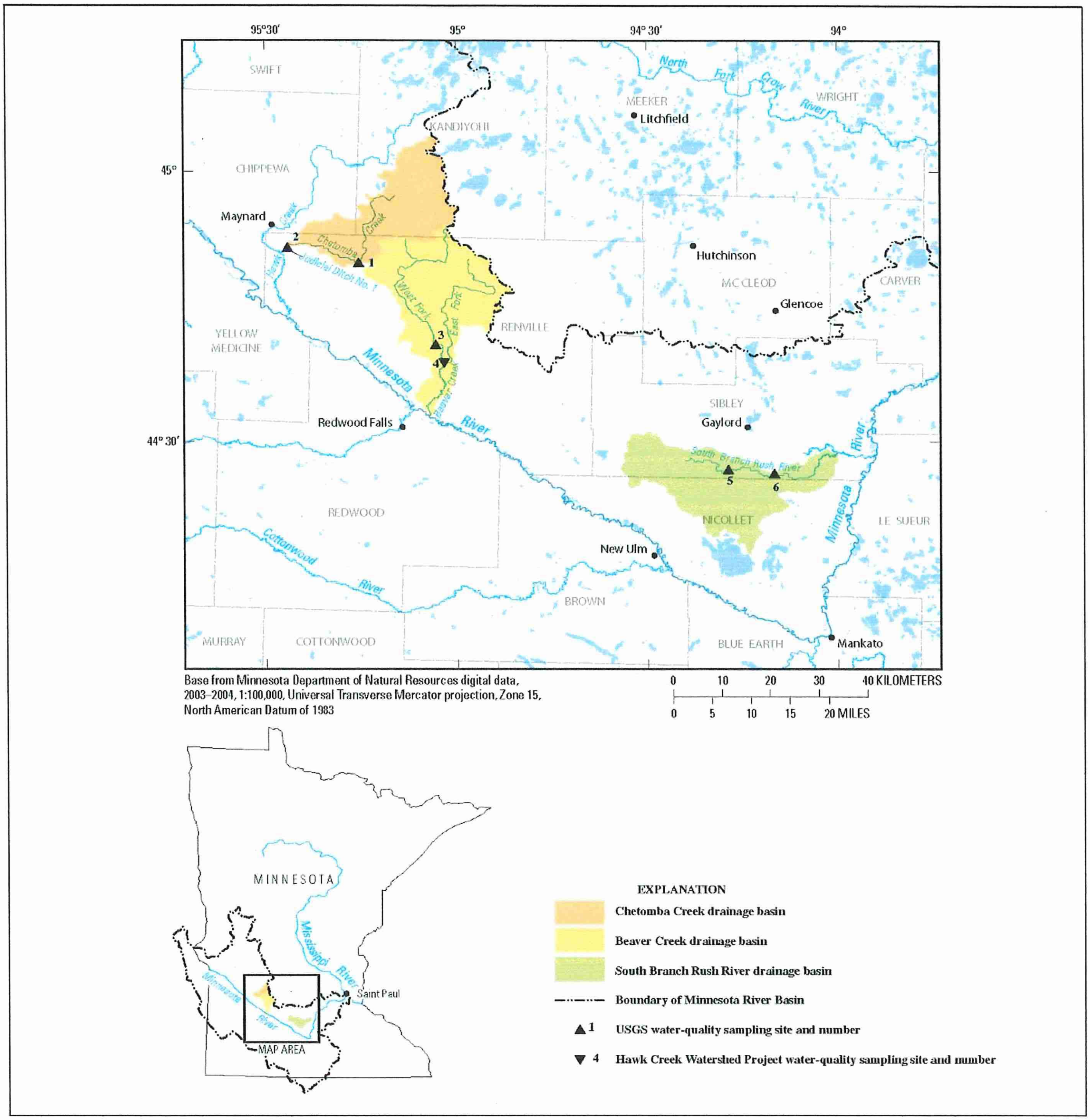


Figure 1. Location of the Minnesota River basin, Chetomba Creek basin, West Fork Beaver Creek basin, South Branch Rush River basin, and location of stream-gaging and water-quality stations.

Stream conditions are influenced by interactions among physical and chemical factors at differing spatial scales. However, loss of riparian vegetation and natural land cover in the Minnesota River basin has reduced habitat, modified hydrologic conditions, and changed water quality (Stark and others, 1996). Two important factors that influence physical, chemical, and biological conditions are local and watershed-wide land-cover characteristics. Retired land cover may be important to water quality, aquatic habitat, instream temperature, and reduction of sediment and overland runoff.

To address concerns about degradation of agricultural streams, Governor Tim Pawlenty has requested funding to retire additional agricultural lands (currently about 200,000 acres are in land-retirement programs) to improve water quality and aquatic biology. However, there currently are no existing state or Federal programs to evaluate the effects of land-retirement programs or large-scale best-management practices (BMPs) on water quality and aquatic biology. Furthermore, the efficacy of prioritizing retired lands within a given basin is unknown.

There have been several analyses of the small scale agricultural BMPs such as crop-residue management and conservation tillage. Land-use BMPs and agricultural-practice changes at the farm-field scale have shown promise in reducing nonpoint sources of contaminants, but a broader-scale analysis of current land-use practices is needed to better understand cumulative downstream effects on stream quality. It is difficult to link the effects of retired lands to water-quality benefits. However, the U.S. Geological Survey (USGS) and the Minnesota Board of Soil and Water Resources (BWSR) entered into a cooperative agreement to attempt to evaluate agricultural land retirement programs on a basin scale.

Acknowledgments

The authors appreciate the assistance of Konrad Schmidt, Minnesota Department of Natural Resources, for providing fish identification and Stephanie Klamm, Hawk Creek Watershed Project, for providing flow and nutrient data for Chetomba Creek and West Fork Beaver Creek. The authors also thank many USGS personnel and students for the onsite help, data collection, GIS analysis, and record keeping. Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources. Currently 40% of net Minnesota State Lottery proceeds are dedicated to building the Trust Fund and ensuring future benefits for Minnesota's environment and natural resources.

Purpose and Scope

This study is part of the USGS effort to provide an understanding of agricultural watershed processes and improve understanding of agricultural areas and those areas where land has been retired from agricultural production. The purpose of this study is to compare and characterize three watersheds in the Minnesota River basin, which have varying amounts and locations of agricultural land retirement. This report is the first of two reports and its purpose is to describe site selection and present the water quality and biological data collected in three small watersheds of the Minnesota River basin.

Specific objectives are to (1) characterize and compare streamflow, water quality, and biological conditions at Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River, (2) describe seasonal variability of stream quality, and (3) compare spatial and temporal variability in water quality and aquatic biological conditions to the degree and location of agricultural land retirement. Water-quality parameters analyzed were field parameters, major ions, pesticides, waste-water compounds, nutrients, and sediment. Biological measurements and analyses included physical habitat characterization, benthic macroinvertebrate, periphyton, and fish collections, measurements of dissolved oxygen, and phytoplankton chlorophyll-*a*.

Data collection sites included in this report are USGS stream-gaging stations located on Chetomba Creek (site 1, fig. 1), West Fork Beaver Creek (site 3), and South Branch Rush River (site 6). A second site was selected in the Chetomba Creek subbasin; Chetomba Creek near Maynard (also called Judicial Ditch No. 1, site 2, fig. 1). The establishment of fully-instrumented sampling sites with automated samplers, streamflow gages, and water-quality monitors can provide the infrastructure for future evaluations of agricultural-land retirement and other BMPs in the basins. Land owners, scientists, and local, State, and Federal agencies with responsibilities for land, water resources, and wildlife can use this information to improve management of natural resources in the Minnesota River basin. Refining management practices through research and monitoring can lead to enhanced protection of the Nation's natural resources while sustaining economically viable agricultural production.

Description of Minnesota River Basin Study Area

The Minnesota River originates near the western border of Minnesota, travels southeast to Mankato (fig. 1), and then turns northeast, where it joins the Mississippi River at St. Paul, Minn. (Ojakangas and Matsch, 1982). The basin is located primarily within south-central Minnesota (fig. 1) in an area characterized by dissected till plains, undulating till plains, lake plains and glacial moraines (Stark and others, 1996). Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River basins are part of the till plains and drumlins physiographic province (Payne, 1994). Rock formations are not well exposed in much of the study area because of a lack of topographic relief and the easily erodible nature of the rocks. Very little bedrock is exposed at the surface (Ojakangas and Matsch, 1982) except in places along the Minnesota River. Wagner and Alexander (1993) reported that basin geology was an important determinant of water quality in the Minnesota River.

Precipitation and evapotranspiration affect runoff. Average annual precipitation is about 24 in. (National Oceanic and Atmospheric Administration, 2007) and generally increases from about 22 in. per year in the west to about 31 in. per year in the east. Runoff is the depth to which the drainage area would be covered if all the runoff was evenly distributed (Payne and others, 1994, p. 5). Runoff ranges from about 2 to 6 in. per year (Winterstein and others, 1993) and dominates stream flow during spring and early summer. Higher runoff values in the east indicate that the further east the watershed, the more water it would deliver to the Minnesota River per unit area.

Streamflow varies seasonally throughout Minnesota because of the freezing during the winter, thawing during the spring, and seasonal variations in precipitation and runoff (Tornes, 1986). The Minnesota River basin comprises 12 tributary-river basins (Payne, 1994). Ground-water discharge dominates in the late summer when precipitation begins to decrease and continues through the fall and winter depending on rainfall and snowmelt. However, ground water discharge varies across the Minnesota River basin depending on local geology. Landforms also affect hydrology.

Agriculture has a major influence 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 also have changed local hydrologic conditions. For example, farm ponds that have been built for recreational purposes or to provide water for livestock, receive runoff, and may interact with ground water.

Suspended sediment is a concern because it can bind and transport harmful substances such as pesticides and nutrients (Baker, 1980). One source of sediment in Minnesota River basin streams is from soil particles exposed by cultivation that are loosened by raindrops and sheet and rill erosion and carried to receiving waters (Tornes, 1986). Other sources of suspended sediment are construction activities and erosion of stream banks and streambeds. Most of the sediment in the basin is transported in spring. Tornes (1986) reported that almost one fourth of the annual sediment load for 19 stream sites in Minnesota was carried during April.

Description of Selected Subbasins

Fields that are along the ditches and streams in the selected subbasins typically are plowed up to the break in slope of the ditch (as shown in the photograph, fig. 2). However, ditches constructed after 1971 require a 16.5 ft setback (Greg Payne, personal commun., 2005).

Figure 2. Photograph of the South Branch Rush River, September 2005.

Chetomba Creek is located primarily within Kandiyohi and Renville Counties, with a small part of the basin in Chippewa County. The Chetomba Creek stream-gaging station has a contributing drainage are of 74,476 acres. Land use in Chetomba Creek is primarily agricultural. Agricultural chemicals applied to enhance crop production in the area include commercial fertilizers (such as nitrate, ammonia, and phosphorus), manure, and pesticides (U.S. Department of Agriculture Census, 2002). In Chippewa, Kandiyohi, and Renville Counties, approximately 55-60 percent of the farms are treated with fertilizer (table 1).

Table 1. Estimates of fertilizer application for selected counties in the Minnesota River basin, 2002.
[Modified from U.S. Department of Agriculture (2002).]

County	Acres treated with commercial fertilizer	Acres treated with manure	Total	Percentage of county area (farms only) treated with fertilizer[1]
Chippewa	171,300	14,000	185,300	54.5
Kandiyohi	185,200	41,000	226,200	55.4
Nicollet	136,400	28,700	165,100	64.2
Renville	354,300	46,500	400,800	60.4
Sibley	218,200	32,400	250,600	73.8

[1]Fertilizer application to land other than farms (for example golf courses and residences) was not included.

West Fork Beaver Creek is located primarily in Renville County. A secondary site (site 4, fig. 1) is located downstream and is sampled and maintained by the Hawk Creek Watershed Project. In Renville County, 60.4 percent of the farms in the county are treated with fertilizer (table 1).

South Branch Rush River is located primarily in Sibley County and the South Branch Rush River near Norseland drains an area of approximately 52,915 acres. A secondary site (site 5, fig. 1) on the South Branch of the Rush River was established in 2007 for instream comparisons; however, this site did not have sufficient data to include here. Instream comparisons between sites will be reported in more detail after the completion of the second phase of this project, funded under the 2007 Trust Fund (Legal Citation: ML 2007, [Chap. HF 293], Sec.[2], Subd. 5(c)).

Land Retirement Effects on Streams

Much of the Minnesota River basin is planted in row crops (such as corn and soybeans) leaving these fields bare for part of the year, exposing them to erosion and contributing to the sediment load of the Minnesota River. Application of fertilizers adds to the contaminant concerns in the River. Riparian buffers (the zone of vegetation adjacent to the stream) have been proposed as an effective method of buffering a stream and its aquatic organisms against excess sediment and nutrients. Riparian buffers store soil and attenuate nutrients through plant uptake.

In addition to riparian buffers, upland areas that are either environmentally sensitive, such as land adjacent to wetlands, have been taken out of production. Marginal pastureland, hillsides, and areas with substantial risk of ground water contamination also qualify for certain land retirement programs. Typically, however, land retirement programs require the land to be adjacent to a stream or wetland. In this report, land that is adjacent to a stream or river is considered riparian; upland areas are those that are not directly adjacent to a river or stream, but may be connected to a wetland. Upland land retirement works in much the same way as riparian buffers—trapping sediment and nutrients in the vegetation before it can runoff into a water body or by protecting the ground water by trapping nutrients or contaminants in the subsurface.

Figure 3 shows how a retired agricultural field, such as a CRP field planted in native grasses acts as a trap for sediment, nutrients, and pesticides. Suspended sediment is carried by runoff, it enters a grass filter, and the resulting reduction in velocity causes the transport capacity of the runoff to be lowered, which allows sediment deposition to occur (Wilson and others, 1997). Root systems for native prairie grasses also tend to be deeper and, therefore, trap nutrient and pesticides flowing with the subsurface flow. Figure 3 also shows how hydrology is modified when a typical Minnesota River basin field is planted in row crops and tile drains are installed. The effect of tile drains on the hydrology is that surface flows are concentrated at the tile drain and transported directly to the stream or drainage ditch. Row crops typically have shallow root systems, therefore, reducing the ability to trap nutrients and pesticides in subsurface flow.

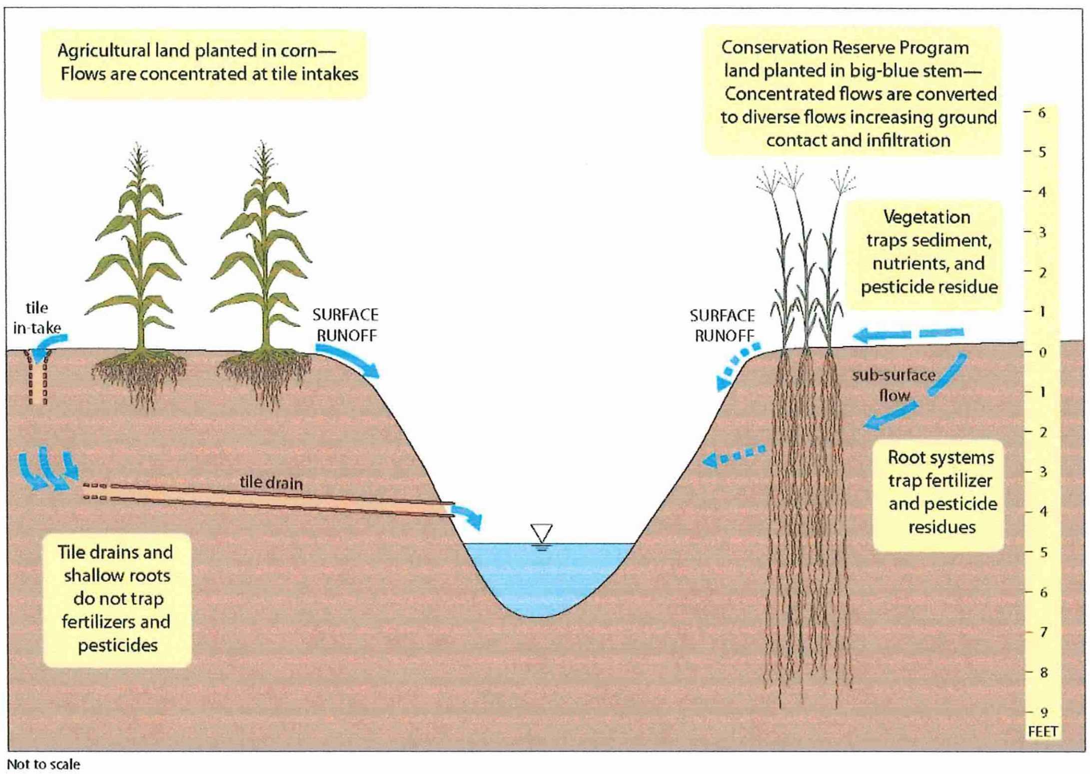


Figure 3. Schematic diagram of land in row crops and land in conservation reserve.

Several programs were designed to encourage the retirement of agricultural land and are currently in practice in the Minnesota River basin. Three of those programs account for the majority of the agricultural land retirement in the basin—the Conservation Reserve Program, the Conservation Reserve Enhancement Program, and the Reinvest in Minnesota program.

The Conservation Reserve Program (CRP) was designed to retire cropland from production. It was established by the Food Security Act of 1985. Under the program, the U.S. Department of Agriculture (USDA) established contracts with voluntary agricultural producers to retire highly erodible and environmentally sensitive cropland and pasture from production for 10-15 years (U.S. Department of Agriculture, 2004). Unlike other programs, the primary goal of CRP was to reduce soil erosion (Osborn and others, 1995). It is thought that enrollment of agricultural lands in land retirement programs such as CRP will improve water quality of streams by decreasing the amount of soil exposed to erosion and reduce sediment and nutrients transported to the stream.

Another conservation reserve program designed to improve water quality is the Conservation Reserve Enhancement Program (CREP). The CREP establishes funding support and partnerships among USDA, state, and non-government organizations (Allen, 2005). The Minnesota CREP was established in 1998. The primary goal of CREP is improvement in drinking and surface water quality and wildlife habitats (Allen, 2005). The difference between CRP and CREP is that CREP focuses on state defined priorities—for Minnesota the primary area of focus for the 1998 CREP was the Minnesota River and the key environmental objective is to improve water quality and wildlife habitat (Allen, 2005). CREP contracts run for 10-15 years.

Finally, in Minnesota there also is the Reinvest in Minnesota (RIM) program, established in 1986 and administered through the Minnesota Board of Water and Soil Resources. The RIM program enrolls a variety of land types, similar to those enrolled in the CRP and CREP programs. RIM reserve funds also are used to leverage federal funds through CREP in the Minnesota River basin. In addition to an enrollment payment, RIM reserve provides funds to share the cost of establishing conservation practices or wildlife habitat. Unlike the CRP or CREP programs, the RIM program puts land in a permanent conservation easement.

Research has shown that there have been improvements in water quality and benefits to fish and wildlife (Haufler, 2005) produced by conservation reserve programs. Mayer and others (2006) concluded that riparian buffers are effective at improving water quality by reducing nitrogen levels in ground water and streams. Buffers can help moderate peak flows and maintain stream baseflow, which in turn helps moderate water temperature (Stewart and others, 2006).

Numerous wildlife species have been documented to use CRP (Burger, 2005; Clark and Reader, 2005) and there also have been documented benefits to fish through enhanced water quality (Allen, 2005). The evidence of improvement is particularly abundant for bird populations. Ferrand and Ryan (2005) reported that bird populations had increases in reproduction and population that were attributable to CRP in the Midwest. Johnson (2005) also found benefits to birds associated with CRP when compared to cropland in the northern Great Plains. Reynolds (2005) reported that CRP in the Prairie Pothole Region was estimated to produce 2.2 million ducks per year.

Although benefits have been reported by the authors above, responses of wildlife to CRP vary (Haufler, 2005) and studies have been confined to small areas (Johnson, 2005), leaving the need for more studies to look at conservation programs on a wider or watershed scale (Allen, 2005).

Tile Drain Effects on Streams

Because of the poorly drained soils and resulting low infiltration rates in much of the Minnesota River basin, tile drains are used to help drain the water from agricultural fields. A drainage tile is a subsurface pipe designed for the removal of excess water from fields without the longer residence time of ground-water storage. This may reduce ponded water and flood damage to fields and draws oxygen into the soil. But, these tile drains also provide a direct path for surface water and any associated contaminants to reach drainage ditches and streams (Wilson and others, 1997). Because the selected subbasins have high runoff potential, when this is combined with the tile drains, rapid fluctuations in streamflow occur during precipitation events (ZumBerge and others, 2003).

Tile drains have many advantages and disadvantages. The water-quality effect of tiles drains is mainly an increase in nitrate concentrations and a decrease in sediment concentrations. One study indicated that tile drains were the major contributor of nitrate to drainage ditches (Baker and others, 2006, p. 24). Baker and others (2006) also reported that orthophosphate concentrations were lower in water from tile drains than in a ditch in Indiana. The Minnesota Department of Agriculture has completed research on different types of conservation drainage that may prevent certain contaminants, mainly nitrate, from entering the drainage water. Wilson and others (1997) concludes that the effect of tile drains depends more on the type of tillage than other factors (no till versus conventional tillage).

On a basin scale, tile drains may have a long-term effect on streamflow, which may cause long-term changes in the concentrations of dissolved constituents. Tomer and others (2003) concluded that agricultural and wetland best management practices are needed to achieve water-quality goals in tile-drained watersheds. Tile lines typically are broken when agricultural land is retired (Stephanie Klamm, Hawk Creek Watershed District, personal commun., 2008). The use of buffers and agricultural land retirement may be the best management practices that are needed to mitigate the effects of the tile drains.

Methods

Site Selection and agricultural land distribution

One of the goals of this study was to evaluate effects of retired lands on the water quality and aquatic habitat of streams in the Minnesota River basin to enhance prioritization of future land retirements. That being said, it would be beneficial to evaluate the differences between riparian (along the stream or river) and upland land retirements. The initial task was to select three basins for further study. Ideally, these basins would represent varying degrees of land retirement, with one basin being primarily riparian and one basin having primarily upland land retirement. One challenge was finding an appropriate basin with a significant amount of upland land retirement. Few subbasins with significant land retirement existed in the Minnesota River basin and these had factors that precluded them.

A set of 17 selection parameters was considered to prioritize the subbasins within the Minnesota River basin (table 2). The selection of three basins required minimizing any differences listed in Table 2, while maximizing differences in land retirements.

