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EVALUATION OF WATERSHED QUALITY IN THE MINNESOTA RIVER BASIN

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PREFACE

Multiple stressors and responses continually define and shape watersheds. The purpose of this research is to develop procedures for defining watershed quality. This research focuses on assessing their susceptibility from agricultural activity. Section 101 in the Federal Clean Water Act requests that procedures be developed to protect fish, wildlife and water quality, and provide definitions for biological integrity. Past studies have generally relied on either chemical-specific, toxicological or biosurvey approaches to define healthy watersheds. Simultaneous physical, chemical and biological information is required if more holistic appraisals of watershed quality are to be achieved. This research project addresses the kinds of information necessary to establish baseline conditions in a river basin and on individual watershed quality. An important product of this research is to provide regulators with procedures to classify and formulate goals on present status of watershed resources and later remediation activities.

ABSTRACT

The Minnesota River has been noted for having water quality problems, particularly for pollutants associated with sediment transport. This research describes procedures and the results obtained to evaluate the baseline (or existing) watershed quality within the basin. Field work was conducted over three-years (1989-1992). Three kinds of procedures were employed: physical (or habitat related), chemical (surface and sediment pore water quality) and biological (toxicological and macroinvertebrate assessments). The basin was divided into four categories of stream conditions: mainstem, principal tributary, reservoir, and upper watershed locations. The study area extended from Lac Qui Parle to Fort Snelling on the river's mainstem, and several tributaries and upper watershed areas - most located near Mankato, Minnesota. Aquatic insects were the major macroinvertebrate component found at all sites. Habitat quality estimates were highest in the principal tributary locations. Significant associations were found between ammonia nitrogen and sediment toxicity. Positive associations were found with ammonia nitrogen and components of the macroinvertebrate community. Correlations were also obtained with habitat and the macroinvertebrate measurements. Lower quality watershed locations generally exhibited lower macroinvertebrate diversity and community integrity scores. Principal stressors affecting the macroinvertebrate community appeared to be elevated concentrations of ammonia and nitrite-nitrate nitrogen. More watershed studies are needed to increase the confidence in linking habitat and chemical stressors to biological quality.

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LIST OF SELECTED ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BOD	biological oxygen demand
C	Celsius
CCA	canonical correspondence analysis
DMW	dilute mineral water solution
drn ar	drainage area
EPT	Ephemeroptera/Plecoptera/Trichoptera
ERL-D	Environmental Research Laboratory - Duluth
ft	foot
ICI	index community integrity
i.e.	that is
in	inch
mg	milligram
μg/l	micrograms per liter
mg/l	milligrams per liter
mi^2	square miles
m	meters
mm	millimeters
NH_3-N	total ammonia nitrogen as N
NO_2+NO_3	nitrite plus nitrate nitrogen as N
NT	not toxic
$P < 0.01$	probability less than 1 % by chance alone
QHEI	qualitative habitat evaluation index
RPM	revolutions per minute
T-P	total phosphorus as P
U.S. EPA	United States Environmental Protection Agency
YCT	yeast-cerophyl-trout chow

SYMBOLS

<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
-	no information
%	percent
±	plus, minus
x G	times gravity

1. INTRODUCTION

1.1 BACKGROUND

The Minnesota River has long been known to have water quality problems associated with sediment transport. An early study by the Federal Water Pollution Control Administration (1966), predecessor to the U.S. Environmental Protection Agency, characterized the river as high in turbidity, bacteria coliform and nutrient levels from Mankato (upper limit of study at river mile 110) to the river's mouth at Fort Snelling near the Twin Cities of Minneapolis and St. Paul, Minnesota. Upstream from Chaska (river mile 30) benthic macroinvertebrate populations were depicted as sparse and largely found on a bottom composed of sand and gravel. Downstream from Chaska, the river bottom was classified as mainly organic sludge/sand and dominated by pollution-tolerant forms, especially sludgeworms. Subsequent studies by the Minnesota Pollution Control Agency (MPCA, 1982) and Mankato State University (King, 1985) characterized the river as high in alkalinity, turbidity, and suspended solids. Total phosphate and nitrate levels were also frequently found to be elevated. Water quality standards most often exceeded were coliform bacteria, turbidity, ammonia and dissolved oxygen (MPCA, 1982). The MPCA has recommended that the river's quality can be upgraded through reductions in nonpoint source loadings of sediments and nutrients.