Whereas some of the parameters considered for site selection are self-explanatory, others warrant further discussion. For example, it was desirable to have no in-line lakes (parameter 2) or dams (parameter 13) because these not only affect the hydrology, but also influence nutrient conditions and algal production. The availability of gages (parameter 14) and whether current work was occurring at the site (parameter 15) was important in site selection because of the value that additional data (both current and historic) would add to the project. In addition, current work at a site would increase feasibility of storm sampling and reduce costs of collection.

Cluster analysis was used to group subbasins with similar soils (parameter 4). Cluster analysis is a method of grouping objects of a similar kind into respective categories. In this case, soil types of every major watershed in the Minnesota River basin were clustered in order to assign them to a group based on soil type. In order to perform the cluster analysis, every major watershed in the Minnesota River basin was processed with a STATSGO basin aml (Arc macro language) model. The STATSGO (State solid geographic data base) basin aml intersects the major watershed with the STATSGO soils data for the Minnesota River basin. A frequency command was run on each basin to identify the area of each MUID contained within each minor watershed. The three subbasins selected for intensive study—Chetomba Creek basin, West Fork Beaver Creek basin, and South Branch Rush River basin—were all in the same soil category and have similar geologic and hydrologic settings. These basins had soils with slow infiltration rates, layers of soil that impede downward movement of water, or soils with moderately fine or fine textures.

Table 2. Parameters considered for selection of sites for further study of water quality and biological response to agricultural land retirement, Minnesota River basin.

1	**Basin size from 100-300 square miles and similar among all three to assure perennial streams**
2	**No major inline lakes and less than 5% lakes in the watershed**
3	**Slopes similar and less than 7 foot per mile (to avoid high slope stream reaches)**
4	**Similar soil hydrogroup, based on cluster analysis**[1]
5	**Climate (evapotranspiration and rainfall similar)**
6	**Similar sinuosity/drainage network**
7	**Similar amount of wetlands and agricultural land use in the basin**
8	**Proximity of retired lands to the stream**
9	**Similar riparian conditions (shading is a factor for algal production and nutrient uptake)**
10	**Similar instream macrophyte characteristics (macrophytes influence nutrient concentrations)**
11	**No point sources including wastewater treatment plants and confined animal feeding operations**
12	**Similar bed substrate**
13	**No dams that restrict fish movement**
14	**Availability of gages (including historical data)**
15	**Current work occurring at site**
16	**Feasibility of site access**
17	**Retired land percentage**

[1]Cluster analysis is discussed in the text, above.

One site was selected in each basin for more intensive sampling and instrumentation. The three primary data collection sites were USGS stream-gaging stations located on Chetomba Creek near Renville, Minnesota (05314510, site 1, fig. 1), West Fork Beaver Creek near Bechyn, Minnesota (0531656290, site 3, fig. 1), and South Branch Rush River near Norseland, Minnesota (05326189, site 6, fig. 1).

The subbasins differ with respect to the degree, amount, and location of land retirement (riparian, up-land, and no land-retirement conditions) (table 3). A second site was selected in the Chetomba Creek subbasin, Chetomba Creek near Maynard, Minnesota (also called Judicial Ditch No. 1, site 2, fig. 1). Chetomba Creek was re-routed through Judicial Ditch No. 1 in the 1970s, making this site downstream from the Chetomba Creek site 1. The intervening drainage area between these two sites has few tributary ditches or streams and substantial land retirement (table 3). Secondary sites were established on West Fork Beaver Creek (site 4, fig. 1) and South Branch Rush River (site 5) for instream comparisons; however, these two sites did not have sufficient data to include here.

Table 3. Percentage of land retirement in selected subbasins of the Minnesota River Basin, 2006-2007.
[Percentage land retirement for Judicial Ditch No. 1 is for intervening drainage area only; ft, feet]

SITE NAME	SITE NUMBER (FIG. 1)	DRAINAGE AREA (ACRES)	PERCENTAGE LAND RETIREMENT				
			Basin	300-ft buffer[1]	200-ft buffer[1]	100-ft buffer[1]	50-ft buffer[1]
Chetomba Creek	1	74,476	3.1	3.9	4.3	5.1	5.7
Judicial Ditch No. 1	2	96,031	6.3	9.4	11.3	15.3	18.7
West Fork Beaver Creek	3	58,974	3.7	6.2	7.5	9.5	10.4
South Branch Rush River	6	52,915	1.5	2.7	3.2	5.1	7.6

[1] The buffers are defined by the percentage of retired land within 300, 200, 100, and 50 feet on either side of the stream.

Land retirement data were obtained in 2007 from the Farm Services Agency (FSA, St. Paul. Minn.) and included a geographic information system (GIS) coverage of land with Conservation Reserve Program (CRP) contracts. Land retirement data also were obtained from the Conservation Reserve Enhancement Program (CREP), Re-invest in Minnesota (RIM) program, and some smaller amounts of retired agricultural land in other programs including Pheasants Forever, Wildlife Management Areas, and U.S. Fish and Wildlife Service Waterfowl Production Areas.

In order to determine the intensity of retired land, the percentage of retired land within 300-, 200-, 100-, and 50-ft of the streams in the selected subbasins was determined (table 3). A schematic over an aerial photograph of a CRP field in the Minnesota River basin illustrates how this was done (fig. 4).

Streamflow Measurement

Stream water-surface elevation (stage) was measured to the nearest 0.01 ft at the 3 stream-gaging stations with pressure transducers (Buchanan and Somers, 1968). Stage data at the three primary sites were electronically recorded and transmitted by satellite in 15-minute increments to a downlink site and then to the computer at the USGS office in Mounds View, Minn. Methods used to determine streamflow are described in Buchanan and Somers (1969). Streamflow measurements were made approximately every six weeks during the open-water season (generally, from about April- October). A stage-streamflow relation was developed on the basis of streamflow measurements and the stage of the stream at the time of measurement (Kennedy, 1983; 1984). Streamflow and stage data was then disseminated on the World Wide Web at http://waterdata.usgs.gov/. Streamflow and other water data in this report is compared and analyzed in terms of water year. The water year is a 12 month period that begins on October 1 and ends on September 30. For example, the 2006 water year begins October 1, 2005 and ends on September 30, 2006.

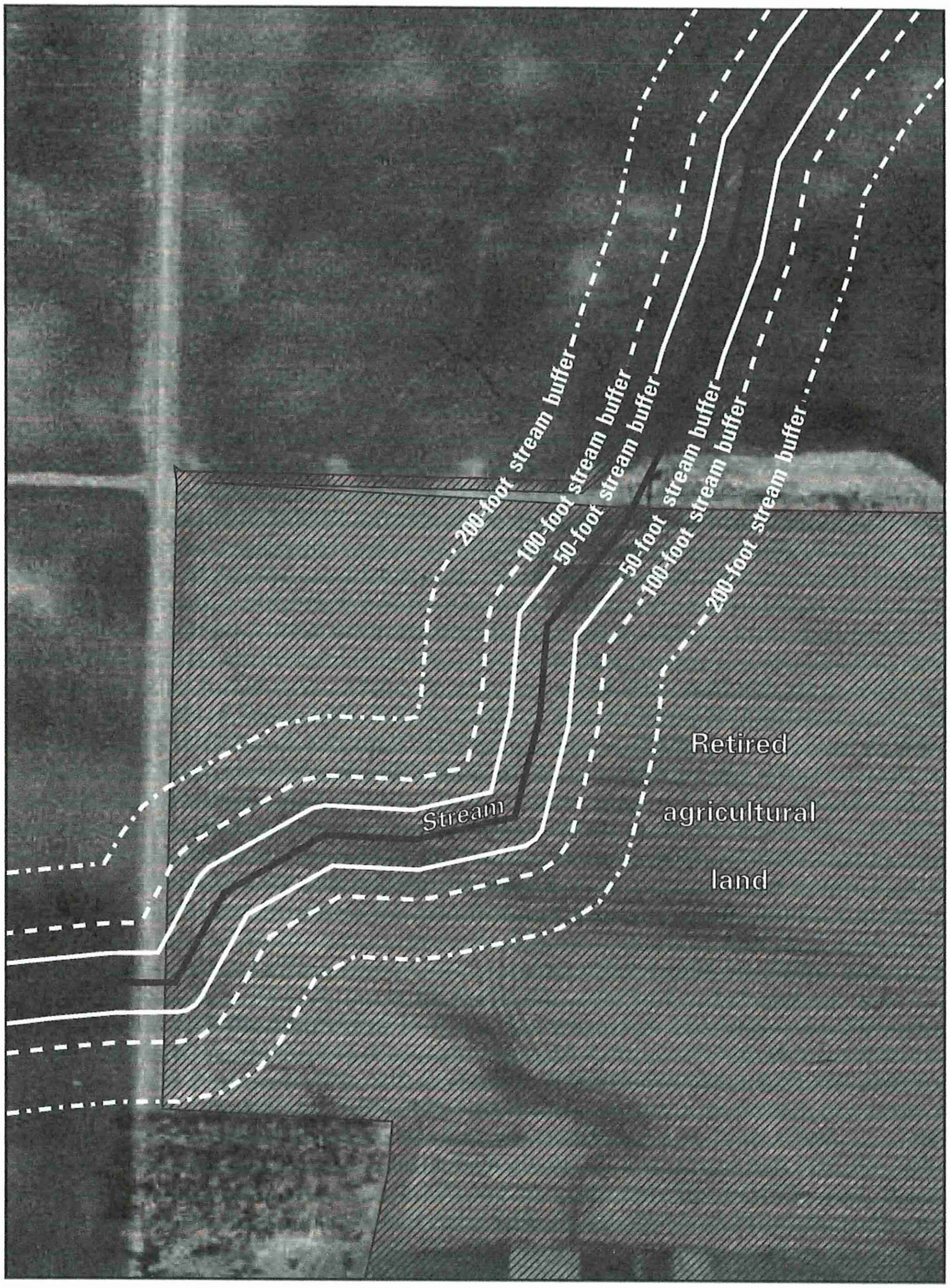


Figure 4. Schematic diagram showing areas of retired lands intensity.

Real-Time Water-Quality Monitoring

Continuous, real-time water-quality monitoring was used at the three stream-gaging sites to document physical properties of the water. Real-time monitoring of specific conductance, pH, water temperature, dissolved oxygen, and turbidity occurred during the growing season in 2006 and 2007 (generally from April through August). The water-quality monitors installed at these stream-gaging stations have multiple sensors that measure physical properties of water quality. These devices are connected to data-collection platforms at each stream-gaging station, and data are transmitted by satellite to a downlink site and the computer at the USGS office in Mounds View, Minn. The sensors were calibrated according to methods presented in Wagner and others (2006).

Sample Collection and Analysis

Water-quality sample collection and analysis

Water-quality samples were collected manually according to methods described in the *National Field Manual* (U.S. Geological Survey, 2006) and with automated samplers. The collection of samples for water-quality constituents was completed using depth- and width- integrating techniques with the exception of samples collected with automated sampling equipment and occasional grab samples.

Nutrient samples were analyzed at the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado. Sediment samples were collected using methods described by Guy and Norman (1970) and analyzed for suspended sediment concentration (SSC) at the USGS Sediment Laboratory in Iowa City, Iowa. In addition, water also was analyzed onsite with a water-quality monitor at the time of collection for specific conductance, pH, water temperature, dissolved oxygen, and turbidity.

Quality assurance was assessed with field blanks and replicate samples. No detectable concentrations of nitrite plus nitrate, total nitrogen, or total phosphorus were present in blank samples. The median annual variation between duplicate analyses of nitrite plus nitrate, total nitrogen, and total phosphorus was less than one percent.

Algal sample collection and analysis

Algal samples were collected for this study according to Moulton and others (2002). Benthic algae (periphyton) were collected once each year from sandy stream-bed substrate (episammic) during low-streamflow conditions. Periphyton samples were collected from the upper 5- to 7-mm layer of episammic (sand) habitat in 5 depositional areas of the reach. At each location the lid of a Petri-dish (47mm in diameter) was pressed carefully into substrate to avoid disturbing periphyton. A spatula was placed under the Petri-dish to enclose the collection. The five samples are composited into one container with rinse water. Several subsamples were removed for processing. Samples were split for chlorophyll a, ash free dry mass, and for taxonomic identification. The sample is homogenized and an aliquot of 3-5 mL is removed for chlorophyll a and ash free dry mass analyses. These analyses were completed at the USGS National Water Quality Laboratory. The remaining sample was preserved with 4 percent buffered formalin for taxonomic identification. Algae (diatoms and soft algae) were identified to the lowest possible taxon by the Academy of Natural Sciences, Patrick Center for Environmental Research (Charles, Knowles & Davis, 2002). Approximately 600 algal cells were counted from each sample and results were tabulated as the abundance (cells per cm^2) and biovolume (μm^3 per cm^2) for each taxon. Taxon richness was reported as the number of taxa encountered during a count of about 600 algal cells (Charles and others, 2002). The relative abundance (percent cell density) of each taxon was calculated for each sample.

Indicators of periphyton standing crop such as total cell density and biovolume were calculated by summing results for all taxa in each sample. Biovolume was estimated by measuring the dimensions of representative cells and calculating cell volume in accordance with the nearest geometric shape (Charles and others, 2002). Total cell biovolume was converted to units of cm^3/m^2 by dividing by 10^8. Conversion of algal biovolume to algal biomass was based on a specific density of 1.0 g cm^3 (Porter and others, 2008; Leland & Porter, 2000; Leland and others, 2001); thus, biovolume units of cm^3 per m^2 are proportional to biomass units of grams per m^2. The biomass conversions were used to estimate chlorophyll-a values for samples based on previously established chlorophyll–biovolume relations (Porter, 2000).

Invertebrate sample collection and analysis

Stream invertebrate communities were collected using modified methods from Moulton and others (2002). Samples were collected from sandy bottom substrates using a core sampler. The core sampler was depressed approximately 4 inches into the stream bottom sediment, and a spatula was used to enclose the collection prior to placing it in a compositing container. Samples were collected from five locations within each sampling reach. Tap water was used to separate the invertebrates from bottom substrate through successive rinsing and sieving. All sieves had mesh sizes of 500µM. The sieved samples were preserved with 10 percent formalin prior to transfer to the laboratory. During 2006, samples were sent to the Minnesota Department of Natural Resources Laboratory in St. Paul, Minnesota for identification and enumeration. During 2007, samples were sent to the USGS NWQL for identification and enumeration. Invertebrate data were analyzed using the U.S. Geological Survey, Invertebrate Data Analyses System (IDAS).

Fish collection and analyses

Fish were collected during August or September 2006 and 2007 at each stream by electrofishing equipment (pulsed DC) and conducted according to protocols established for the USGS's National Water-Quality Assessment Program (Moulton and others, 2002). Briefly, backpack electrofishing gear was used to make two collection passes within the reach. Sampling time was recorded to normalize catch per unit of effort.

Index of biotic integrity (IBI) scores were used to measure fish community response and community health. Biotic integrity is commonly defined as "the ability to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity and functional organization comparable to those of natural habitats within a region" (Karr and Dudley. 1981). The IBI was calculated following Bailey and others (1993) using 8 of the 12 metrics related to the composition and structure of the fish community (table 5). The sum of the metric scores is the IBI score, which ranges from 12 to 60 (greater number indicates better aquatic resource quality). Physical habitat was characterized at each stream location at the time of fish collections following Fitzpatrick and others (1998).

Table 4. Description of individual metrics that comprise the Index of Biotic Integrity.

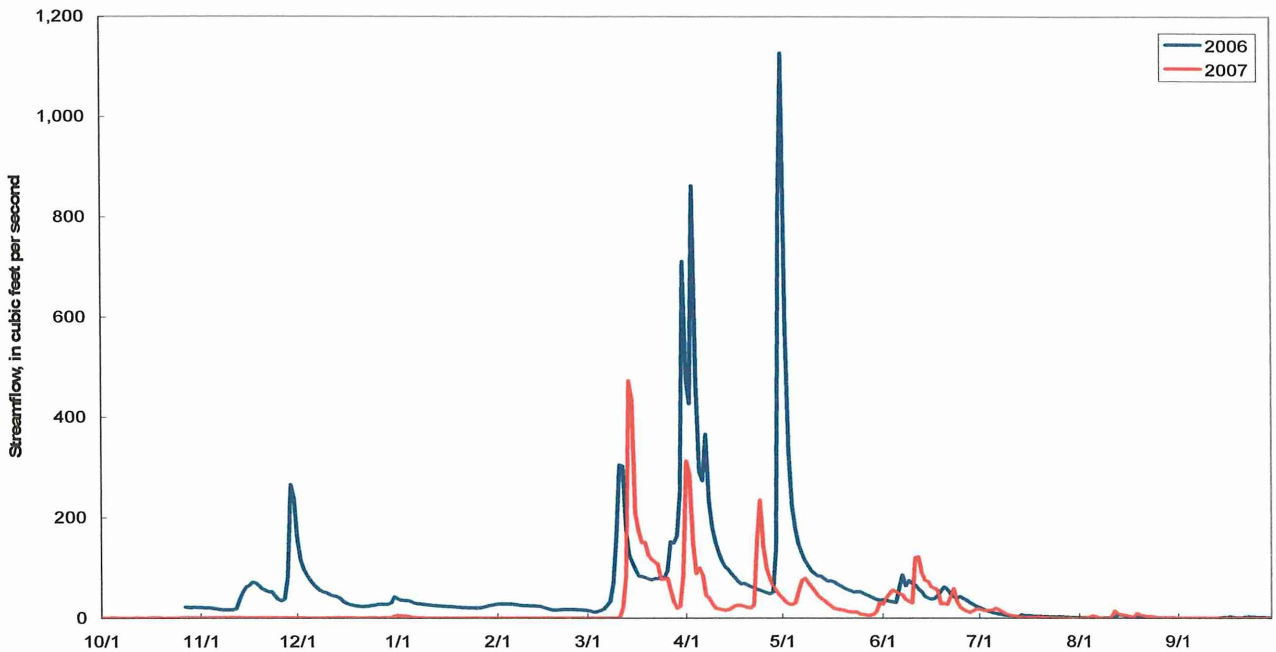
Metric	Description
Number of fish species collected	The number of fish in the community is associated with the complexity of the environment. Stream degradation in the form of habitat, hydrologic, or chemical alterations will result in a simplification of the community and a decrease in the number of species (Karr and others, 1986; Bailey and others, 1983).
Percent of fish classified as tolerant	Tolerant species can thrive in streams with degraded conditions. Common carp, white sucker, black bullhead, fathead minnow, and creek chub were classified as tolerant by Bailey and others (1983).
Number of Darter Species	Darters belong to the perch family and are habitat specialists meaning they have strict environmental requirements including coarse gravel found in stream riffles. This metric is considered to be sensitive to habitat changes and chemical changes (Karr and others, 1986; Bailey and others, 1983).
Number of minnow species	Minnows are an important and diverse component of the fish community in most warm or cool water streams throughout the Midwest. Because minnows exhibit a wide range of food and habitat preferences, this group of fish is sensitive to a wide range of environmental degradation.
Number of intolerant species	The presence of intolerant fish species in a stream is an indication of a high resource quality. Intolerant fish species are often the first species to disappear following a disturbance.
Proportion of benthic insectivores	Fish with specialized feeding behaviors like those who consume insects from bottom substrate in a certain habitat will not be able to respond to degraded conditions as quickly as omnivores.
Proportion of omnivores	Omnivores are able to consume a wide variety of food sources so they are able to tolerate environmental degradation because they are flexible eaters.
Catch per unit effort (on all fish except tolerant ones) per hour	The assumption is that a site with little degradation will yield more fish in an hour than a site with degradation.

Water Quality in Streams of the Minnesota River Basin

Streamflow

The drainage areas of Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River account for about 2 percent of the Minnesota River drainage basin. Many other tributaries contribute surface water and are a possible source for nutrients, sediment, and other chemicals. Streamflow in Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River basins was variable in 2006 and 2007 (fig. 5). In general streamflow was greater in 2006 than in 2007. The maximum peak flow for Chetomba Creek near Renville and South Branch Rush River near Norseland occurred in 2006. The maximum peak flow for West Fork Beaver Creek occurred in 2007. Zero flow occurred during many days in 2007 for Chetomba Creek and South Branch Rush River.

a **Chetomba Creek near Renville, Minnesota (05314510)**



b **Chetomba Creek near Maynard, Minnesota (Judicial Ditch No. 1 05314518)**

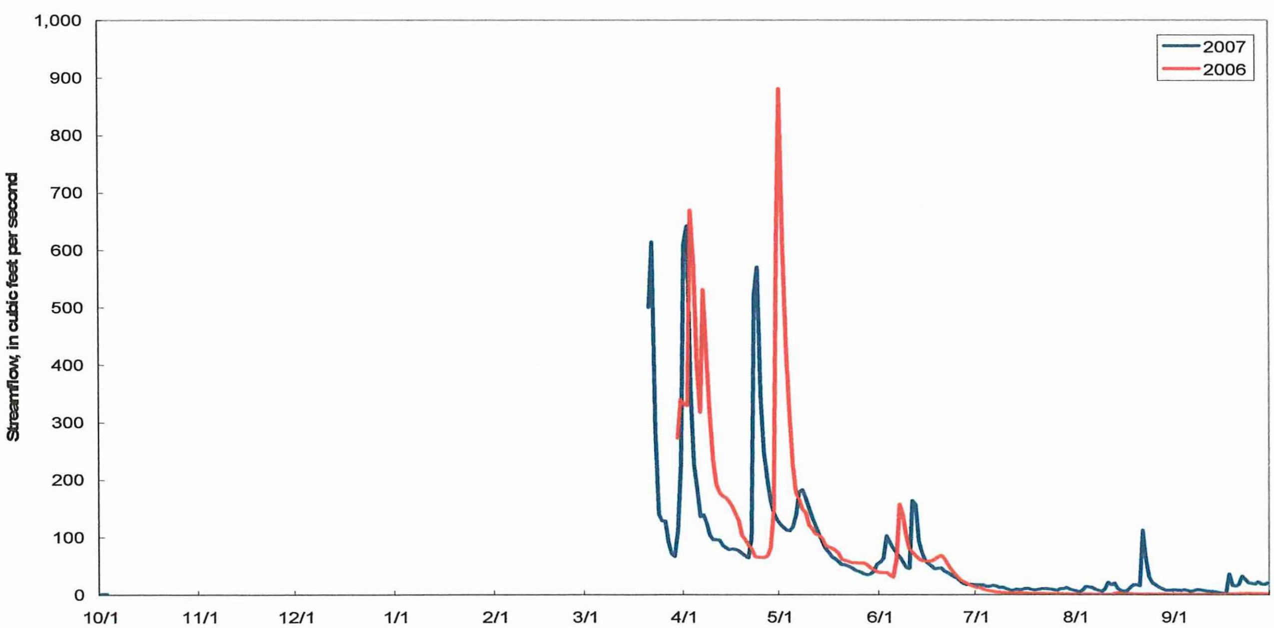
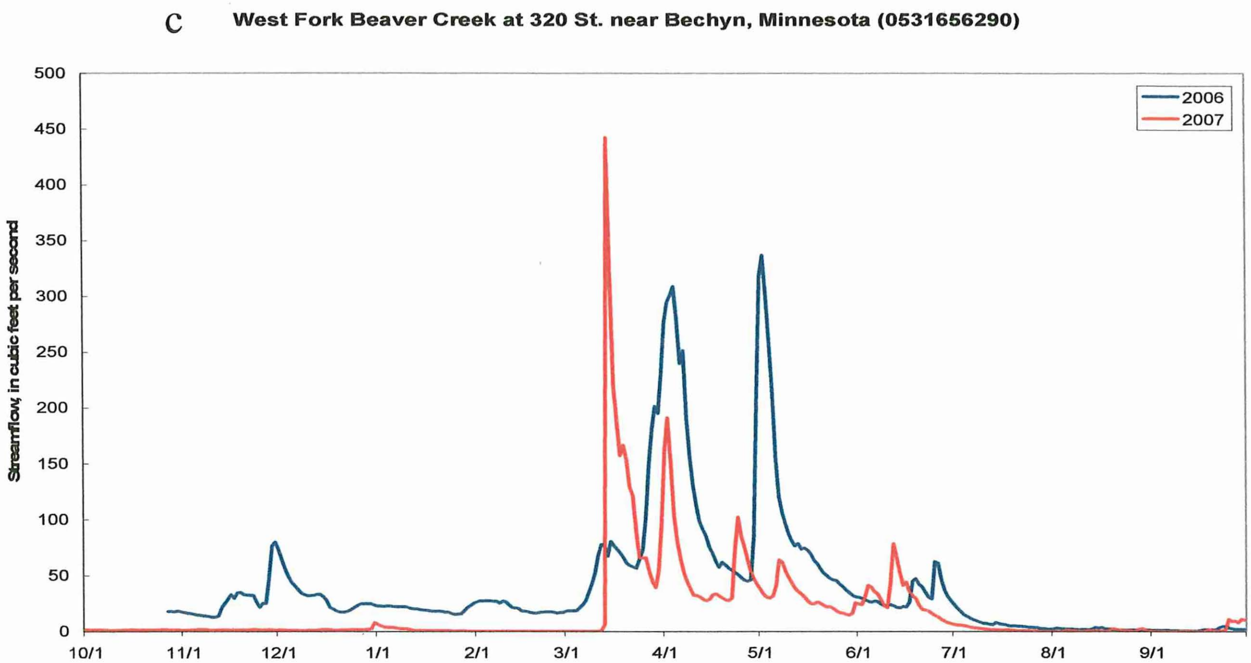


Figure 5. Mean daily streamflow for (a) Chetomba Creek near Renville, (b) Chetomba Creek near Maynard, (c) West Fork Beaver Creek near Bechyn, and (d) South Branch Rush River near Norseland, Minnesota, 2006-07.

c



d

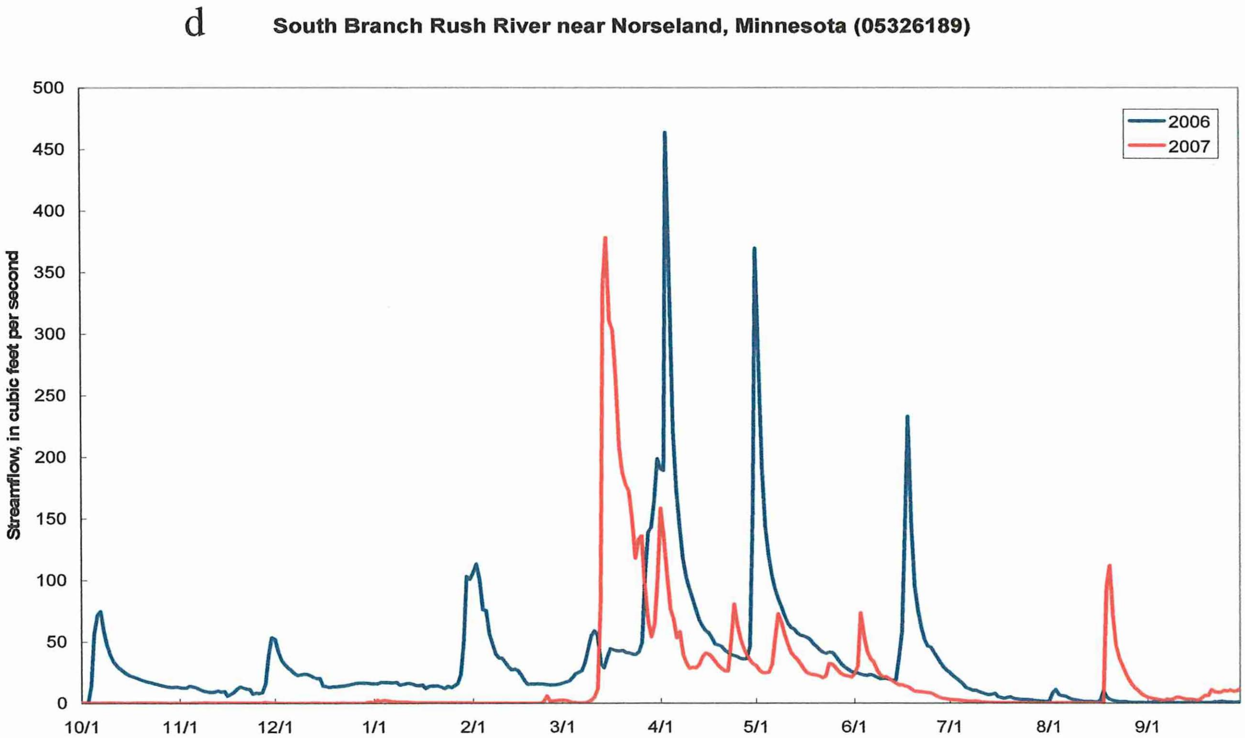


Figure 5. (continued) Mean daily streamflow for (a) Chetomba Creek near Renville, (b) Chetomba Creek near Maynard, (c) West Fork Beaver Creek near Bechyn, and (d) South Branch Rush River near Norseland, Minnesota, 2006-07.

The hydrologic conditions during the years of sample collection affect water-quality and biological communities. The hydrologic conditions for Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River had noticeable rainfall events that affected the streamflow. Stage measurements during runoff indicate that Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River respond rapidly to rainfall.

Streamflow at Chetomba Creek near Renville ranged from 0 – 1,360 cubic feet per second (ft^3/s). Streamflow at West Fork Beaver Creek ranged from 0 - 442 ft^3/s. Streamflow at South Branch Rush River near Norseland ranged from 0- 528 ft^3/s during 2006 and 2007 water years. Mean annual streamflow was lower during 2007 than in 2006 for Chetomba Creek, West Fork Beaver Creek and South Branch Rush River (table 5). Because of the brief period of record at these sites, the data from a longer term site, High Island Creek near Henderson, Minnesota (05327000), is presented in table 5. The period of record for High Island Creek is 1973-2007. The water year 2007 was a low flow year for the High Island site.

Table 5. Comparison of streamflow at selected sites in the Minnesota River basin, 1973-2007.

USGS Site No.	Site name	Period of Record	Mean annual streamflow 2006	Mean annual streamflow 2007	Mean annual streamflow Period of record	Minimum (date)	Maximum (date)
05314510	Chetomba Creek near Renville	2005-2007	59.9	20.7	40.3	0[2]	1,360 (05-01-06)
05314518[1]	Chetomba Creek (Judicial Ditch No. 1) near Maynard	1999-2007	141	71.6	99.2	0 (06-09-02)	1,996 (04-23-01)
0531656290	West Fork Beaver Creek at 320 St near Bechyn	2005-2007	40.9	17.9	29.4	0[2]	442 (03-14-07)
05326189	South Branch Rush River near Norseland	2004-2007	35.1	19.9	27.5	0[2]	528 (04-03-06)
05327000	High Island Creek near Henderson	1973-2007	122.9	54.1	102	0.46 (10-03-76)	2,750 (06-17-93)

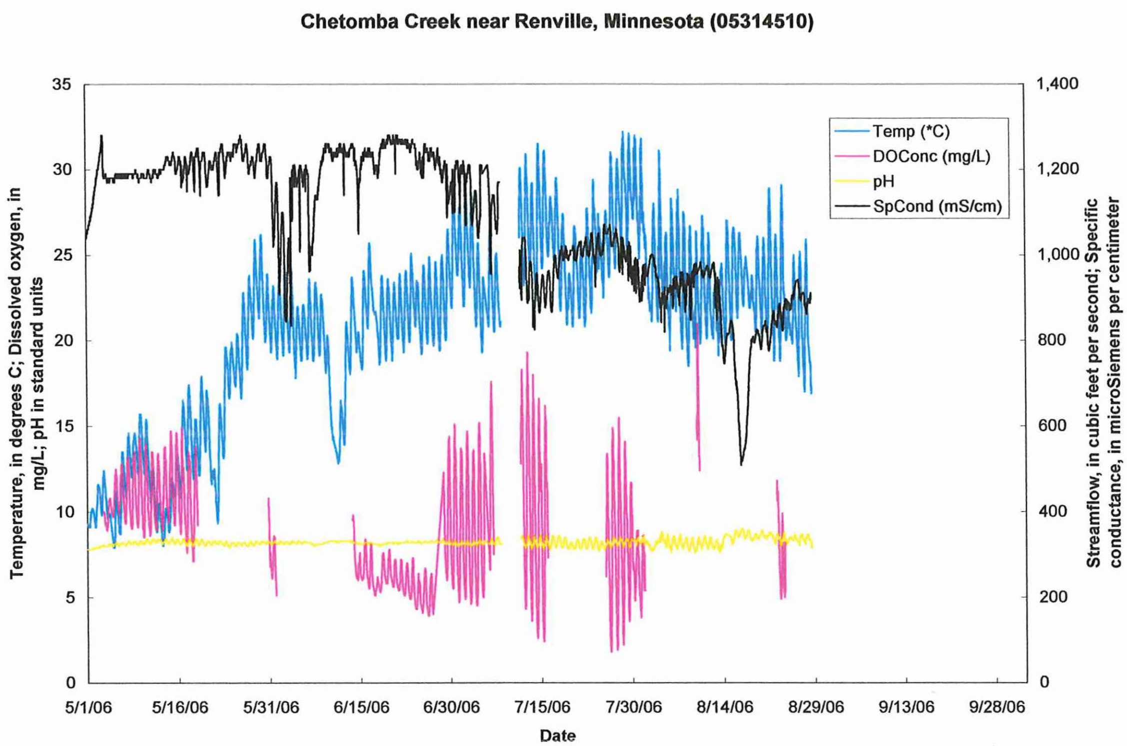
[1] Streamflow data collected by the Hawk Creek Watershed Project, during open-water season only.

[2] Zero flow occurred on several dates during the period of record

The data from High Island Creek show that the mean annual streamflow for the period of record is nearly twice that of the 2007 water year. This indicates that the 2007 water year was historically a very low water year and was likely a very low water year at the sites with shorter periods of record (Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River). Because of the effect of streamflow on water quality, concentrations of nutrients and sediment in this report may not be representative of historical conditions.

Continuous Water-Quality Parameters

Continuous data was collected during the growing season from April 2006 through August 2007. Figures 6 through 9 show the continuous temperature, dissolved oxygen, pH, and specific conductance at Chetomba Creek near Renville, Chetomba Creek near Maynard, West Fork Beaver Creek near Bechyn, and South Branch Rush River near Norseland, Minnesota.



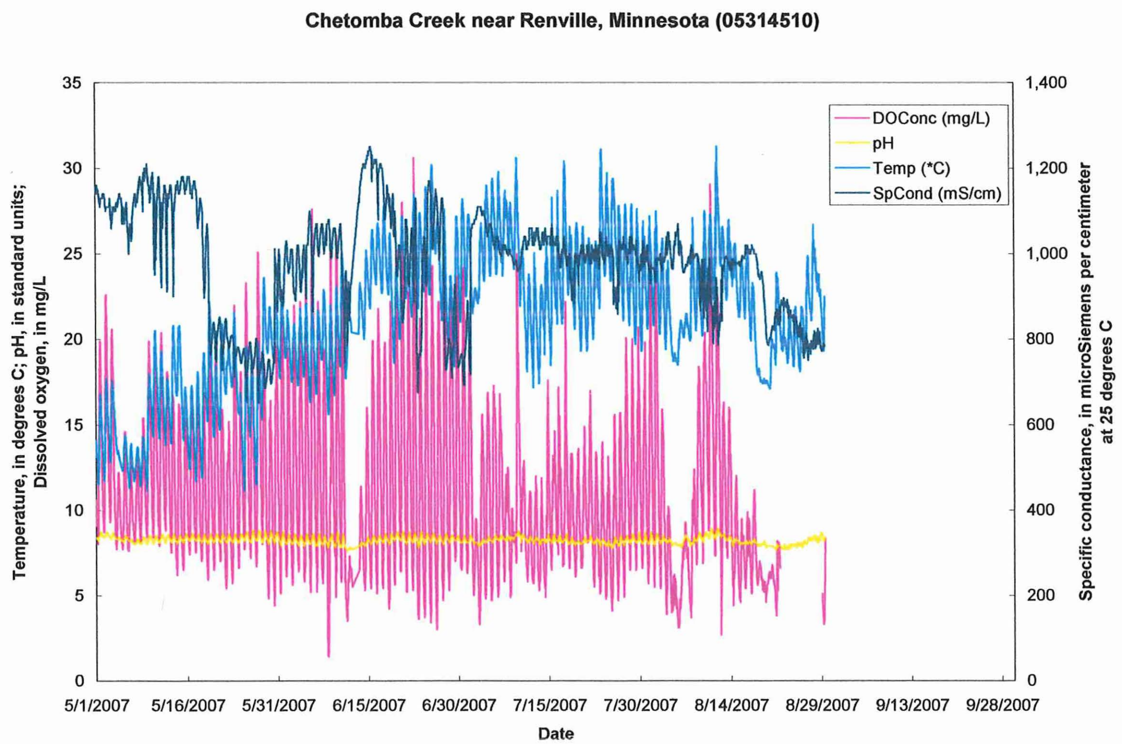
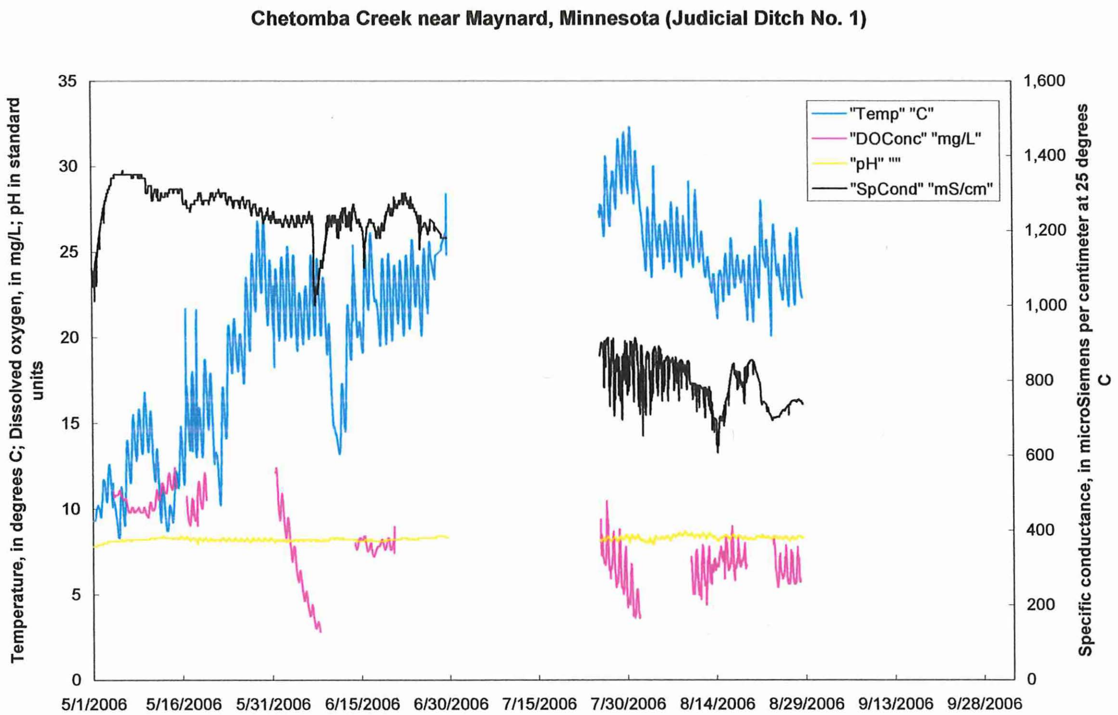


Figure 6. Continuous water-quality for Chetomba Creek near Renville, Minnesota, 2006-07.



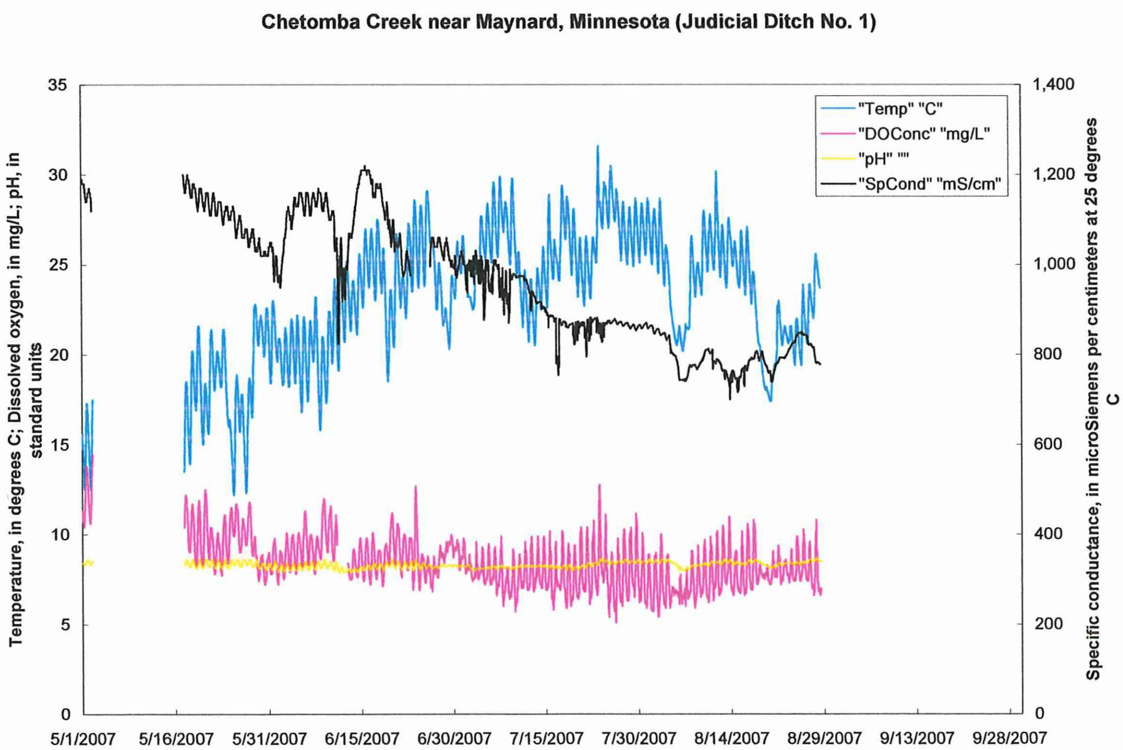
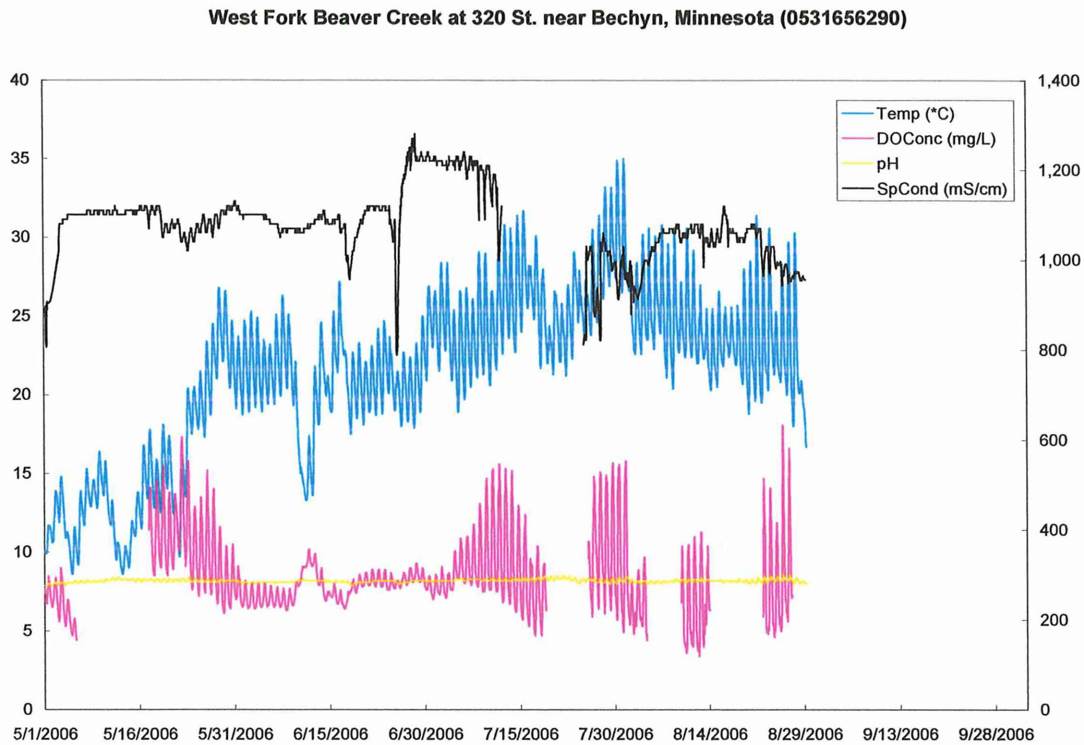


Figure 7. Continuous water-quality for Chetomba Creek near Maynard, Minnesota, 2006-07.