Benthic macroinvertebrate surveys and ambient toxicity testing are useful in defining watershed quality. Macroinvertebrate surveys furnish "ground truth" information as to the living conditions of a waterbody. Factors making macroinvertebrates useful are their relative permanence and immobility in streams, occurrence in a wide variety of habitat conditions, and their sensitivity to pollutant gradients. An unimpacted stream usually has a diverse community of benthic forms with relatively larger proportional numbers of pollution-sensitive species. Impacted streams are usually characterized by low diversity and greater numbers of pollutant-tolerant species. Toxicity tests are useful in identifying problem watershed reaches, and assist in elucidating cause/effects and concentration gradients in waterways (Ankley et al., 1990). The biological surveys reveal the extent of the degradation, the toxicity test findings assist in verifying and quantifying the problem watershed areas.

2.1 SCOPE and PURPOSE

The purpose of this report is to present habitat, chemical, and benthic survey and toxicity test results for characterizing watershed quality in the Minnesota River basin. The field work was conducted in 1989-1992. During the same time period, determinations were made by others of land use practices and chemical analyses were performed on the watershed quality.

Our objective is to further consolidate this information into a format that describes problem reaches and supplies information defining watershed integrity. These findings have been described in a series of reports (Arthur et al., 1994; Proctor, 1994; and Zischke et al., 1994) to the Legislative Commission on Minnesota Resources and recently published by the Minnesota Pollution Control Agency. It was our hypothesis that the relative influences from these physical, chemical, and biological descriptors can be used to define watershed quality in the Minnesota River basin.

2. METHODS

2.1 BASIN DESCRIPTION

The Minnesota River is 335 miles long and begins at the terminus of Big Stone Lake in eastern South Dakota. Three dams, located at Big Stone, Marsh, and Lac Qui Parle Lakes, convert the uppermost 85 miles into headwater lakes. Downstream from the Granite Falls Dam the river flows unobstructed for 240 miles to its confluence with the Mississippi River at Fort Snelling. The drop in elevation between Big Stone Lake and Fort Snelling is 274 feet or an average gradient of 0.8 feet per mile. The Minnesota River basin covers 17,000 square miles. Mean annual flow measured at the mouth is 5,000 cubic feet per second (cfs). The middle and lower sections of the river are slow moving in velocity. The largest tributary entering of the Minnesota is the Blue Earth River which enters at Mankato with a mean annual flow of 1300 cfs. Other major tributaries entering from the southwest are the Lac Qui Parle, Yellow Medicine, Redwood and Cottonwood Rivers with combined mean annual flows of 600 cfs. Major northern tributaries to the Minnesota are the Pomme de Terre and Chippewa Rivers and Hawk Creek, combined mean annual flow of 450 cfs. The river greatly increases flow downstream, for example, at Lac Qui Parle dam mean annual flow is 600 cfs, while at river mile 39 (Jordan) the mean flow is 3400 cfs. The lower 22 miles of the river has been dredged to accommodate barge shipping (Waters, 1977).

The Minnesota River basin lies within three U.S. EPA ecoregions (Gallant et al., 1989). The uppermost sections of the river and headwater reservoirs lie in the Northern Glaciated Plains, the middle undammed portion in the Western Corn Belt Plains and downstream from Mankato the river is classified within the North Central Hardwood Forest ecoregion. Using U.S. Geological Survey mapping nomenclature, the river basin is in Accounting Unit 070200, Upper Mississippi River Region 7. Exceptionally high levels of nitrite-nitrate nitrogen levels are present in the Northern Glaciated Plains and Western Corn Belt ecoregions and have been associated with row crop fertilization of corn and soybeans (Fandrei et al., 1988).

Land use throughout the Minnesota River basin is principally farming. Most of the land is under cultivation (over 90 percent) and less than 3 percent is under forestation. Soil composition ranges from clay to silt loam in composition. Erosion from rainfall and wind is a common problem. The basin is flat to gently rolling in topography. The area near Mankato has the

greatest percentages of poorly drained wet soils and erosion problems. Open ditch and tile drainage systems are commonly found on much of the cultivated lands and contribute increased nutrient loads to the river (MPCA, 1982).