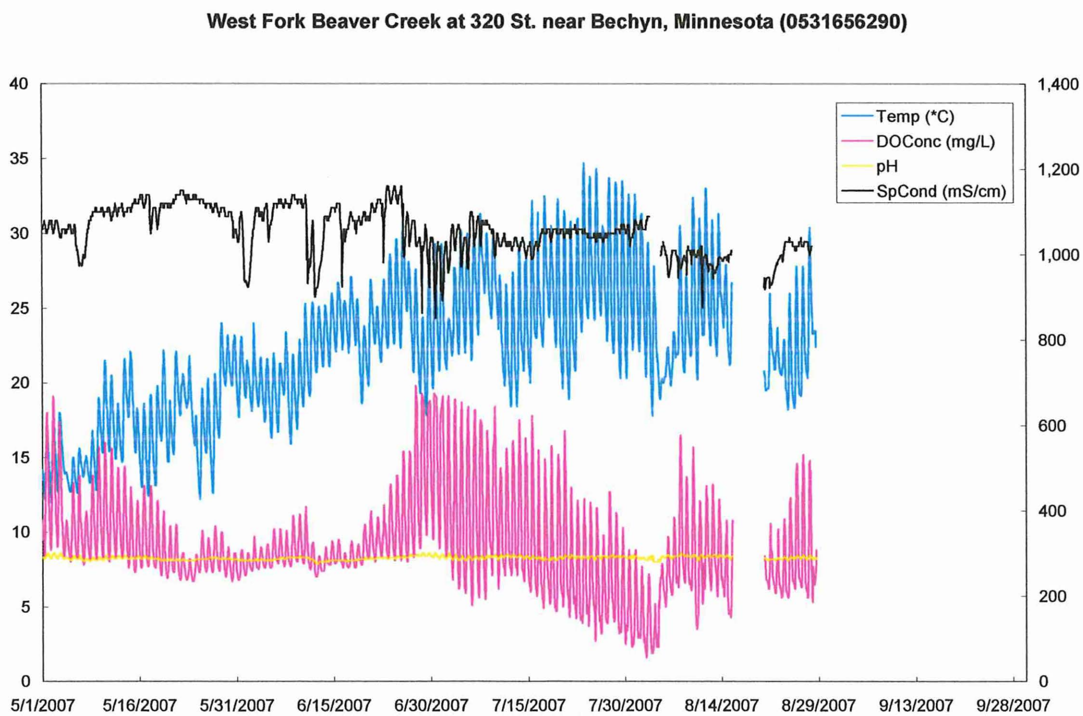
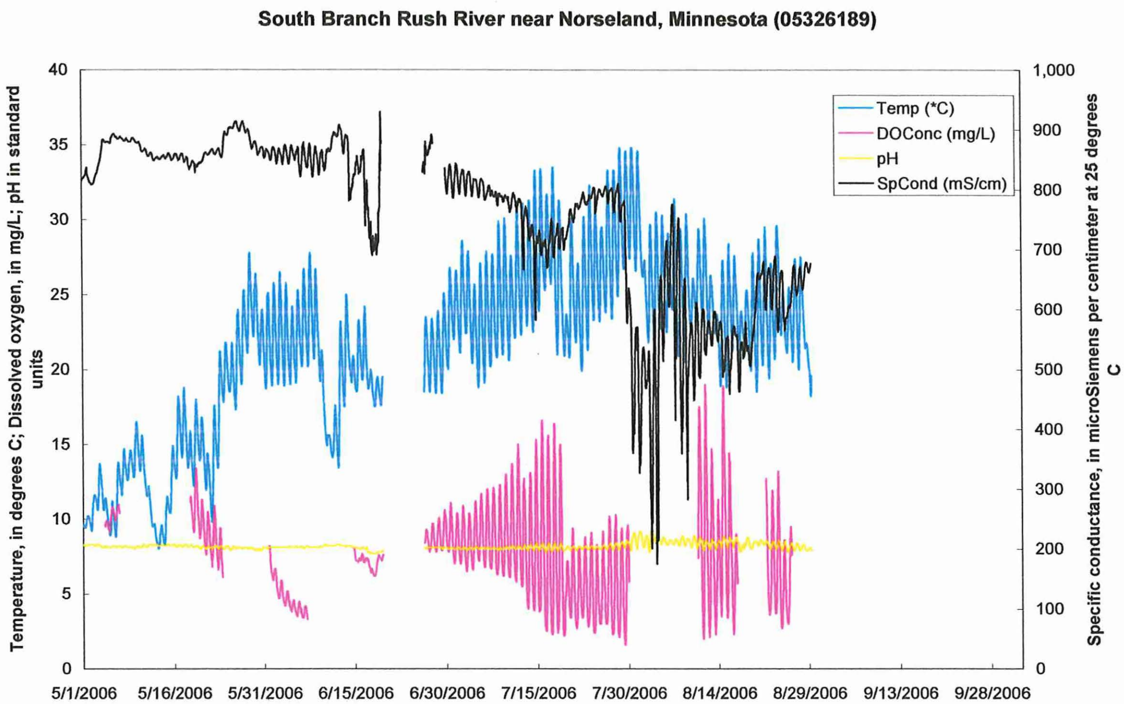


Figure 8. Continuous water-quality for West Fork Beaver Creek near Bechyn, Minnesota, 2006-07.



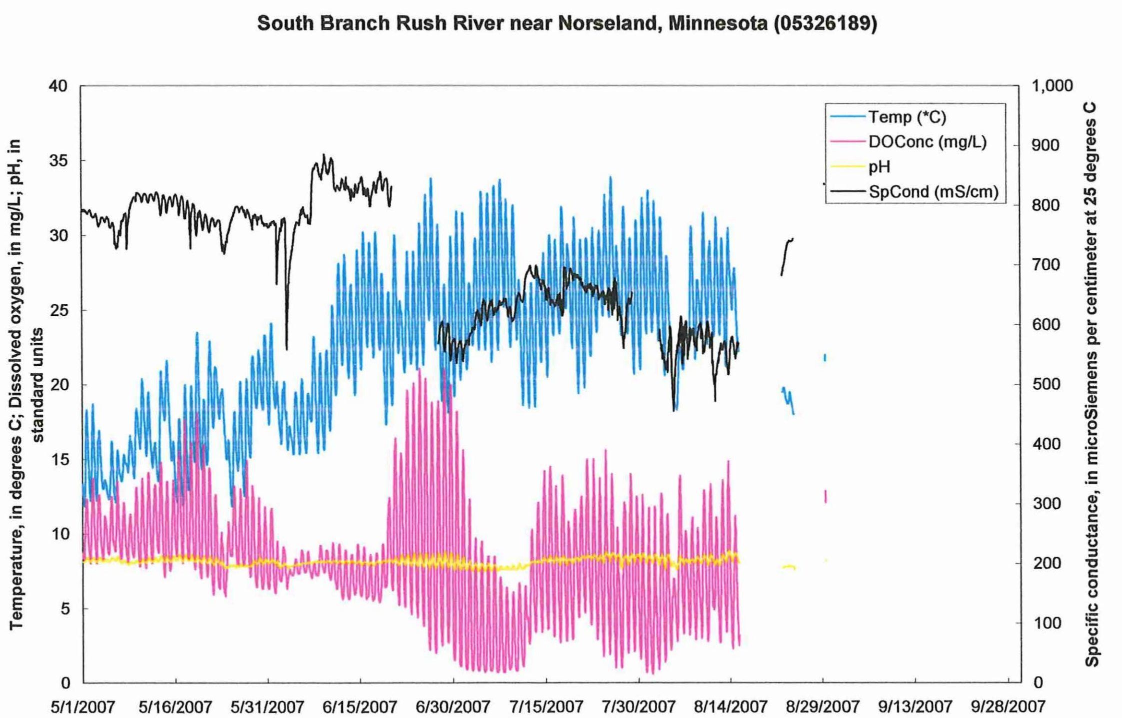


Figure 9. Continuous water-quality for South Branch Rush River near Norseland, Minnesota, 2006-07.

Figures 6-9 show that, not only is there substantial seasonal variation in the water-quality parameters, but diurnal variation, and variation between years. Seasonal variation is perhaps easiest to identify with continuous temperature measurements (the blue trace in figures 6-9). Water temperature is an important parameter due to the effect it has on stream biology. Specific conductance also has a seasonal component. Generally for these sites it is higher in the spring and lower later in the summer, when streamflow is low. This indicates that the higher specific conductance (and thus dissolved constituents) are coming from runoff and not entering the stream from ground water recharge.

Diurnal variation is evident for most parameters. Of particular concern for most streams is the diurnal variation in dissolved oxygen. Dissolved oxygen and pH concentrations increase during the day as algae increase photosynthetic activity. The uptake of carbon dioxide during the day accompanied by the uptake of nitrate and phosphate and hydrogen ions results in a pH increase during the day. The reduced dissolved oxygen and pH concentrations at night occur as algae are respiring and are augmented by oxygen utilization during microbial decomposition. Diurnal variation in dissolved oxygen can cause stress to aquatic organisms, particularly fish. There is a noticeable difference between the dissolved oxygen diurnal variations (flux) at Chetomba Creek near Maynard (fig. 7) when compared to the other sites. Dissolved oxygen flux is lower at this site than the other sites. This may be due in part to improved water quality at this site, but is more likely due to the drop-structure located at the Maynard site. As water flows over the structure, the water level in Chetomba Creek is lowered by a few feet. As the water drops, it is oxygenated. The water-quality monitor at this site is located in a pool below the structure.

Nutrients

Nitrate plus nitrate concentrations (table 6, figure 10) were highest in South Branch Rush River, the subbasin with little or no land retirement, and lower in Chetomba Creek and West Fork Beaver Creek, subbasins with more riparian or upland land retirement. Nitrite plus nitrate and total nitrogen decreased with increasing retired land percentage (fig. 10). Payne (1994) reported nitrate concentrations were as high as 28 mg/L in the Rush River, downstream from the South Branch Rush site, so historically nitrite plus nitrate concentrations in the basin were higher than the current (2006-2007) high nitrogen concentration, which was 19.5 mg/L. Even in a basin with little or no land retirement, other BMPs may have helped improve water quality.

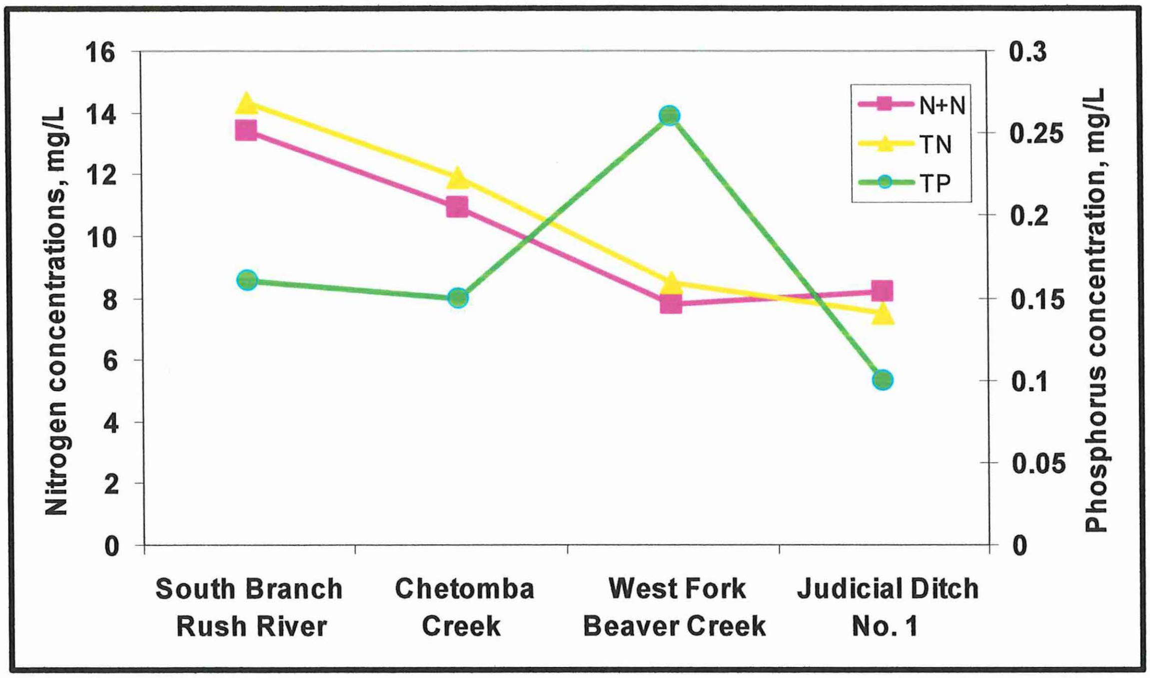


Figure 10. Comparison of nutrient concentrations at selected sites in order of increasing land retirement percent, Minnesota River basin, 2006-07.

Table 6. Average chlorophyll-a and nutrient concentrations at selected streams in the Minnesota River basin, 2006-2007.

[All nutrient concentrations are in milligrams per liter; chy-a, chlorophyll-a concentrations in micrograms per liter; number in parentheses is number of samples; --, not applicable]

Site name (site number, fig. 1)	Chy-a	Nitrite plus nitrate			Total nitrogen			Total phosphorus		
		Routine	Event	Total	Routine	Event	Total	Routine	Event	Total
Chetomba Creek-Renville (1)	13.7(6)	9.6(11)	15.9(3)	10.9(14)	10.3(10)	17.4(3)	11.9(13)	0.13(11)	0.23(3)	0.15(14)
Chetomba Creek-Maynard (2)	6.08(5)	8.2(8)	--(0)	8.2(8)	7.5(8)	--(0)	7.5(8)	0.10(8)	--(0)	0.10(8)
West Fork Beaver Creek (3)	19.1(6)	6.1(12)	13.0(4)	7.8(16)	6.7(12)	14.0(4)	8.5(16)	0.21(12)	0.39(4)	0.26(16)
South Branch Rush River (6)	15.1(6)	10.0(11)	19.5(6)	13.4(17)	11.3(11)	19.8(6)	14.3(17)	0.14(11)	0.19(6)	0.16(17)

Table 6 indicates that the average nitrite plus nitrate concentration at Chetomba Creek near Maynard is 8.2 mg/L, whereas average total nitrogen is 7.5 mg/L. Total nitrogen should be larger than nitrite plus nitrate and this discrepancy is due to one sample collected on June 13, 2006, in which nitrite plus nitrate was 15.3 mg/L and total nitrogen was 3.27 mg/L.

Total phosphorus concentrations were lowest at Chetomba Creek near Maynard (Judicial Ditch No. 1, fig. 10) and highest in West Fork Beaver Creek. Chetomba Creek near Maynard (Judicial Ditch No. 1), which is downstream from a substantial amount of retired land (table 2), had lower nutrient concentrations than the upstream Chetomba Creek site. This may indicate that the retired land between the Chetomba Creek near Renville site and the Chetomba Creek near Maynard site leads to improved water quality. Total phosphorus at West Fork Beaver Creek is noticeably higher that the other sites (fig. 10) and as a result, total phosphorus does not decrease with increasing land retirement percentage.

When the upstream Chetomba Creek near Renville site is compared to the downstream Chetomba Creek near Maynard site (Judicial Ditch No. 1), nitrite plus nitrate, total nitrogen, and total phosphorus all decrease as the retired land percentage in the 50-ft buffer increases from 5.7 percent to 18.7 percent (fig. 11). These concentrations are for low-flow samples, as there was no autosampler at Chetomba Creek near Maynard to capture high-flow event samples. The Hawk Creek Watershed Project collected high flow samples at this site and these will be compared during Phase 2 of this project. Initial results indicate that high-flow nutrient concentrations are higher at Chetomba Creek near Renville than at Chetomba Creek near Maynard.

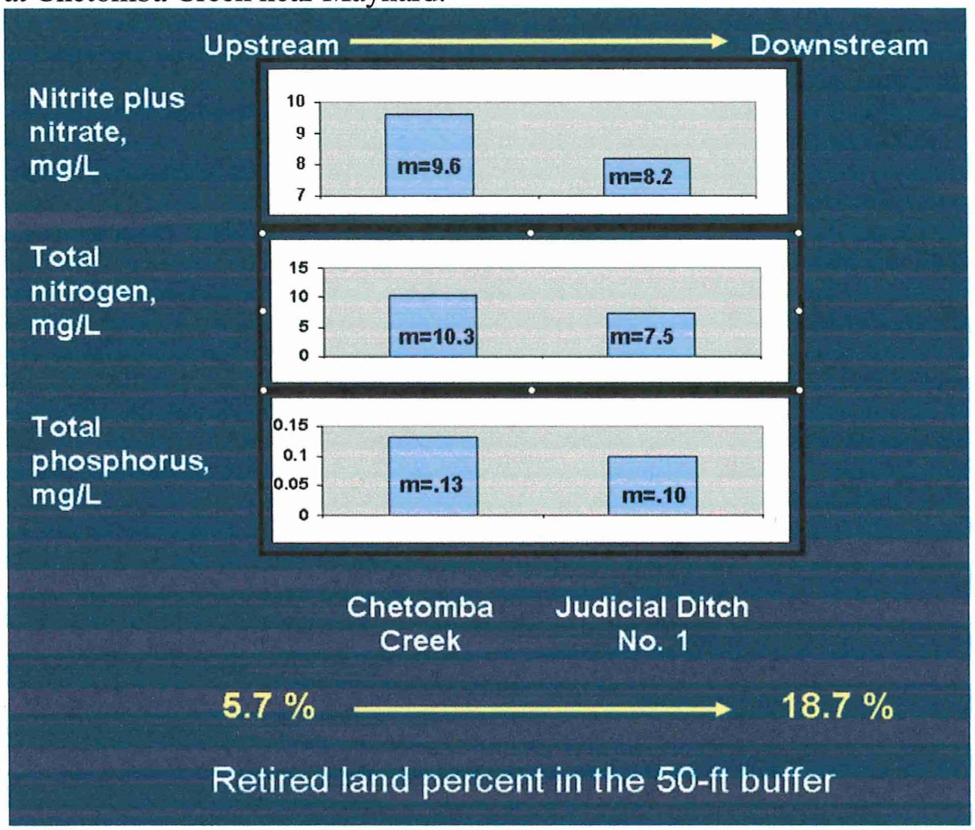


Figure 11. Comparison of low-flow nutrient concentrations at Chetomba Creek near Renville and Chetomba Creek near Maynard, Minnesota, 2006-07.

Suspended Sediment

Suspended sediment in the Minnesota River is commonly high when compared to other Minnesota streams (Tornes, 1986). There also are wide fluctuations between average and maximum concentrations. Tornes (1986) suggests that because the Minnesota River basin is relatively flat, most sediment is transported after storms erode fine-grained soils exposed by heavy cultivation. Heavily cultivated clay and loess contributes large quantities of suspended sediment. The west to east precipitation gradient could cause the eastern part of the basin to have more runoff producing storms, therefore producing higher sediment loading, irrespective of land-use activity (Payne, 1994).

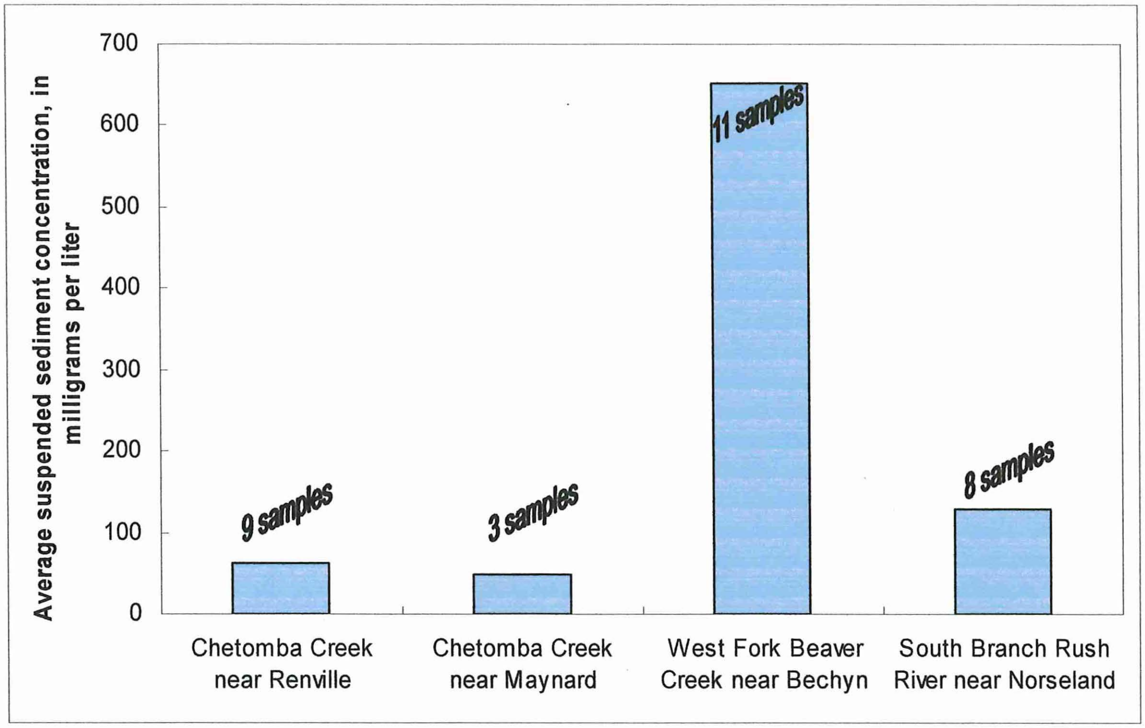


Figure 12. Suspended sediment concentrations at (a) Chetomba Creek near Renville, (b) Chetomba Creek near Maynard, (c) West Fork Beaver Creek near Bechyn, and (d) South Branch Rush River near Norseland, Minnesota, 2006-07.

Figure 12 shows average suspended sediment concentrations at Chetomba Creek near Renville, Chetomba Creek near Maynard, West Fork Beaver Creek, and South Branch Rush River near Norseland, Minnesota during 2006-2007. As with total phosphorus, West Fork Beaver Creek has the highest suspended sediment concentrations. Sediment and total phosphorus often are related because most of the phosphorus carried by the stream is in the solid phase. For this reason, it is possible to estimate total phosphorus concentrations with continuous measures of turbidity from the water-quality monitor because turbidity is a representation of the solid material in the water.

The average suspended sediment concentrations in figure 12 were calculated using both the rainfall event and low-flow samples. However, rainfall event samples include only those samples that were composites over the course of a storm event. During many of the storm events, the automated samplers collected 24 sample bottles. These samples were analyzed individually and the results will be compared to the continuous turbidity readings in a future report.

Physical Habitat Description

Physical habitat characteristics varied among streams and among years (table 7). Stream reach volume and habitat composition changed between 2006 and 2007 due to flow conditions. During 2006, stream widths and depths generally were greater than in 2007, leaving less habitat volume in 2007. Chetomba Creek had the greatest overall reach volume during both years. The dominant types of instream cover at Chetomba Creek and South Branch Rush River were macrophyte/macroalgal cover and overhanging vegetation. West Fork Beaver Creek had little or no macrophyte/macroalgal cover; rather the instream cover consisted of overhanging vegetation and woody debris. The bottom substrate at Chetomba Creek, and South Branch Rush River was primarily gravel. At West Fork Beaver Creek the bottom substrate tended toward finer silt and clay.

Table 7. Summary of physical habitat at selected streams in the Minnesota River basin, 2006-2007.

[m, meters; m², square meters; m³, cubic meters; mm, millimeters; >, greater than]

	CHETOMBA CREEK		WEST FORK BEAVER CREEK		SOUTH BRANCH RUSH RIVER	
Site number (fig. 1)	1		3		6	
Collection year	2006	2007	2006	2007	2006	2007
Reach length (m)	150	150	150	150	150	150
Average wetted channel width (m)	6.2	4.9	4.6	3.9	4.2	2.6
Average depth (m)	0.17	0.14	0.15	0.16	0.10	0.08
Average velocity (m)	0.04	0.03	0.06	0.02	0.08	0.008
Reach volume (m^3)	158	103	104	94	63	31
Reach area (m^2)	930	735	690	585	630	390
Instream habitat cover						
Macrophyte/macroalgal cover (percent)[1]	98	44	1.8	0.0	22	22
Overhanging vegetation (percent)	75	22	16	15	38	18
Woody debris (percent)	0	0	26	6	0	0
Bottom substrate composition						
Silt, clay, and organic detritus (percent)	0	2	70	89	0	0
Sand > 0.062 – 2 mm (percent)	0	18	15	4	13	60
Fine gravel > 2 – 16 mm (percent)	77	55	6	7	78	40
Coarse gravel > 16 – 32 mm (percent)	23	24	6	0	9	0

[1]Percentage of measurements where selected cover was present (out of 55 measurements).

Biological Community Characteristics

Biological communities are an important component of stream quality assessment as organisms respond to physical habitat, hydrologic, and chemical alterations in predictable patterns. The combination of physical, chemical, and biological measures provides an integrated asement of resource quality. Biological communities form in response to chemical and physical environments and intra-species interactions. Benthic algae form the base of the aquatic food chain and provide food resources for invertebrates and fish. They have life cycles ranging from days to weeks and respond rapidly to changes in dissolved nutrients, light, and temperature. Excessive amounts of nutrients in streams can produce nuisance growth of algae. This is commonly referred to as eutrophication. Excessive algal growth can result in organic enrichment through rapid algal cell growth and decay resulting in reductions in dissolved oxygen. Aquatic invertebrates are important elements of resource assessment because they tend to live in or on stream sediments, have life cycles of months to years and integrate the effects over approximately one year (Barbour and others, 1999). Aquatic invertebrates are a very diverse group of organisms with a wide range of sizes, habitat requirements, life histories, and sensitivities to resource degradation. Fish are widely used for measuring water resource quality. They are longer lived (years to decades) than algae or invertebrates. The combination of algal, invertebrate, and fish characterizations provides information covering a wide variety of conditions and over differing time periods

Algal Community Characteristics

One hundred thirty four algal taxa were collected among all sites and all sampling periods. A majority of the taxa collected were diatoms (118), followed by green algae (7), blue-green algae (6), and Euglenoids (3). Diatoms typically comprise the majority of benthic algal taxa, and blue-green and green algae also are common in streams (Allan, 1995). Most of the algal taxa from the three steams in this study were classified as moderately tolerant (Bahls, 1993).

Taxa richness (number of taxa collected at a site) was least at South Branch Rush River and greatest at West Fork Beaver Creek (table 8). In terms of percent richness, diatoms were the dominant algal group with approximately 48 to 65 of the taxa at each site. Green and blue-green algae were the next most abundant algal groups based on taxa richness.

Table 8. Summary of algal community characteristics at selected streams in the Minnesota River basin, 2006-2007.

	CHETOMBA CREEK		WEST FORK BEAVER CREEK		SOUTH BRANCH RUSH RIVER	
Site number (fig. 1)	1		3		6	
Collection year	2006	2007	2006	2007	2006	2007
Taxa Richness	57	59	68	68	51	55
Total Biovolume (um^3/cm^2)	142,093,768,095	28,263,879,203	6,372,056,381	15,581,295,449	2,747,235,099	1,684,053,461
Total Algal Density (# cells/cm^2)	10,692,097	7,564,199	4,159,463	3,488,720	2,764,782	1,952,888
Percent of algal taxa classified as blue-greens	5.26	6.78	4.41	2.94	0	3.64
Percent of algal taxa classified as greens	8.77	3.39	1.47	0	0	5.45
Percent of algal taxa classified as diatoms	84.21	89.83	92.65	95.59	98.04	90.91
Percent of algal biovolume classified as blue-greens	0.15	1.41	1.33	0.07	0	0.15
Percent of algal biovolume classified as greens	98.28	87.43	46.47	0	0	0.34
Percent of algal biovolume classified as diatoms	1.55	11.16	52.05	99.26	99.44	99.51
Percent of algal density classified as blue-greens	61.56	50	34.29	8	0	5.18
Percent of algal density classified as greens	3.46	1.02	0.86	0	0	6.10
Percent of algal density classified as diatoms	34.86	49.98	64.55	90.77	99.32	88.72

Algal biovolume and cell density are indicators of algal standing crop. Biovolume is a measure of the algal cell volume per unit area. This is essentially the thickness of the algal cells on the substrate. Total algal biovolume was greatest at Chetomba Creek, followed by West Fork Beaver Creek, and

South Branch Rush River (table 8). The greater volume of algae at Chetomba Creek indicates that there are conditions ideal for algal growth (long residence time, little riparian shading, and sufficient dissolved nutrient concentrations). Green algae are the dominant algal group at Chetomba Creek in terms of the percent of total algal biovolume (Figure 13a) while diatoms were dominant at the other two sites. Density is the number of algal cells per unit area. Density measures often highlight smaller cells such as blue-green algae that are large in number, but have low cell volume. The percent of density was dominantly blue-green algae at Chetomba Creek, whereas diatoms were predominant at the other sites. There was variance between years in the composition of the community likely due to differences in hydrologic conditions and nutrient and light availability.

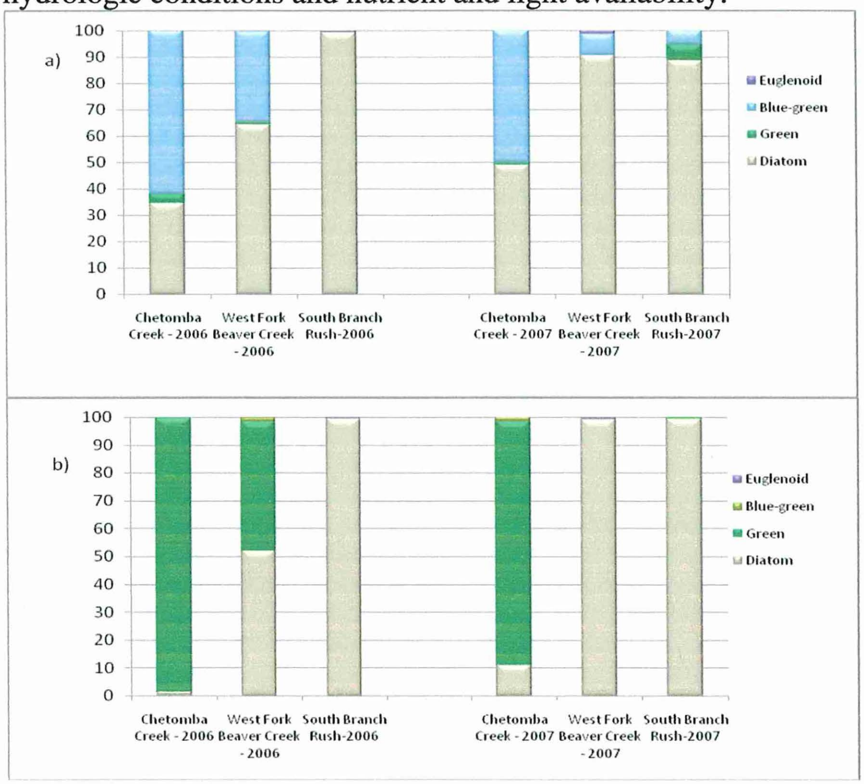


Figure 13. Distribution of algal taxa by (a) cell biovolume and (b) cell density.

Streams with degraded conditions can have a dominance of one or two organisms that are able to thrive under degraded conditions. The percent of algal biovolume comrised by the most dominant taxa was greatest at Chetomba Creek (figure 14). Over 95 percent of algal biovolume at Chetomba Creek was dominated by two taxa, *Cladophora sp*. and *Spirogyra sp*. These filamentous green algae become abundant when nitrogen and phosphorus concentrations are relatively high (Stevenson and others, 1996). South Branch Rush and West Fork Beaver Creek also had a few taxa that were dominant. Three diatom species, *Cyclotella meneghiniana Kützing*, *Synedra sp*., and *Nitzchia amphibia Grunow* comprised over 50 Percent of the biovolume at the South Branch Rush River. *Spirogyra sp.* and *Synedra sp.* comprised over 50 percent of the biovolume at the West Fork Beaver Creek.

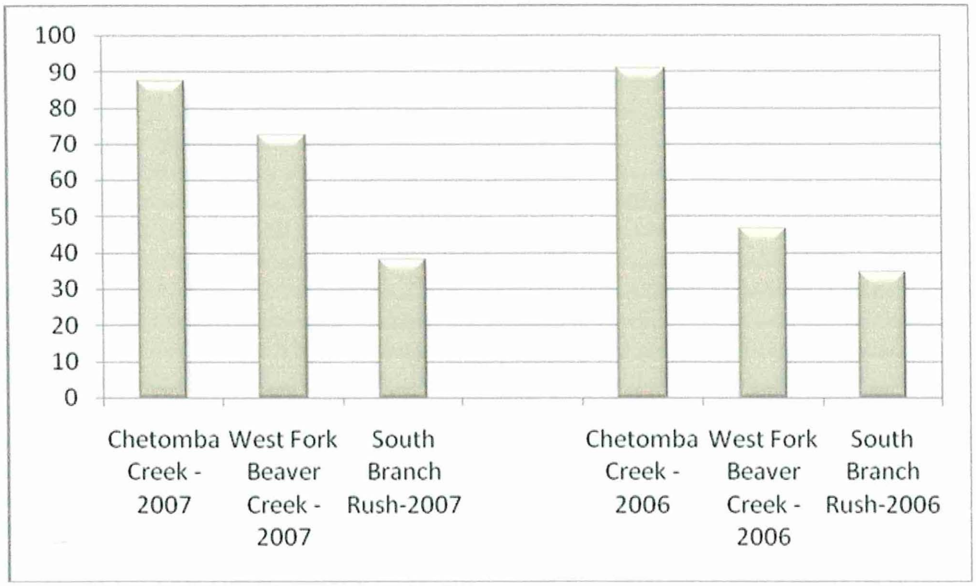


Figure 14. Percent of total algal biovolume represented by the most abundant taxa, Minnesota River basin, 2006-2007.

Periphyton are important primary producers in streams and are important in nutrient uptake in streams. They transform many inorganic forms of nutrients into organic forms and are primary consumers of inorganic phosphorus (Stevenson and others, 1996). In stable nutrient enriched streams algae can grow rapidly because they respond so rapidly to chemical conditions. Periphyton are limited by light availability, nutrient resources, grazing by other aquatic organisms, water temperature, and residence time. In this study, all three streams have fairly stable conditions with similar light availability with the exception of West Fork Beaver Creek that has greater suspended sediment concentrations and greater turbidity that may limit light availability. A significant proportion of periphyton in all streams are those found in mesoeutrophic to eutrophic conditions. Chetomba Creek had the greatest algal biovolume and density, and the algal community was dominated by very few taxa that are indicative of enriched conditions.

Invertebrate Community Characteristics

Benthic macroinvertebrates are widely uses as indicators of water quality because they form permanent and relatively immobile stream communities, are quick to react to environmental change, and are a major source of food for fish and other aquatic species. Invertebrate composition and community structure are determined by physical and chemical environmental factors. There were 72 benthic invertebrate taxa collected among all three streams, of which, 53 were in the class insecta (Appendix 2). The remaining 19 non-insect taxa were distributed among the following classes (Hirudinea, Oliogochaeta, Malacostraca, Bivalvia, Gastropoda, Nematoda, and Nematophora). The insect taxa were distributed among the following orders: Diptera (27 taxa), Ephemeroptera (9), Coleoptera (5), Trichoptera, (5), Odonata (4), Hemiptera (2), and Collembola (1).

During 2006 and 2007, invertebrate taxa richness was least at West Fork Beaver Creek. South Branch Rush River and Chetomba Creek had the greatest invertebrate richness during 2006 and 2007, respectively (table 9). Insect taxa richness followed a similar pattern (figure 15).

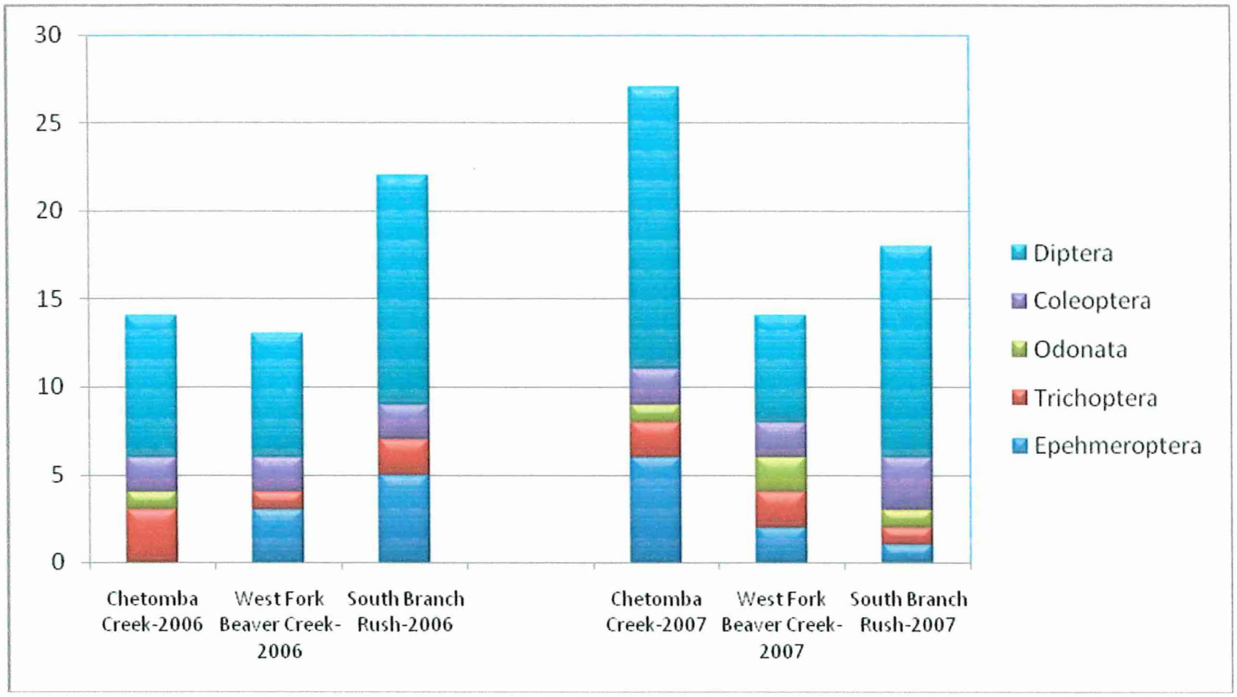


Figure 15. Distribution of insect taxa richness among insect orders.

Some macroinvertebrates, for example, Diptera and Oligochaeta, tend to be tolerant of poor water-quality conditions. Other organisms, for example, the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are more sensitive to organic and nutrient conditions. Numerous sensitive taxa are only expected at sites with good water quality. Diptera were the dominant taxa in terms of taxa richness in all three streams (table 9, figure 15). There were no Plecoptera present in any of the streams sampled likely due to the absence of suitable habitat (hard substrates with little silt cover), warm water temperatures and no rapidly flowing water. The percent of taxa classified as Ephemeroptera and Trichoptera varied among sites and temporally within a site. During 2006, South Branch Rush River had the greatest combined Ephemeroptera and Trichoptera richness followed by West Fork Beaver Creek, and Chetomba Creek. During 2007, Chetomba Creek had the greatest taxa richness and South Branch Rush River had the least.

The distribution of invertebrate abundance varied among sites and within each site in different years. During 2006, Chetomba Creek and West Fork Beaver Creek invertebrate abundance was comprised predominantly of non-insect taxa and *Diptera* in comparison to the South Branch Rush River. The abundance of *Ephemeroptera* and *Trichoptera* was least at Chetomba Creek and greatest at South Branch Rush River. During 2007, Chetomba Creek and West Fork Beaver Creek had greater relative abundance of *Ephemeroptera* and *Trichoptera* than South Branch Rush River, which was dominated by non-insects and *Diptera.*

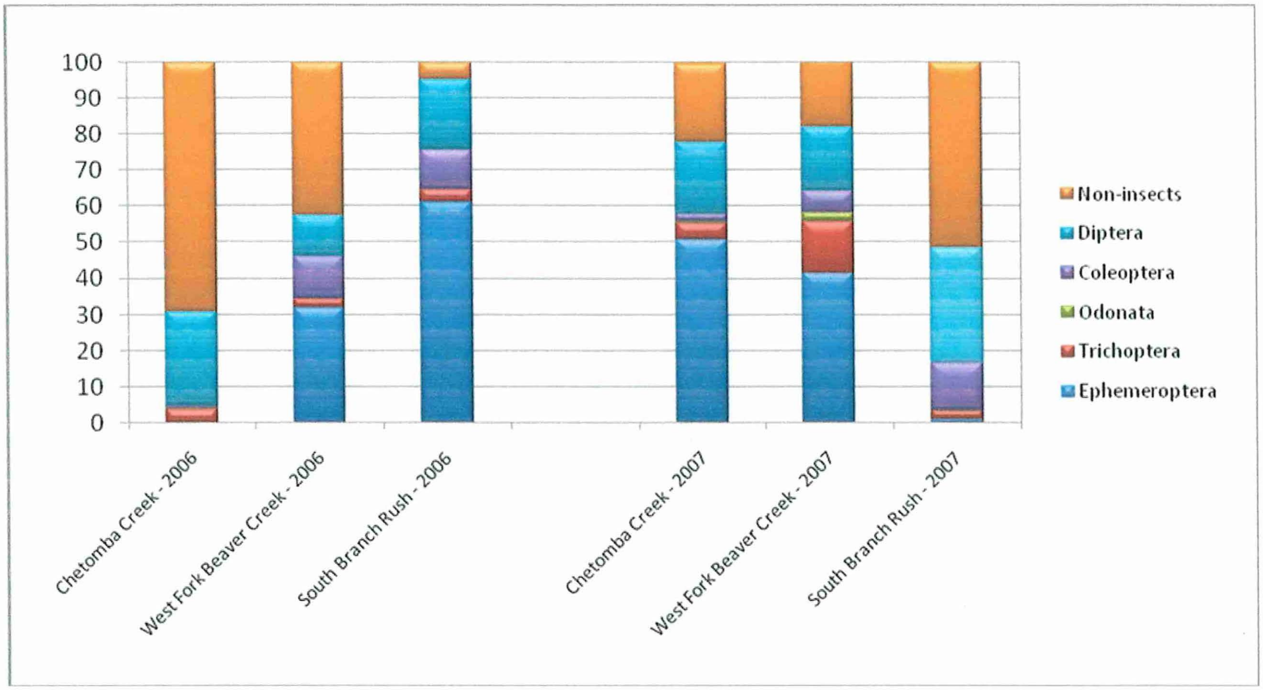


Figure 16. Distribution of invertebrate taxa abundance, Minnesota River basin, 2006-2007.

All three streams were dominated by very few taxa, which can be indicative of an unstable community. The abundance of taxa was dominated (over 35%) by 1 taxa in all three streams (table 9). The freshwater snail (*Physella sp.*) an aquatic worm (*Megadrile sp.*), and a burrowing midge (Dicrontendipes) were the dominant organisms at Chetomba Creek during 2006. These taxa are generally indicative of nutrient enrichment, live in depositional habitats, and feed by collecting or scraping. (U.S. Environmental Protection Agency, 2008; Merritt and Cummins, 1996; Pennak, 1989). The dominant taxa at Chetomba Creek, during 2007, differed from those that were dominant in 2006, but are generally indicative of similar environmental conditions (taxa are typically found in depositional areas with macrophyte cover and are collectors or scrapers). *Caenis sp.* is a mayfly that is typically found in depositional areas and feed by collecting and scraping algal cells from rocks (Merritt and Cummins, 1996). *Physa sp.* is a freshwater snail that occurs where there is a moderate amount of aquatic vegetation and organic debris (Pennak, 1989). *Chironomus sp.* is a midge in the family chironomidae which are generally found in depositional environments as they are burrowers and primarily feed by gathering their food (Merritt and Cummins, 1996; Pennak, 1989).

Table 9. Summary of invertebrate community characteristics at selected streams in the Minnesota River basin, 2006-2007.

	CHETOMBA CREEK		WEST FORK BEAVER CREEK		SOUTH BRANCH RUSH RIVER	
Site number (fig. 1)	1		3		6	
Collection year	2006	2007	2006	2007	2006	2007
Invertebrate Taxa Richness	20	38	14	23	25	25
Ephemeroptera richness	0	6	3	2	5	1
Trichoptera richness	3	2	1	2	2	1
Diptera Richness	8	16	7	6	13	12
Percent Ephemeroptera (abundance)	0	51	32	41	61	1
Percent Trichoptera (abundance)	4	5	2	14	4	3
Percent Diptera (abundance)	26	20	12	18	20	32
Percent of invertebrates classified as tolerant (abundance)	72.7	25.2	3.16	9.64	5.04	61.1
Percent of invertebrates classified as intolerant[1]	4.36	1.67	0	4.81	3.18	2.83
Average abundance weighted tolerance score	7.58	6.72	5.60	5.64	5.89	7.29
Percent dipterans and non-insects	94.7	40.2	53.9	29.8	14.5	83.2
Percent Tanysarsini Midges (abundance)	0.26	0.90	0	0	9.85	0.25
Percent scrapers (abundance)	38.57	12.91	1.82	1.19	2.94	47.74
Percent filter-collectors (abundance)	0.83	6.07	2.42	19.05	0.61	18.22
Percent of invertebrate abundance comprised by 1 taxa	35.56	49.05	42.42	40.47	48.17	46.96

[1]Bailey and others (1993) was used for fish tolerance classification and IBI calculations; Bailey and others (1993) rates streams with IBI scores of 50-60 as "excellent," 40-49 as "good," 30-39 as "fair," 20-29 as "poor," and 12-20 as "very poor."