Population densities are greatest in the eastern portions of the basin. Human waste loadings (as 5-day BOD values) progressively increase in the river's downstream reaches (MPCA, 1982). Major population centers in the basin are New Ulm, Mankato Minneapolis, and St. Paul.

Koehler and Cooper (1994) have characterized 10 watersheds near Mankato in the Blue Earth, Watonwan and Le Sueur river subbasins. The vast majority of land use was found to be devoted to agriculture, crops being two-year rotations of corn and soybeans. This study estimated that approximately 200,000 tons of soil per year is being lost from 64,000 acres of cropland, and was primarily due to sheet and rill erosion. Approximately 19 percent of the erosion is delivered to the watershed outlets and contributed to further downstream water quality problems.

2.2 STUDY DESIGN

For this study, we divided the Minnesota River Basin into four categories of stream conditions - mainstem, principal tributary, reservoir and upper (first to second order) watershed locations. Fifty sampling locations were initially contained in studies previously reported to the Legislative Commission on Minnesota Resources. Fourteen of these sample sites are located on the river's mainstem, 10 near the mouth of principal tributaries, 4 are on reservoirs, and 22 are on upper watershed sites. To maximize the likelihood of finding watershed descriptors (or exposure and response indicators), 31 sites were selected for further analysis. The sites selected in each of the four watershed categories had relatively similar habitat characteristics.

Descriptions of the location of these 30 sites is given in Appendix A. Study emphasis during 1989-1990 was on a general baseline assessment of the river's mainstem and principal tributaries. Figure 1-1 shows location of the mainstem and tributary stations. Sampling efforts in 1991-1992 were focused on the low order streams, most of which were located south of Mankato (Figure 1-2). Ten sites were located along the river's mainstem, 8 sites near the mouths of principal tributaries, 3 sites near the terminus of reservoirs, and 9 were upper watershed