During 2006, West Fork Beaver Creek was dominated by an aquatic worm, a mayfly (*Hexagenia sp.*), and a midge (*Stictochironomus sp.*) (table 10). Worms, midge larvae, and Hexagenia mayfly nymphs are the most common invertebrates found in depositional environments. Hexagenia is a dominant component of the benthic fauna of muddy and silty sediments in mesotrophic (intermediate level of productivity) rivers (Merritt and Cummins, 1996). They ripple their abdomen to force oxygen-rich water through a burrow developed in the soft sediments. Because mayflies can't survive in water that lacks oxygen, they are good indicators of the amount of organic enrichment. When organic enrichment is low, a greater density of *Hexagenia* larvae are expected (Wright and Tidd, 1933). In contrast, Megadrile is indicative of organic or nutrient enrichment, but the presence of *Hexagenia sp.* indicates that the enrichment is moderate. During, 2007, West Fork Beaver Creek was dominated again by the mayfly *Hexagenia sp.*, the Trichoptera, and *Cheumatopsyche sp.*, which are generally found in warm streams and are net spinners with fixed retreats that feed by filtering algae and detritus (Merritt and Cummins, 1996). *Stictochironomus sp.*, the third most dominant organism, is a burrowing midge found in depositional habitats and feed by gathering algal cells and detritus.

Table 10. The percent of total abundance comprised by three most abundant taxa collected, Minnesota River basin, 2006-2007.

Site Name	Collection Date	Most Abundant taxa and Percent of Abundance		Second most Abundant taxa and Percent of Abundance		Third most Abundant taxa and Percent of Abundance	
Chetomba Creek	8/21/2006	36	Physella sp.	26	Megadrile	8	Dicrotendipes sp.
Chetomba Creek	7/31/2007	49	Caenis sp.	10	Physa sp.	6	Chironomus sp.
West Fork Beaver Creek	7/31/2007	40	Hexagenia sp.	13	Cheumatopsyche sp.	11	Stictochironomus sp.
West Fork Beaver Creek	8/22/2006	42	Megadrile	28	Hexagenia sp.	10	Dubiraphia sp.
South Branch Rush	8/22/2006	48	Caenis sp.	10	Paratanytarsus sp.	9	Dubiraphia sp.
South Branch Rush	7/30/2007	47	Physa sp.	18	Microtendipes sp.	12	Dubiraphia sp.

During 2006, South Branch Rush River was dominated by a mayfly (*Caenis sp.*), a midge (*Paratanytarsus sp.*), and a riffle beetle (*Dubiraphia sp.*) (table 10). These organisms in combination are indicative of ample algal resources existing on hard substrates and in the water column and are found in flowing waters (Merritt and Cummins, 1996). During 2007, the dominant organisms were reflective of similar environmental conditions during 2006.

The greatest average abundance-weighted tolerance scores and the percent of taxa classified as tolerant occurred at Chetomba Creek (table 9). The abundance weighted values were calculated by weighting the tolerance value by the abundance of the organisms in a sample. Tolerance values range from 0 to 10 where 0 represents the most sensitive organisms and 10 represented the value for a tolerant organism (table 11). A higher abundance weighted tolerance value indicates that the communities at these sites were composed of more organisms considered tolerant.

Table 11. Water-quality-evaluation ratings for abundance weighted tolerance scores (modified from Hilsenhoff, 1987).

Abundance-weighted tolerance score	Water-quality-evaluation rating	Degree of organic pollution
0.00 – 3.50	Excellent	No apparent organic pollution.
3.51 – 4.50	Very good	Possible slight organic pollution.
4.51 – 5.50	Good	Some organic pollution.
5.51 – 6.50	Fair	Fairly significant organic pollution.
6.51 – 7.50	Fairly poor	Significant organic pollution.
7.51 – 8.50	Poor	Very significant organic pollution.
8.51 – 10.00	Very poor	Severe organic pollution.

In this study, the relation of invertebrate metrics with land retirement characteristics was evaluated. Invertebrates respond to changes in physical habitat, hydrology, food resources, and water chemistry. Each taxa requires a particular physical habitat. Therefore, the absence of a taxa may not be an indicator of degraded water quality, but rather the absence of suitable physical habitat. Very few of the invertebrate measures were related directly with the percent of land retirement, possibly due to differences in physical habitat among the streams. The local habitat conditions may have more influence on the invertebrate community than the retired land characteristics. One metric that evaluates biological resource quality, the average abundance weighted tolerance scores, declined (improved) with increasing percent of retired land in the 50-foot buffer during 2006 (figure 17). That pattern was not as clear in 2007; however, the basin with the greatest percentage of retired lands in the 50-foot buffer had the lowest average tolerance score. There also was no clear relation between tolerance value and percent land retirement in the basin; although, West Fork Beaver Creek, the basin with the greatest percent of land retirement in the basin, had the lowest average tolerance values.

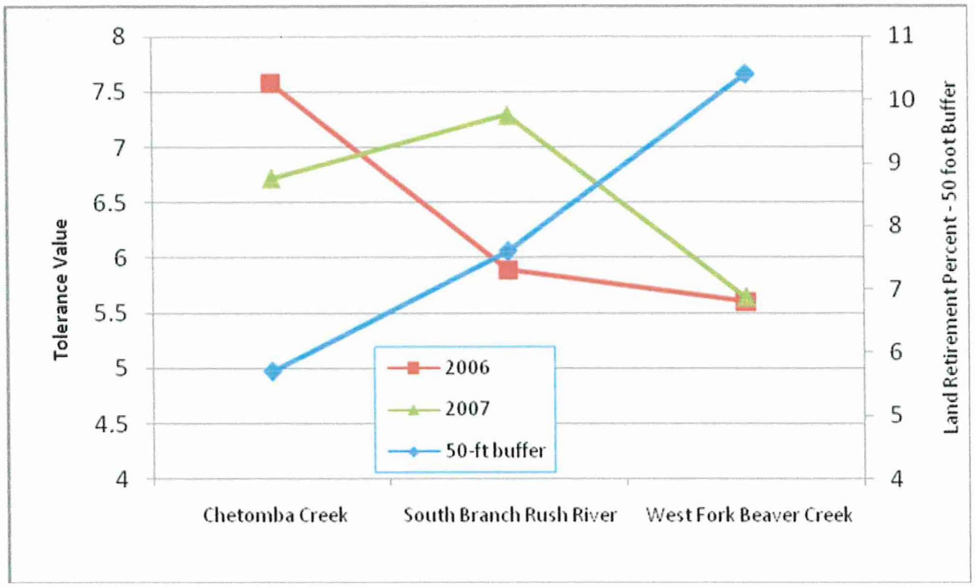


Figure 17. Average invertebrate abundance weighted tolerance values plotted with the percent of land retirement in the 50-foot buffer, Minnesota.

Fish Community Characteristics

There were 21 species of fish within five families collected among all sites and time periods. The majority of fish were in the *Cyprinidae* family (12), followed by two taxa each of the remaining families (*Cataostomidae*, *Centarchidae*, *Gasterosteidae*, *Ictaluridae*, and *Percidae*). Most of the fish collected were invertivores, planktivores, or detrivores, and five of the taxa were classified as tolerant fish. At Chetomba Creek, fathead minnows, creek chubs, and bigmouth shiners composed most (more than 50 percent) of the abundance during 2006 and creek chubs composed most of the abundance during 2007. At West Fork Beaver Creek, common shiner and bluntnose minnows (*Pimephales notatus*) composed most of the abundance during both years. At South Branch Rush River, fathead minnows and bluntnose minnows composed most of the abundance during both years. At South Branch Rush River, fathead minnows and bluntnose minnows composed most of the abundance in 2006, where as creek chubs composed most of the abundance during 2007.

Table 12. Summary of fish community characteristics at selected streams in the Minnesota River Basin, 2006-2007.

[m, meters; m², square meters; m³, cubic meters; mm, millimeters; >, greater than]

	CHETOMBA CREEK		WEST FORK BEAVER CREEK		SOUTH BRANCH RUSH RIVER	
Site number (fig. 1)	1		3		6	
Collection year	2006	2007	2006	2007	2006	2007
Number of fish species collected	8	9	13	15	16	11
Percent of fish classified as tolerant[2]	56	41	8	11	33	78
Number of Darter Species	1	1	1	1	1	1
Number of Minnow Species	2	3	7	8	6	5
Number of Intolerant Species	0	0	1	1	1	0
Proportion of tolerant species	55.6	41.2	8	11	32.6	77.5
Proportion of specialized insectivores	0	0	5.3	1.1	2.8	0
Proportion of omnivores	44.7	20.1	75.7	64.3	82.2	7.4
Catch per unit Effort on fall fish except tolerant ones) per hour	1014	1126	55	259	693	1016
Index of biotic integrity (IBI) scores[2]	14	20	30	28	19	23

[2]Bailey and others (1993) was used for fish tolerance classification and IBI calculations; Bailey and others (1993) rates streams with IBI scores of 50-60 as "excellent," 40-49 as "good," 30-39 as "fair," 20-29 as "poor," and 12-20 as "very poor

The sites in figure 18 are in the order of increasing land retirement at the primary sites. The number of fish species collected at each site is not related to land retirement percent. However, the percent of tolerant species decreases with increasing land retirement percentage indicated better resource quality at sites with higher land retirement.

The IBI is a composite index that evaluates an array of ecological attributes of fish communities. The IBI as originally created by Karr (1981) is comprised by 12 measures or metrics. Each of these metrics has a range of sensitivity to differing types of environmental degradation. Six classes exceptional, good, fair, poor, very poor, and no fish were used.

IBI scores indicated poor quality at all streams during both sampling periods except the West Fork Beaver Creek had a rating of "fair" during 2006. IBI scores generally decrease with increasing physical and chemical perturbations such as poor water quality, poor instream habitat, and migration barriers (Karr and others, 1987). Two of the metrics that influenced the overall IBI score, species richness (the number of fish taxa collected) and percent tolerant fish, show that West Fork Beaver Creek had a moderate number of fish species and the smallest percentage of tolerant species, whereas South Branch Rush River had a moderate number of fish species and a high percentage of tolerant species.

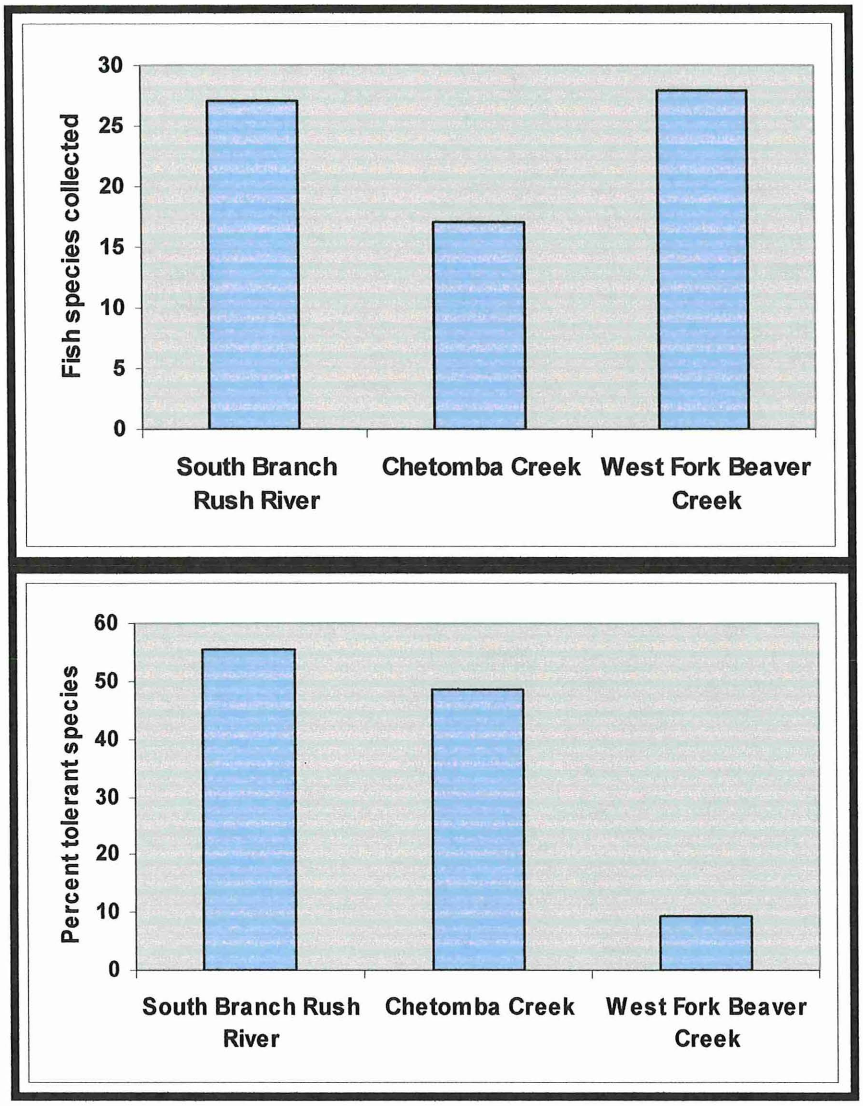


Figure 18. Total fish species and tolerant fish at Chetomba Creek near Renville, West Fork Beaver Creek near Bechyn, and South Branch Rush River near Norseland, Minnesota, 2006-07.

In this study, IBI scores increased as the local land retirement percentages (50- and 100-ft buffers) increased (figure 19). The relation was not as clear with retired land percentages at greater buffer distances. In addition to low percentages of retired land, the Chetomba Creek site has very little instream habitat diversity with the exception of very dense macrophyte and macroalgae mats that may not provide good habitat due to increased dissolved-oxygen variability. Number of fish species collected indicates better resource quality for the West Fork Beaver Creek than other streams likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics. The greater IBI score at West Fork Beaver Creek compared to Chetomba Creek and South Branch Rush River coincides with greater percentages of retired land and diversity of physical habitat cover types. The substrate at West Fork Beaver Creek was primarily silt and clay which is not preferable for many fish and invertebrate species but a lack of extensive macroalgae cover may lead to more stable dissolved oxygen conditions within the stream.

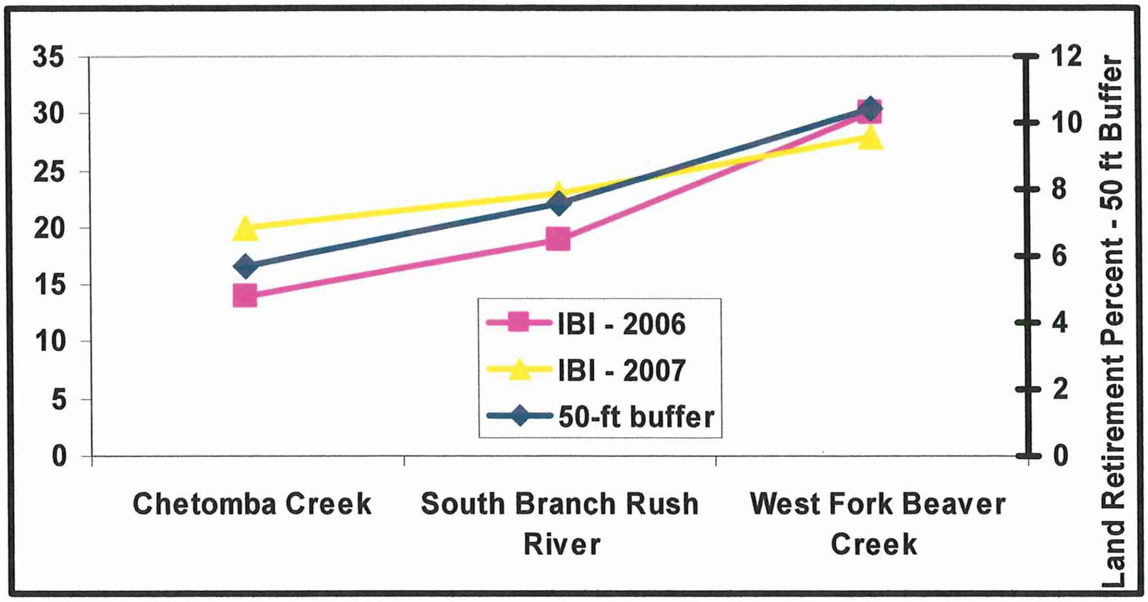


Figure 19. IBI scores at Chetomba Creek near Renville, West Fork Beaver Creek near Bechyn, and South Branch Rush River near Norseland, Minnesota, 2006-07. Sites are in order of increasing land retirement in the 50-ft buffer.

Chlorophyll-a concentrations follow a pattern similar to that of total phosphorus (figure 20). Concentrations of chlorophyll a are highest at West Fork Beaver Creek and lowest at Chetomba Creek near Maynard (Judicial Ditch No. 1).

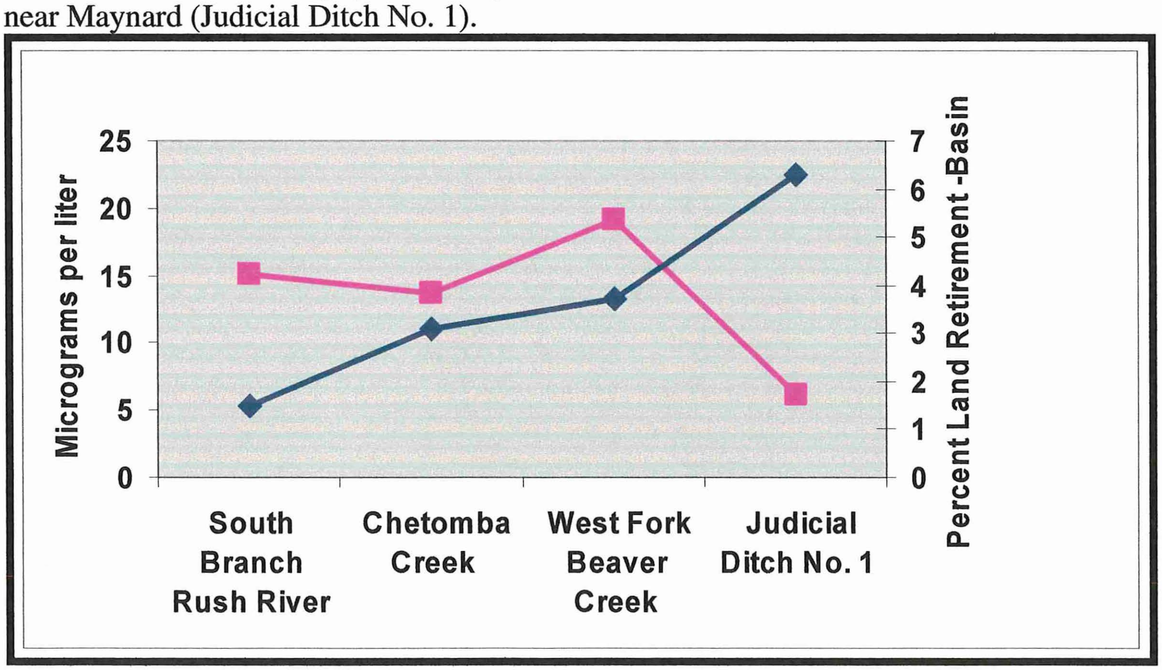


Figure 20. Chlorophyll-a at selected sites in the Minnesota River basin in order of increasing land retirement, 2006-07

Summary of the Relation of Stream Quality to Retired Lands Intensity

Retired land is assumed to improve water quality and aquatic resource quality by reducing surface runoff and reducing agricultural chemical entry into streams. In this study, both nitrogen and phosphorus concentrations were lowest in the subbasin with the highest retired land percentage. Nitrogen concentrations were highest in the subbasin with little or no land retirement. IBI scores increased as local land retirement percentages (50- and 100-ft buffers) increased likely due to a combination of factors including habitat quality, food resources, and dissolved oxygen characteristics.

Paired watershed studies, such as the one presented here, have their challenges. It is difficult to find watersheds that are similar and impossible to find watersheds with no differences. The relation between land retirement percentage and stream quality is likely affected by the differences among sites. For example, the drop structure at Chetomba Creek near Maynard presents a challenge for interpreting dissolved oxygen results and precluded this site from biological sampling. In addition the difference in resource quality at West Fork Beaver Creek when compared to the other sites may be due in part to factors such as stream shape—a more sinuous stream may cause travel time to increase, which causes nutrient uptake to increase.

In addition to the difficulties in pairing watersheds, conditions in the Minnesota River basin are highly variable from year to year and therefore it may not be prudent to draw conclusions from such a short term data set. Data collected during Phase 2 of this study will add important information to this data set. Land retirement contracts are decreasing across the Midwest due to the increase in corn prices. Data from this study should serve as a baseline for future studies, should land retirement in these basins decrease substantially. Additionally, if land retirement contracts shift to favor upland CRP, the benefits between riparian and upland CRP may be sufficiently addressed.

The data from 2006-2007 provide a response that a watershed may have to land retirement. Land owners, scientists, and local, State, and Federal agencies can use this information to improve management of natural resources in the Minnesota River basin, while sustaining economically viable agricultural production.

References

Allen, Arthur, 2005, The Conservation Reserve Enhancement Program in fish and wildlife benefits of farm bill conservation programs –2000-2005 Update in Haufler, J.B., editor, Wildlife Society Technical Review 05-2, p. 115-132.

Bailey, P.A., Enblom, J.W., Hanson, S.R., Renard, P.A., and Konrad Schmidt, 1993. A Fish Community Analysis of the Minnesota River Basin. Minnesota Pollution Control Agency, St. Paul, Minnesota, variously paged.

Bahls L.L. , 1993, Periphyton Bioassessment Methods for Montana Streams, Water Quality Bureau, Department of Health and Environmental Services, Helena, MT.

Baker, R.A., 1980 Contaminants and sediments, Volume 1, Fate and transport, case studies, modeling, toxicity: Ann Arbor, Mich., Ann Arbor Science, 558 p.

Baker, N.T., Stone, W.W., Wilson, J.T., and Meyer, M.T., 2006, Occurrence and Transport of Agricultural chemicals in Leary Weber Ditch Basin, Hancock County, Indiana, 2003-04: U.S. Geological Survey Scientific Investigations Report 2006-5251, 44 p.

Barbour, M.T., J. Gerritson, B.D. Snyder, and J.B. Stribling, 1999, Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish. Second edition. EPA/841/B-99/002, Washington, DC: U.S. Environmental Protection Agency.

Battaglin, W.A., and Goolsby, D.A., 1999, Spatial data in geographic information system format on agricultural chemical use, land use and cropping practices in the United States: U.S. Geological Survey Water-Resources Investigations Report 94-4176, *http://water.usgs.gov/pubs/bat/bat000.html*

Buchanan, T.J., and Somers, W.P., 1968, Stage measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A7, 28 p.

Buchanan, T. J., and Somers, W. P., 1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations Report, book 3, Chap. A8, 65 p.

Burger, L. W., Jr., The Conservation Reserve Program in the Southeast—issues affecting wildlife habitat value *in* Haufler, J.B., editor, 2005, Fish and wildlife benefits of farm bill conservation programs—2000-2005 update: The Wildlife Society Technical Review 05-2, p. X-XX.

Clark, W.R., and Reeder, K.F., 2005, Continuous enrollment Conservation Reserve Program—factors influencing the value of agricultural buffers to wildlife conservation *in* Haufler, J.B., editor, 2005, Fish and wildlife benefits of farm bill conservation programs—2000-2005 update: The Wildlife Society Technical Review 05-2, p. 93-114.

Fenneman, 1938 (no reference from proposal)

Ferrand, D.T., and Ryan, M.R., 2005, Impact of the Conservation Reserve Program on wildlife conservation in the Midwest, *in* Haufler, J.B., editor, 2005, Fish and wildlife benefits of farm bill conservation programs—2000-2005 update: The Wildlife Society Technical Review 05-2, p. 41-62.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and M.E. Gurtz, 1998. Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program. U.S. Geological Survey Water-Resources Investigations Report 98-4052, 67 p.

Guy, H.P., and Norman, V.W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chap. C2, 59 p.

Haufler, J.B., editor, 2005, Fish and wildlife benefits of farm bill conservation programs—2000-2005 update: The Wildlife Society Technical Review 05-2, 205 p.

Hilsenhoff, W.L., 1987, An improved biotic index of organic stream pollution, Great Lakes Entomology, v. 20, pp. 31-39.

Hilsenhoff, W.L., 1988, Rapid field assessment of organic pollution with a family-level biotic index, Journal of the North American Benthological Society, v. 7, p. 65–68.

Johnson, D.H., 2005, Grassland bird use of Conservation Reserve Program fields in the Great Plains in Haufler, J.B., editor, 2005, Fish and wildlife benefits of farm bill conservation programs—2000-2005 update: The Wildlife Society Technical Review 05-2, p. 17-32.

Karr, J. R. and Dudley, D. R,. 1981, Ecological perspectives on water quality goals. Environmental Management v.5, pp.55-68

Kennedy, E.J., 1983, Computation of continuous records of Streamflow: U.S. Geological Survey Techniques of Water Resources Investigations, book 3, chap. A13, 53 p.

Kennedy, E.J., 1984, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A10, 59 p.

Charles D.F., Knowles C. & Davis R.S. (Eds) (2002) Protocols for the Analysis of Algal Samples Collected as Part of the U.S. Geological Survey National Water-Quality Assessment Program. Patrick Center for Environmental Research Report No. 02-06. The Academy of Natural Sciences, Philadelphia, PA.

Lange-Bertalot H. (1979) Pollution tolerance of diatoms as a criterion for water quality estimation. Nova Hedwigia, 64, 285–304.

Leland H.V., Brown L.R. & Mueller D.K., 2001, Distribution of algae in the San Joaquin River, California, in relation to nutrient supply, salinity, and other environmental factors. Freshwater Biology, 46, 1139–1167.

Leland H.V. & Porter S.D. 2000) Distribution of benthic algae in the upper Illinois River basin in relation to geology and land use, Freshwater Biology, v. 44, pp. 270–301.

Lowe R.L., 1974, Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. Publication EPA-670/4-74-005. Office of Research and Development, National Environmental Research Center, U.S. Environmental Protection Agency, Cincinnati, OH.

Magner, J.A., and Alexander, S.C., 1993, The Minnesota River Basin: A hydrogeologic overview, Minnesota Pollution Control Agency, 21 p.

Mayer, P.M., Reynolds, S.K., McCutchen, M.D., and Canfield, T.J., 2006, Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: A review of current science and regulations: EPA/600/R-05/118, Cincinnati, OH, U.S. Environmental Protection Agency, 27 p.

Merritt, R.W., Cummins, K.W., 1996, An introduction to the aquatic insects of North America, third edition, Kendall, Hunt Publishing, Dubuque, Iowa, 862 p.

Moulton, S,R., Kennen, J.G., Goldstein, R.M., and Hambrook, J.A., 2002, Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 02-150, 75 p.

North American Benthological Society, 1996, History of the EPT taxa richness metric, accessed February 9, 2004, at http://www.benthos.org/Bulletin/bull1302.htm

Ojakangas, R.W., and Matsch, C.L., 1982, Minnesota's Geology: Minneapolis, University of Minnesota Press, 255 p.

Osborn, C.T., Llacuna, Felix, and Lisenbigler, Michael, 1995, The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1-12 and fiscal years 1986-93, Statistical Bulletin No. 925, Economic Research Service, U.S. Department of Agriculture, Washington, DC, November 1995, 102 p., accessed at *http://www.ers.usda.gov/publications/sb925/.*

Ohio Environmental Protection Agency, 1987, Biological criteria for the protection of aquatic life, Volume II—Users manual for biological field assessment of Ohio surface waters: Ohio Environmental Protection Agency [variously paged].

Ohio Environmental Protection Agency, 1989, Biological criteria for the protection of aquatic life, Volume III—Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities: Ohio Environmental Protection Agency [variously paged].

Payne, G.A., 1994, Sources and transport of sediment, nutrients, and oxygen-demanding substances in the Minnesota River basin, 1989-92: U.S. Geological Survey Water Resources Investigations Report 93-4232, 71 p.

Pennak, R.W., 1989, Freshwater Invertebrates of the United States, third edition, J. Wiley and sons, Inc. New York, 628 p.

Porter, Stephen D., Mueller, David,K., Spahr, Norman, E., Munn, Mark, D., and Dubrovsky, Neil, M., 2008, Efficacy of algal metrics for assessing nutrient and organic enrichment in flowing waters, Freshwater biology, v. 53 (5), pp. 1036-1054.

Porter S.D., 2007, Algal Attributes. An Autecological Classification of Algal Taxa Collected by the USGS National Water-Quality Assessment (NAWQA) Program. Data Series Report. U.S. Geological Survey, Denver, CO.

Reynolds, R.E., 2005, The Conservation Reserve Program and duck production in the U.S. Prairie Pothole Region in Haufler, J.B., editor, 2005, Fish and wildlife benefits of farm bill conservation programs—2000-2005 update: The Wildlife Society Technical Review 05-2, p. 33-40.

Shelton, L.R., 1994, Field guide for collecting and processing stream-water samples for the National Water-Quality Assessment Program: U.S.Geological Survey Open-File Report 94-455.

Stark, J.R., Andrews, W.J., Fallon, J.D., Fong, A.L., Goldstein, R.M., Hanson, P.E., and S.E. Kroening, 1996. Water-quality Assessment of Part of the Upper Mississippi River Basin, Minnesota and Wisconsin—Environmental Setting and Study Design. U.S. Geological Survey Water Resources Investigations Report 96-4098, 62 p.

Stevenson, R.J., Bothwell, M.L., and Lowe, R.L.,1996, Algal Ecology, Freshwater benthic Ecosystems, Academic Press, San Diego, California, 753 p.

Steward, Steven, Gemill, Eldon, and Pentz, Nancy, 2006, An evaluation of the effectiveness of urban riparian forest buffers: Water Environment Research Foundation: Alexandria, Virginia, variously paged.

Tomer, M.D., Meek, D.W., Jaynes, D.B., and Hatfield, J.L., 2003, Evaluation of nitrate nitrogen fluxes from a tile-drained watershed in central Iowa: Journal of Environmental Quality, vol. 32, pages 642-653.

Tornes, L.H., 1986, Suspended sediment in Minnesota streams: U.S. Geological Survey Water-Resources Investigations Report 85-4312, 33 p.

U.S. Department of Agriculture, 2004, The Conservation Reserve Program—economic implications for rural America: Agricultural Economic Report Number 834, 106 p.

U.S. Environmental Protection Agency, 2008, website: Biological indicators of watershed health, Accessed August, 2008 at http://www.epa.gov/bioindicators/html/invertebrate.html

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps, A1-A9, available online at *http://pubs.water.usgs.gov/twri9A4/.*

Wilde, F.D., and Radke, D.B., eds., 1998, Field measurements, in National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water Resources Investigations, book 9, chap. A6, p. 3-20.

Wilson, B., Burt, E., Oduro, P., Headrick, M., AbuLaban, A., Brown, J., Brooks, E., 1997, Minnesota River surface tile inlet research—modeling component: St. Paul, Minn., Final report to the Legislative Commission on Minnesota Resources, ___ p.

Winterstein, T.A., Payne, G.A., Miller, R.A., and Stark, J.R., 1993, Selected basin characteristics and water-quality data for the Minnesota River basin: U.S. Geological Survey Open-File Report 93-164, 100 p.

ZumBerge, J.R., Perry, J.A., and Lee, K.E., 2003, Influence of local riparian cover and watershed runoff potential on invertebrate communities in agricultural streams in the Minnesota River basin: U.S. Geological Survey Water Resources Investigations Report 03—4068, 13 p.

Appendix 1. Algal species composition, density, and biovolume for samples collected from Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River.

[Episammic, collected from sandy bed substrate; water column, collected from the water column; cm2, centimeter squared; mL, milliliter].

Collection Date	Sample Type	Algae Group	Phylum	Class	Family	Genus	Species	Quantity	Density (number of algal cells per cm^2)	Biovolume (volume of algal cells per cm2)
					Chetomba Creek near Renville, Minnesota					
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	exiguum	4	24846.90101	1685396.354
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	pediculus	62	385126.9657	35949825.29
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	copulata	12	74540.70304	131450589.7
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	33	204986.9334	229548646.7
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	pediculus	4	24846.90101	86243100.72
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Cyclotella	meneghiniana	26	161504.8566	132004120.9
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stauroneidaceae	Craticula	cuspidata	2	12423.45051	70448089.52
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Diploneidaceae	Diploneis	parma	6	37270.35152	41271290.76
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Fragilaria	vaucheriae	2	12423.45051	2658073.19
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	angustatum	17	105599.3293	31694212.58
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	truncatum	2	12423.45051	16630024.28
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	subclavatum	10	62117.25253	49069532.71
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	olivaceum	14	86964.15355	35153587.04
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Gomphonema	insigne	7	43482.07677	124002376.6
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Gomphonema	lagenula	15	93175.8788	21718339.7
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Gomphonema	11 SAVANNAH EAM	2	12423.45051	16175332.56
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Nitzschiaceae	Hantzschia	amphioxys	1	6211.725253	6897369.401
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Melosiraceae	Melosira	varians	1	6211.725253	30193645.01
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	gregaria	2	12423.45051	3163089.076
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	minima	6	37270.35152	1664171.168
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	tenelloides	2	12423.45051	1562482.325
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	subminuscula	11	68328.97779	4194916.066
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	capitatoradiata	9	55905.52728	30914091.97
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	acicularis	2	12423.45051	2255683.483
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	amphibia	142	882064.986	164918543.3
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	dissipata	13	80752.42829	19395884.71
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	onticola	10	62117.25253	5637671.212
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	frustulum	15	93175.8788	5018829.687
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	heufleriana	5	31058.62627	152794085.7
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	2	12423.45051	3232434.322

8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	inconspicua	22	136657.9556	3820977.567
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	intermedia	2	12423.45051	6707775.801
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	22	136657.9556	18291202.13
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	solita	2	12423.45051	2236267.311
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhoicospheniaceae	Rhoicosphenia	abbreviata	41	254680.7354	102556530.1
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	ulna	9	55905.52728	62893718.19
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	7 NAWQA MORALES	8	49693.80203	428410267.3
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Encyonema	minutum	4	24846.90101	5047095.55
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Encyonema	silesiacum	4	24846.90101	8063865.328
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Fallacia	pygmaea	3	18635.17576	20297447.17
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	lanceolatum	13	80752.42829	17057685.27
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	frequentissimum	13	80752.42829	7124527.816
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Sellaphora	pupula	7	43482.07677	19491851.33
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Sellaphora	seminulum	2	12423.45051	29421091.65
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	apiculata	2	12423.45051	4690438.963
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Geissleria	decussis	3	18635.17576	4831168.115
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	capitata	2	12423.45051	3891204.545
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	hungarica	2	12423.45051	2970071.375
8/22/2006	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Cladophoraceae	Cladophora	sp.	2	92515.05697	1.29046E+11
8/22/2006	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Desmidiaceae	Closterium	acerosum	1	13216.43671	1441767864
8/22/2006	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Oedogoniaceae	Oedogonium	sp.	1	66082.18355	1542096673
8/22/2006	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	quadricauda	2	105731.4937	3812026.935
8/22/2006	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Zygnemataceae	Spirogyra	sp.	2	92515.05697	7617440743
8/22/2006	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Homoeotrichaceae	Heteroleibleinia	sp.	7	3251243.431	35441074.19
8/22/2006	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	sp.	2	1546323.095	137218360.1
8/22/2006	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	chalybeum	3	1784218.956	44605473.89
8/22/2006	Episammic	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Phacus	sp.	1	13216.43671	19824655.06
8/22/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Zygnemataceae	Spirogyra	sp.	1		7296270.583
8/22/2006	Water Column	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	chalybeum	4		85512.88937
8/22/2006	Water Column	Blue-Green Algae	Cyanophyta	Myxophyceae	Pseudanabaenaceae	Pseudanabaena	sp.	1		3322.869717
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Euglena	sp.	66		962886.0313
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Trachelomonas	scabra	3		57209.4522
				West Fork Beaver Creek at 320 St near Bechyn, Minnesota						
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	montana	4	17900.47513	3860023.491
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	pediculus	15	67126.79671	6265976.754
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	copulata	18	80552.15606	142051630.6
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pinnulariaceae	Caloneis	amphisbaena	2	8950.231571	72676671.33

8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	13	58176.55316	65147318.55
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	pediculus	3	13425.35934	46599156.06
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Cyclotella	meneghiniana	67	299833.0213	245065041.6
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stauroneidaceae	Craticula	cuspidata	6	26850.71869	152258974.5
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stauroneidaceae	Craticula	halophila	2	8950.231571	67135687.01
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Cymatopleura	solea	1	4475.115785	91682884.02
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Diploneidaceae	Diploneis	parma	12	53701.43737	59466239.14
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Epithemia	adnata	17	76077.02828	92391621.04
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Epithemia	sorex	2	8950.231571	15893569.61
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	truncatum	1	4475.115785	5990387.623
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	subclavatum	2	8950.231571	7070236.736
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	olivaceum	6	26850.71869	10853886.78
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Gomphonema	insigne	4	17900.47513	51048653.21
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Gomphonema	lagenula	6	26850.71869	6258626.559
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Nitzschiaceae	Hantzschia	amphioxys	1	4475.115785	4969074.681
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Melosiraceae	Melosira	varians	2	8950.231571	43504840.24
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Meridion	circulare	2	8950.231571	2385182.197
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	gregaria	4	17900.47513	4557574.186
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	minima	20	89502.38763	3996401.613
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	tripunctata	2	8950.231571	8071769.818
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	veneta	20	89502.38763	15056104.34
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenella	2	8950.231571	2015493.117
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	subminuscula	2	8950.231571	549480.9292
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	erifuga	9	40276.07803	16578480.5
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	recens	13	58176.55316	27621685.32
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	capitatoradiata	17	76077.02828	42068331.41
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	trivialis	53	237181.3404	172501831.4
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	rostellata	2	8950.231571	6589092.05
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	acicularis	2	8950.231571	1625062.982
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	amphibia	33	147678.9528	27611341.74
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	capitellata	4	17900.47513	6460966.13
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	fonticola	7	31325.83447	2843087.033
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	frustulum	6	26850.71869	1446288.308
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	gracilis	3	13425.35934	4572857.747
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	heufleriana	14	62651.66894	308217253.2
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	4	17900.47513	4657491.102
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	subtilis	3	13425.35934	23349815.72
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	umbonata	2	8950.231571	7460689.281
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	inconspicua	11	49226.3096	1376375.228
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	intermedia	74	331158.8558	178802125.7
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	solita	6	26850.71869	4833229.258
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pleurosigmataceae	Pleurosigma	salinarum	2	8950.231571	24667218.89

8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Reimeria	sinuata	7	31325.83447	5194150.413
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhoicospheniaceae	Rhoicosphenia	abbreviata	3	13425.35934	5406212.87
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Rhopalodia	gibba	3	13425.35934	93975980.94
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	angusta	6	26850.71869	29447003.13
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	brebissonii	12	53701.43737	75286029.55
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	ulna	8	35800.95026	40276069.04
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	7 NAWQA MORALES	17	76077.02828	655860060.8
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Encyonema	silesiacum	3	13425.35934	4357094.258
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Fallacia	lenzii	2	8950.231571	67135687.01
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	lanceolatum	4	17900.47513	3781194.911
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	frequentissimum	15	67126.79671	5922382.032
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	apiculata	2	8950.231571	3379134.876
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	scalaris	2	8950.231571	104843012.6
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Diatomaceae	Fragilariforma	virescens	6	26850.71869	23011065.91
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Placoneis	abiskoensis	3	13425.35934	100703620.4
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	capitata	4	17900.47513	5606687.943
8/22/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	hungarica	2	8950.231571	2139729.745
8/22/2006	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Zygnemataceae	Spirogyra	sp.	1	35960.78395	2960914146
8/22/2006	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Oscillatoriaceae	Oscillatoria	sp.	1	503450.9754	15061210.45
8/22/2006	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	sp.	1	779150.319	69140614.52
8/22/2006	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Pseudanabaenaceae	Pseudanabaena	sp.	1	143843.1358	642123.9999
8/22/2006	Episammic	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Euglena	sp.	1	11986.92798	9867442.033
8/22/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Oocystaceae	Ankistrodesmus	falcatus	4		12259.75707
8/22/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Chlamydomonadaceae	Chlamydomonas	sp.	3		41267.06794
8/22/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	ecornis	4		20399.39008
8/22/2006	Water Column	Blue-Green Algae	Cyanophyta	Myxophyceae	Pseudanabaenaceae	Pseudanabaena	sp.	1		9867.916128
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Euglena	sp.	13		563230.8558
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Phacus	sp.	1		78947.36842
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Phacus	longicauda	1		1967658.385
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Phacus	longicauda	1		78947.36842
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Trachelomonas	volvocina	1		77355.55557
8/22/2006	Water Column	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Trachelomonas	scabra	3		169894.7368
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	minutissimum	5	30874.28159	1226421.725
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	affine	1	6174.85632	243783.9949

7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	exiguum	4	24699.42527	1675392.89
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	deflexum	3	18524.56895	1584574.622
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	lanceolatum	19	117322.27	24782491.37
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	frequentissimum	22	135846.839	11985331.01
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	dubium	2	12349.71263	3235624.71
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	6	37049.1379	41488397.95
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	22	135846.839	99624411.77
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	3	18524.56895	14096044.71
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	pediculus	7	43223.99422	150029626.8
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Tabularia	tabulata	21	129671.9827	73565033.64
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Cyclotella	meneghiniana	34	209945.1148	171596204
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Geissleria	decussis	15	92622.84476	24012466.53
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	capitata	11	67923.41949	21274598.27
7/31/2007	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Cladophoraceae	Cladophora	glomerata	1	25728.56799	24707199293
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Fragilaria	vaucheriae	7	43223.99422	9248037.818
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	gracile	2	12349.71263	12962161.67
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	parvulum	26	160546.2643	39308800.02
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	subclavatum	8	49398.85054	39022629.19
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	olivaceum	9	55573.70686	22464602.5
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	minutum	19	117322.27	20565270.45
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Melosiraceae	Melosira	varians	14	86447.98844	422333540.6
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	minima	7	43223.99422	1824563.597
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	tripunctata	2	12349.71263	11228061.53
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	veneta	16	98797.70108	16619763.29
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenella	2	12349.71263	2806738.501
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	capitatoradiata	4	24699.42527	13658046.74
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	reichardtiana	2	12349.71263	1639947.374
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenelloides	3	18524.56895	2213241.742
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	trivialis	16	98797.70108	71855502.39
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	amphibia	62	382841.0917	72767862.14
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	dissipata	4	24699.42527	5957045.727
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	fonticola	4	24699.42527	2241683.802
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	frustulum	6	37049.1379	2113286.849
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	16	98797.70108	25863161.82
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	inconspicua	9	55573.70686	1619554.116
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	pusilla	8	49398.85054	6113208.244
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	2	12349.71263	1652966.992
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	elegantula	2	12349.71263	144664533.8
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	lacuum	2	12349.71263	433026.6691
7/31/2007	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	acuminatus	1	51457.13598	3017648.307
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Reimeria	sinuata	6	37049.1379	6198154.605
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhoicospheniaceae	Rhoicosphenia	abbreviata	65	401365.6606	168875451.9

7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Simonsenia	delognei	8	49398.85054	2581082.645
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Stephanodiscus	parvus	1	6174.85632	3087428.159
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	angusta	6	37049.1379	40631541.1
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	minuta	8	49398.85054	41631808.79
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	ulna	24	148196.5516	869193376.6
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	ulna	5	30874.28159	266167181.6
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	ovalis	2	12349.71263	97703426.11
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	montana	8	49398.85054	10652271.63
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	pediculus	35	216119.9711	21197100.82
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	copulata	3	18524.56895	32667595.19
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Pseudostaurosira	brevistriata	2	12349.71263	1761766.674
7/31/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Oscillatoriaceae	Oscillatoria	limosa	3	463114.2238	288301893.8
7/31/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Oscillatoriaceae	Oscillatoria	sp B UL 1996 NAWQA	5	2791549.627	69788740.67
7/31/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	sp.	1	283014.2479	26382127.9
7/31/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	autumnale	1	244421.3959	15243671.91
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	minutissimum	21	60640.74796	2408837.612
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	exiguum	3	8662.96399	587619.6765
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pinnulariaceae	Caloneis	bacillum	2	5775.30933	2740130.955
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	lanceolatum	8	23101.23732	4879774.439
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	frequentissimum	10	28876.54665	2547685.118
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	calcar	4	11550.61866	3026262.089
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	13	37539.51064	42037527.58
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	56	161708.6612	118590394.7
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	38	109730.8773	83498372.17
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	pediculus	8	23101.23732	80183936.66
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	neodiminuta	6	17325.92799	10713154.05
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Sellaphora	pupula	2	5775.30933	2588916.612
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Staurosira	construens	20	57753.0933	11570159.79
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Cyclotella	meneghiniana	17	49090.1293	40123247.7
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stauroneidaceae	Craticula	halophila	2	5775.30933	43320595.28
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stauroneidaceae	Craticula	ambigua	4	11550.61866	86641190.57
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	capitata	1	2887.65466	904455.2437
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Diatoma	vulgaris	3	8662.96399	26860737.74
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Fragilaria	capucina	9	25988.89198	8959943.272
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	acuminatum	2	5775.30933	7778447.188
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	parvulum	18	51977.78397	12726451.94
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	subclavatum	3	8662.96399	6843309.673
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	olivaceum	23	66416.05729	26847414.2
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	sarcophagus	4	11550.61866	5712317.181
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	micropus	4	11550.61866	3406177.317