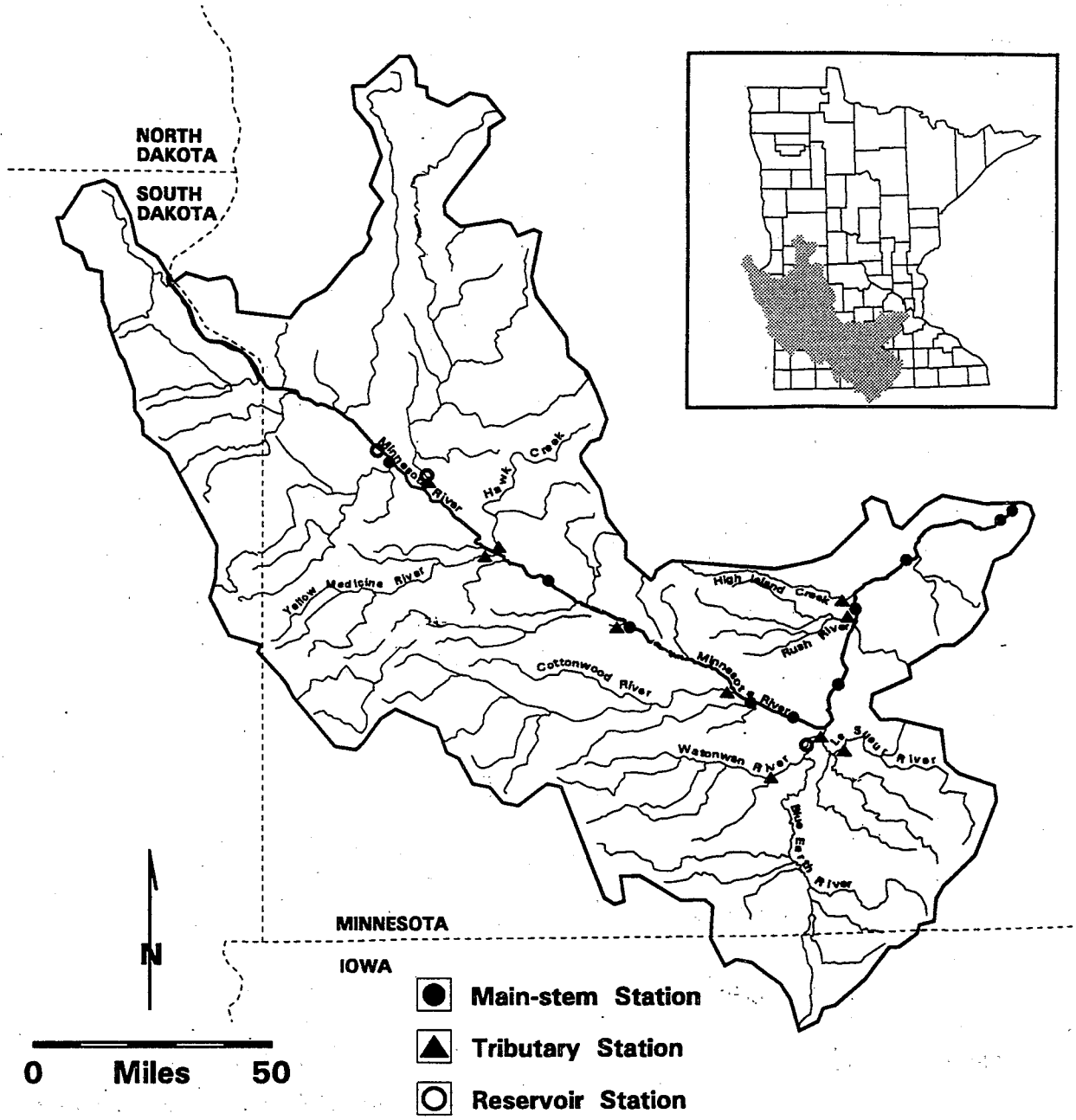


Figure 1-1. Location of Minnesota River mainstem and tributary sampling sites.