7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	minutum	12	34651.85598	6074079.454
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Melosiraceae	Melosira	varians	11	31764.20131	155181026.7
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Meridion	circulare	1	2887.65466	2198767.859
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	minima	13	37539.51064	1584611.182
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	tripunctata	6	17325.92799	15752316.78
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	veneta	4	11550.61866	1943046.709
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenella	2	5775.30933	1312563.582
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	capitatoradiata	19	54865.43863	30338953.92
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	trivialis	20	57753.0933	42003786.41
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	antonii	2	5775.30933	864573.0414
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	amphibia	22	63528.40263	12075051.88
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	frustulum	4	11550.61866	658848.5425
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	34	98180.25861	25701528.36
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	inconspicua	7	20213.58265	589073.3739
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	pusilla	4	11550.61866	1429412.556
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	7	20213.58265	2705519.223
7/30/2007	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	quadricauda	1	23815.70858	858647.877
7/30/2007	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	spinosus	2	47631.41715	767722.8959
7/30/2007	Episammic	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	quadricuada	2	47631.41715	4048670.458
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Reimeria	sinuata	10	28876.54665	4830916.742
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhoicospheniaceae	Rhoicosphenia	abbreviata	14	40427.16531	17009815.44
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	ulna	38	109730.8773	643586849.3
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	pediculus	57	164596.3159	16143647.83
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	copulata	7	20213.58265	35646126.89
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Pseudostaurosira	brevistriata	15	43314.81997	6179140.241
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Pseudostaurosira	pseudoconstruens	4	11550.61866	1692965.128
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Pseudostaurosira	neoelliptica	2	5775.30933	4949440.096
7/30/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Pseudostaurosira	subsalina	4	11550.61866	9898880.192
7/30/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Merismopediaceae	Merismopedia	elegans	1	47631.41715	1190785.429
7/30/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	tenue	3	53585.3443	1339633.607
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Aulacoseiraceae	Aulacoseira	italica	1	5277.80072	3834204.561
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	minutissimum	7	36944.64799	1467555.408
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pinnulariaceae	Caloneis	bacillum	2	10555.61218	5008174.977
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pinnulariaceae	Caloneis	schumanniana	8	42222.45944	34245584.33
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	lanceolatum	2	10555.61218	2229707.69
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	delicatulum	2	10555.61218	2787437.034
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	frequentissimum	19	100278.3425	8847236.618
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	16	84444.91889	61928385.19
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	7	36944.64799	28112579.1
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Sellaphora	pupula	2	10555.61218	4731798.447
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Staurosirella	pinnata	2	10555.61218	1123819.971

7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	calida	2	10555.61218	11425869.47
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	hungarica	2	10555.61218	123648441
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	littoralis	2	10555.61218	123648441
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	compressa	2	10555.61218	123648441
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Cyclotella	meneghiniana	6	31666.84727	25882530.25
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	capitata	24	126667.3891	39674059.93
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	hungarica	4	21111.22435	5047055.414
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Diploneidaceae	Diploneis	ovalis	5	26389.03581	419699479.8
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Diploneidaceae	Diploneis	puella	18	95000.5418	29413355.24
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Epithemia	adnata	10	52778.07162	64096241.69
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Epithemia	turgida	10	52778.07162	676076520.1
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	parvulum	7	36944.64799	9045677.807
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	olivaceum	4	21111.22435	8533806.547
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	pumilum	2	10555.61218	2356391.227
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	sarcophagus	6	31666.84727	15660726.15
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	micropus	4	21111.22435	6225517.062
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	minutum	2	10555.61218	1850279.739
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	pygmaeum	1	5277.80072	6871696.539
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pleurosigmataceae	Gyrosigma	acuminatum	12	63333.69453	436693868.1
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Melosiraceae	Melosira	varians	1	5277.80072	25784200.48
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	gregaria	2	10555.61218	2669208.642
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	veneta	8	42222.45944	7102668.115
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenella	1	5277.80072	1199494.023
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	libonensis	6	31666.84727	8164040.98
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	erifuga	15	79167.11817	32586850.28
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	reichardtiana	2	10555.61218	1401704.557
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenelloides	4	21111.22435	2522285.031
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	trivialis	52	274446.0025	199604395.4
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	acicularis	25	131945.1898	23956837.52
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	amphibia	19	100278.3425	19060233.51
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	dissipata	5	26389.03581	6364548.62
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	fonticola	4	21111.22435	1916023.922
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	frustulum	8	42222.45944	2408373.671
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	linearis	8	42222.45944	115273211.2
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	81	427502.4381	111911154
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	angustata	2	10555.61218	55518583.58
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	inconspicua	16	84444.91889	2460932.044
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	pusilla	11	58055.88308	7184533.631
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	liebethruthii	10	52778.07162	4114824.132
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	lancetulla	2	10555.61218	791670.9133
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	3	15833.42363	185472724.4
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	29	153056.4249	20486081.4

7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	ambigua	1	5277.80072	61824157.65
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	lacuum	2	10555.61218	370118.8616
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	solita	5	26389.03581	4750124.623
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Rhopalodia	gibba	4	21111.22435	163048507.4
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Simonsenia	delognei	5	26389.03581	1378823.224
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	angusta	2	10555.61218	11576269.09
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	gracilis	2	10555.61218	11292763354
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Surirella	minuta	8	42222.45944	35583770.46
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	ulna	20	105556.154	619101516.9
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	pediculus	30	158334.2363	15529461.5
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	copulata	12	63333.69453	111687321.9
7/31/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Merismopediaceae	Merismopedia	elegans	3	214690.4899	5367262.249
7/31/2007	Episammic	Blue-Green Algae	Cyanophyta	Myxophyceae	Phormidiaceae	Phormidium	sp.	1	64407.14698	6003929.493
7/31/2007	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Psammodictyon	constrictum	4	21111.22435	26747921.26
7/31/2007	Episammic	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Trachelomonas	sp.	1	42938.09799	103793448.9
South Branch Rush River at Co Rd 63 near Norseland, Minnesota										
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthidiaceae	Achnanthidium	minutissimum	2	9153.238235	362210.4917
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	pediculus	14	64072.74288	5980894.919
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Catenulaceae	Amphora	copulata	10	45766.2476	80707586.44
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pinnulariaceae	Caloneis	bacillum	2	9153.238235	4286403.125
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Pinnulariaceae	Caloneis	schumanniana	2	9153.238235	68658440
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	placentula	38	173911.7522	194750010.2
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Cocconeis	pediculus	2	9153.238235	31770708.41
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Stephanodiscaceae	Cyclotella	meneghiniana	255	1167039.474	953866175.1
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Surirellaceae	Cymatopleura	solea	2	9153.238235	187524819.4
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Diatoma	vulgaris	1	4576.619118	14190450.98
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhopalodiaceae	Epithemia	adnata	5	22883.1144	27790360.39
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	angustatum	12	54919.50464	16483347.63
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	olivaceum	15	68649.3808	27750192.29
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Gomphonema	kobayasii	14	64072.74288	8492317.28
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Gomphonema	lagenula	10	45766.2476	10667641.94
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Nitzschiaceae	Hantzschia	amphioxys	2	9153.238235	10163563.7
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Melosiraceae	Melosira	varians	4	18306.49528	88983301.29
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Meridion	circulare	3	13729.87616	3658928.367
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptocephala	2	9153.238235	3011185.98
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	minima	4	18306.49528	817409.5596
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	kotschyi	5	22883.1144	5356684.649
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	veneta	4	18306.49528	3079521.232
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	cryptotenella	4	18306.49528	4122420.179
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	erifuga	4	18306.49528	7535338.34
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	capitatoradiata	9	41189.62848	22776638.11

8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Navicula	trivialis	2	9153.238235	6657144.091
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	amphibia	22	100685.7522	18825084.15
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	capitellata	8	36612.99056	13215028.66
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	dissipata	2	9153.238235	2198511.64
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	gracilis	2	9153.238235	3117715.906
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	heufleriana	2	9153.238235	45029701.43
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	4	18306.49528	4763132.725
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	inconspicua	14	64072.74288	1791483.798
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	intermedia	16	73225.99992	39536809.04
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	palea	4	18306.49528	2450262.072
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	solita	2	9153.238235	1647616.936
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Nitzschia	levidensis	4	18306.49528	214442285.7
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Gomphonemataceae	Reimeria	sinuata	1	4576.619118	758851.232
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Rhoicospheniaceae	Rhoicosphenia	abbreviata	2	9153.238235	3685886.767
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Fragilariaceae	Synedra	7 NAWQA MORALES	8	36612.99056	315640591.6
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Thalassiosiraceae	Thalassiosira	weissflogii	32	146451.9998	153891255.3
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Encyonema	minutum	4	18306.49528	3718557.53
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Encyonema	silesiacum	15	68649.3808	22279613.92
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Achnanthaceae	Planothidium	frequentissimum	3	13729.87616	1211342.949
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Sellaphoraceae	Sellaphora	pupula	6	27459.75232	12309472.08
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Bacillariaceae	Tryblionella	apiculata	4	18306.49528	6911566.049
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Diatomaceae	Fragilariforma	virescens	7	32036.37144	27455170.32
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Cymbellaceae	Placoneis	abiskoensis	1	4576.619118	34329220
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Geissleria	decussis	5	22883.1144	5932445.932
8/21/2006	Episammic	Diatoms	Chrysophyta	Bacillariophyceae	Naviculaceae	Hippodonta	capitata	5	22883.1144	7167322.692
8/21/2006	Episammic	Euglenoids	Euglenophyta	Euglenophyceae	Euglenaceae	Euglena	sp.	1	18808.04954	15482477.14
8/21/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Oocystaceae	Ankistrodesmus	falcatus	13		12852.97112
8/21/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	quadricauda	18		39175.65553
8/21/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	ecornis	8		11280.76871
8/21/2006	Water Column	Green Algae	Chlorophyta	Chlorophyceae	Scenedesmaceae	Scenedesmus	acuminatus	5		19913.04677
8/21/2006	Water Column	Cryptophytes	Cryptophyta	Cryptophyceae	Cryptomonadaceae	Cryptomonas	sp.	9		5770.48274
8/21/2006	Water Column	Unknown Phyla	(Undetermined)	(Undetermined)	(Undetermined)	Unknown alga	flagellate	2		40317.3719

Appendix 2. Invertebrate species composition and abundance for samples collected from Chetomba Creek, West Fork Beaver Creek, and South Branch Rush River, 2006-2007.

[Episammic, collected from sandy bed substrate; water collumn, collected from the water collumn; cm2, centimeter squared; mL, milliliter].

Collection Date	Phylum	Class	Order	SubOrder	Family	SubFamily	Tribe	Genus	Species	Abundance
					Chetomba Creek near Renville, Minnesota					
8/21/2006	Annelida	Hirudinea	Rhynchobdellae		Glossiphoniidae					5
8/21/2006	Annelida	Hirudinea	Rhynchobdellida		Glossiphoniidae	Glossiphoniinae		Placobdella	Placobdella papillifera	2
8/21/2006	Annelida	Oligochaeta								99
8/21/2006	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia		1
8/21/2006	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Stenelmis		2
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae					4
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Chironomus		28
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Cryptochironomus		3
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Dicrotendipes		30
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Polypedilum		1
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Tanytarsini	Paratanytarsus		1
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Orthocladiinae		Cricotopus		10
8/21/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Pentaneurini	Ablabesmyia		19
8/21/2006	Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae					2
8/21/2006	Arthropoda	Insecta	Trichoptera	Spicipalpia	Hydroptilidae					11
8/21/2006	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Cheumatopsyche		2
8/21/2006	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae				1
8/21/2006	Mollusca	Bivalvia	Veneroida		Sphaeriidae	Sphaeriinae		Sphaerium		15
8/21/2006	Mollusca	Gastropoda	Basommatophora		Ancylidae			Ferrissia		5
8/21/2006	Mollusca	Gastropoda	Basommatophora		Physidae			Physella		133
7/31/2007	Annelida	Hirudinea	Arhynchobdellae		Erpobdellidae					28
7/31/2007	Annelida	Hirudinea	Rhynchobdellae		Glossiphoniidae					1
7/31/2007	Annelida	Oligochaeta	Tubificida	Tubificina	Tubificidae					68
7/31/2007	Arthropoda	Malacostraca	Amphipoda	Gammaridea	Hyalellidae			Hyalella	Hyalella azteca	8
7/31/2007	Arthropoda	Malacostraca	Decapoda	Pleocyemata	Cambaridae					6
7/31/2007	Arthropoda	Malacostraca	Decapoda	Pleocyemata	Cambaridae	Cambarinae		Orconectes		2
7/31/2007	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia		4

7/31/2007	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Stenelmis		24
7/31/2007	Arthropoda	Insecta	Collembola							4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Ceratopogonidae					4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Ceratopogonidae	Ceratopogoninae				4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Ceratopogonidae	Dasyheleinae		Dasyhelea		4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Chironomus		80
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Cryptochironomus		4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Dicrotendipes		4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Microtendipes		20
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Paratendipes		12
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Polypedilum		12
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Stictochironomus		72
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Tanytarsini			4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Tanytarsini	Cladotanytarsus		4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Tanytarsini	Micropsectra		4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Orthocladiinae				4
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Pentaneurini			24
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Limoniinae		Limonia		4
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Ephemeridae			Hexagenia		1
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Ephemeridae			Hexagenia	Hexagenia bilineata	1
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Potamanthidae			Anthopotamus		4
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Caenidae			Caenis		648
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae			Baetis	Baetis intercalaris	4
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Setisura	Heptageniidae					12
7/31/2007	Arthropoda	Insecta	Odonata	Anisoptera						8
7/31/2007	Arthropoda	Insecta	Trichoptera	Spicipalpia	Hydroptilidae					4
7/31/2007	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Cheumatopsyche		56
7/31/2007	Mollusca	Bivalvia	Veneroida		Sphaeriidae	Sphaeriinae		Sphaerium		36
7/31/2007	Mollusca	Gastropoda	Basommatophora		Lymnaeidae	Lymnaeinae		Stagnicola		2
7/31/2007	Mollusca	Gastropoda	Basommatophora		Physidae	Physinae		Physa		132
7/31/2007	Nematoda									8

West Fork Beaver Creek near Bechyn, Minnesota

8/22/2006	Annelida	Oligochaeta								70
8/22/2006	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia		16
8/22/2006	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Stenelmis		3
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae					2
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Dicrotendipes		1

8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Polypedilum		1
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Stictochironomus		2
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Orthocladiinae		Cricotopus		6
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Pentaneurini	Ablabesmyia		5
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Procladiini	Procladius		2
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Ephemeridae			Hexagenia		46
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Caenidae			Caenis		6
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Leptohyphidae			Tricorythodes		1
8/22/2006	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Cheumatopsyche		4
7/31/2007	Annelida	Oligochaeta	Tubificida	Tubificina	Tubificidae					3
7/31/2007	Arthropoda	Insecta	Coleoptera	Adephaga	Carabidae					1
7/31/2007	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia		1
7/31/2007	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia		3
7/31/2007	Arthropoda	Insecta	Collembola							1
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Cryptochironomus		2
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Glyptotendipes		1
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Polypedilum		1
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Stictochironomus		9
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Orthocladiinae				1
7/31/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Pentaneurini			1
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Ephemeridae			Hexagenia		34
7/31/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Caenidae			Caenis		1
7/31/2007	Arthropoda	Insecta	Hemiptera	Heteroptera	Corixidae	Corixinae	Corixini	Palmacorixa		1
7/31/2007	Arthropoda	Insecta	Odonata	Anisoptera	Gomphidae					1
7/31/2007	Arthropoda	Insecta	Odonata	Anisoptera	Gomphidae			Gomphus		1
7/31/2007	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Ceratopsyche		1
7/31/2007	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Cheumatopsyche		1
7/31/2007	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Cheumatopsyche		10
7/31/2007	Arthropoda	Malacostraca	Amphipoda	Gammaridea	Hyalellidae			Hyalella	Hyalella azteca	2
7/31/2007	Arthropoda	Malacostraca	Decapoda	Pleocyemata	Cambaridae	Cambarinae		Orconectes		1
7/31/2007	Mollusca	Bivalvia	Veneroida		Sphaeriidae	Sphaeriinae		Musculium		3
7/31/2007	Mollusca	Gastropoda	Basommatophora		Physidae	Physinae		Physa		1
7/31/2007	Nematoda									2
7/31/2007	Nematomorpha									1

South Branch Rush River near Norseland

8/22/2006	Annelida	Oligochaeta								43
8/22/2006	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia		87

8/22/2006	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Stenelmis	23
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Ceratopogonidae				1
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Chironomus	1
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Cryptochironomus	5
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Cryptotendipes	20
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Dicrotendipes	40
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Polypedilum	11
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Stictochironomus	4
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Tanytarsini	Paratanytarsus	100
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Orthocladiinae		Cricotopus	1
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae			3
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Pentaneurini	Ablabesmyia	5
8/22/2006	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Procladiini	Procladius	3
8/22/2006	Arthropoda	Insecta	Diptera	Brachycera	Empididae	Hemerodromiinae	Hemerodromiini	Hemerodromia	4
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Carapacea	Baetiscidae			Baetisca	1
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Ephemeridae			Hexagenia	48
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Caenidae			Caenis	489
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Leptohyphidae			Tricorythodes	82
8/22/2006	Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae			Baetis	2
8/22/2006	Arthropoda	Insecta	Trichoptera	Spicipalpia	Hydroptilidae				30
8/22/2006	Arthropoda	Insecta	Trichoptera	Annulipalpia	Hydropsychidae	Hydropsychinae		Cheumatopsyche	6
8/22/2006	Mollusca	Gastropoda	Basommatophora		Ancylidae			Ferrissia	4
8/22/2006	Mollusca	Gastropoda	Basommatophora		Physidae			Physella	2
7/30/2007	Annelida	Hirudinea	Arhynchobdellae		Erpobdellidae				2
7/30/2007	Annelida	Oligochaeta	Tubificida	Tubificina	Tubificidae				96
7/30/2007	Arthropoda	Arachnida							8
7/30/2007	Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae	Laccophilinae	Laccophilini	Laccophilus	8
7/30/2007	Arthropoda	Insecta	Coleoptera	Polyphaga	Hydrophilidae				16
7/30/2007	Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			Dubiraphia	376
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Ceratopogonidae				8
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae			8
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini		8
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Chironomus	320
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Cryptochironomus	16
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Dicrotendipes	16
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Microtendipes	568
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Paratendipes	8

7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Polypedilum		8
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Chironomini	Stictochironomus		24
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Chironominae	Tanytarsini	Cladotanytarsus		8
7/30/2007	Arthropoda	Insecta	Diptera	Nematocera	Chironomidae	Tanypodinae	Pentaneurini			8
7/30/2007	Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Caenidae			Caenis		32
7/30/2007	Arthropoda	Insecta	Hemiptera	Heteroptera	Belostomatidae	Belostomatinae		Belostoma	Belostoma flumineum	1
7/30/2007	Arthropoda	Insecta	Odonata	Anisoptera	Gomphidae			Gomphus		2
7/30/2007	Arthropoda	Insecta	Trichoptera	Integripalpia	Leptoceridae	Leptocerinae		Nectopsyche	Nectopsyche diarina	80
7/30/2007	Arthropoda	Malacostraca	Amphipoda							8
7/30/2007	Mollusca	Gastropoda	Basommatophora		Lymnaeidae					24
7/30/2007	Mollusca	Gastropoda	Basommatophora		Physidae	Physinae		Physa		1464

Catostomidae	northern hog sucker	Hypentelium nigricans**											1	108	0.001	0	0
Centarchidae	orangespotted sunfish	Lepomis humilis											16	152	0.010	0	0
Cyprinidae	sand shiner	Notropis stramineus						6	18	0.004	6	11	129	344	0.080	14	34
Cyprinidae	spotfin shiner	Cyprinella spiloptera						0	0	0.000	3	4	7	11	0.004	15	4
Ictaluridae	stonecat	Noturus flavus											4	8	0.002	2	3
Catostomidae	white sucker	Catostomus commersoni*	42	1643	0.020	4	15	11	285	0.007	6	123	2	98	0.001	1	3
Cyprinidae	bigmouth shiner	Notropis dorsalis	38	38	0.042	98	39	28	52	0.021	66	74	14	11	0.020	57	22
Ictaluridae	black bullhead	Ameiurus melas*															
Cyprinidae	blacknose dace	Rhinichthys atratulus	78	64	0.087	39	31	1	1	0.001	6	3	26	22	0.038	14	7
Percidae	blackside darter	Percina maculata						1	1	0.001							
Cyprinidae	bluntnose minnow	Pimephales notatus						52	105	0.040	15	4	2	3	0.003	1	1
Cyprinidae	brassy minnow	Hybognathus hankinsoni	1	2	0.001			1	1	0.001							
Gasterosteidae	brook stickleback	Culaea inconstans	32	20	0.036	34	12						3	3	0.004		
Cyprinidae	central stoneroller	Campostoma anomalum	203	407	0.226	12	16	26	35	0.020	11	11	1	1	0.001		
Cyprinidae	common carp	Cyprinus carpio*															
Cyprinidae	common shiner	Luxilus cornutus						81	436	0.062	78	22					
Cyprinidae	creek chub	Semotilus atromaculatus*	143	780	0.159	37	18	19	83	0.015	13	13	176	294	0.256	16	29
Cyprinidae	fathead minnow	Pimephales promelas*	88	160	0.098	3	5						1	4	0.001		
Centarchidae	green sunfish	Lepomis cyanellus						1	12	0.001							
Cyprinidae	hornyhead chub	Nocomis biguttatus**						10	73	0.008	13	5					
Percidae	johnny darter	Etheostoma nigrum	20	11	0.022	46	15	24	22	0.018	28	16	5	5	0.007	1	1
Catostomidae	northern hog sucker	Hypentelium nigricans**															
Centarchidae	orangespotted sunfish	Lepomis humilis															

Cyprinidae	sand shiner	Notropis stramineus						7	15	0.005	8	15	1	1	0.001		
Cyprinidae	spotfin shiner	Cyprinella spiloptera						1	1	0.001			3	5	0.004		
Ictaluridae	stonecat	Noturus flavus						1	1	0.001							
Catostomidae	white sucker	Catostomus commersoni*	30	92	0.033			10	22	0.008			12	15	0.017	1	1

[1] trophic groups are from Gerking (1994) and Simon, (1989)
* classified as tolerant Bailey and others (1993)
** classified as intolerant Bailey and others (1993)