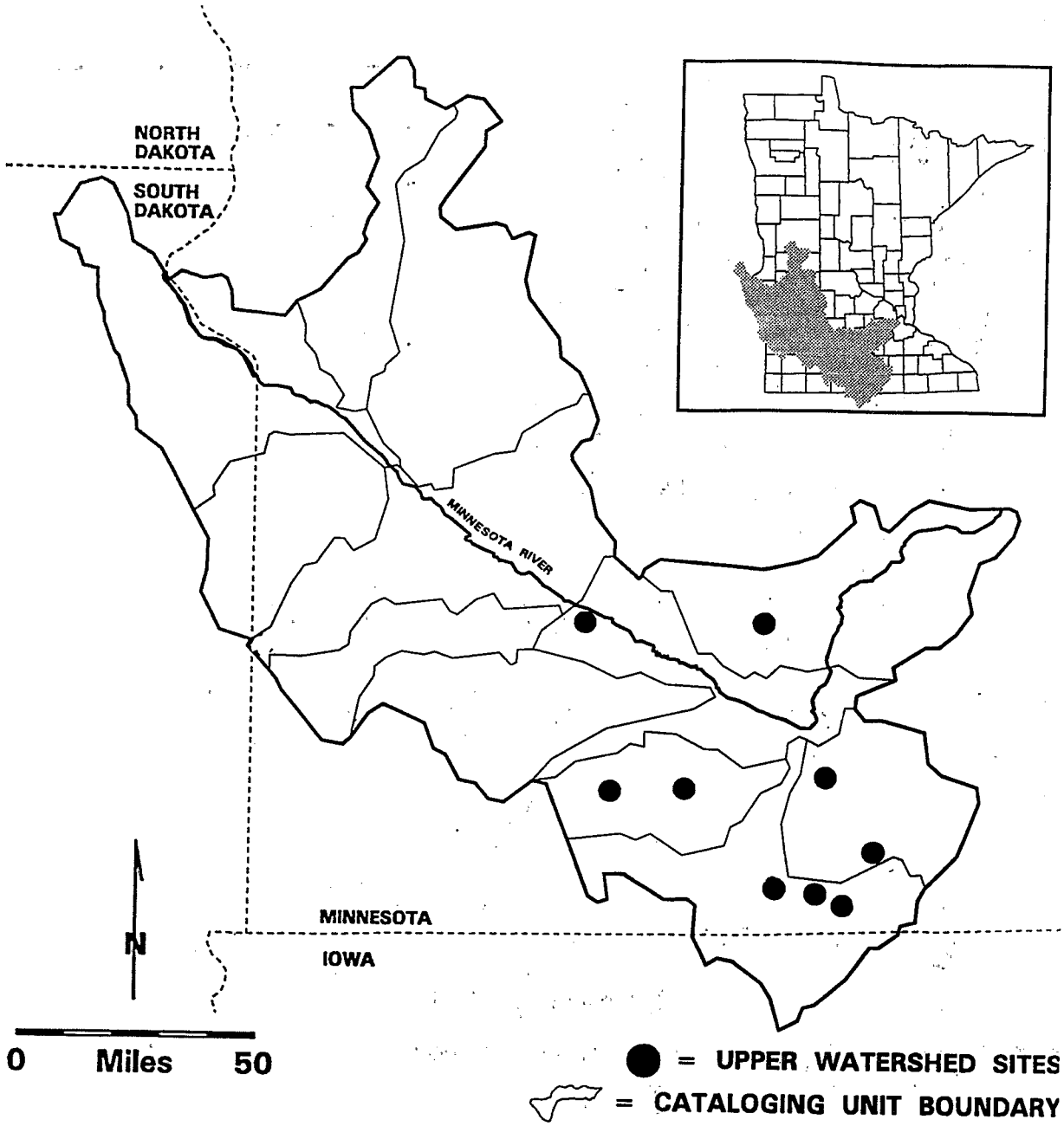


Figure 1-2. Location of Minnesota River Basin Upper Watershed sampling sites.

locations. Study reaches were positioned from 50 to 200 m upstream or downstream from road bridge crossings. Areas sampled at each station were generally two to four times the width of the stream segments. Because the Minnesota Basin is dominated by agricultural activities, it was anticipated that the low order tributaries would be autotrophic, mud-bottomed, with open canopies and affected by excessive inputs of sediment and nutrients. The higher order tributaries and the river's mainstem were found to be a mix of these characteristics. Using Ohio EPA nomenclature (1987), the upper watershed sites can be classified as headwater sites (drainage areas < 20 mi^2), about one-half of the principal tributary sites as wading sites (drainage areas between 20-500 mi^2), and the remaining principal tributaries and all of the mainstem locations as boating sites (> 500 mi^2, see Appendix A).

2.3 HABITAT

An appraisal of habitat quality was conducted once at each sampling location during the summer season. The habitat assessment technique, as described by the Ohio Environmental Protection Agency (1987, 1989), was used for this study. This procedure includes a calculation of a Qualitative Habitat Evaluation Index (QHEI), and provides an empirical evaluation of lotic quality. The seven metrics used for computation of the QHEI were: substrate type/quality, instream cover, channel morphology, riparian zone/bank erosion, pool/riffle-run, map gradient, and drainage area. The total QHEI score was determined by adding together the individual metric scores, the best attainable score being 100.

Substrate embeddedness (proportion of particles ≤ 2.4 mm. was determined at all mainstem and tributary locations, and at four of the upper watershed sites. Representative surficial substrate samples (from a depth of 4 to 6 inches) were collected with a scoop, and proportions of the finer particles separated by passing the sample through a 2.4 mm sieve screen. Percentages of the fine particles (< 2.4 mm) were determined by volume displacement using a large graduated cylinder.

2.4 SEDIMENT PORE WATER

Stream bottom samples were collected with a petite Ponar grab at three or more representative points at each monitoring site for sediment pore water analysis. All samples were kept cold (unfrozen, <4° C) in ice chests for transportation to the laboratory. Sediment pore water was prepared in a refrigerated

centrifuge (at 5° C) by spinning at 2500 X G for 20 minutes. The supernatant (pore water) was refrigerated. Samples were analyzed for anions and cations using ion chromatography and inductive coupled plasma/atomic emission spectrometry procedures. Nutrients (NH_3-N, NO_2+NO_3-N, total phosphorus, and total nitrogen) were determined with an automated ion analyzer and total organic carbon with a Dohrmann instrument using U.S. EPA (1983) procedures. All analyses were conducted using duplicates, spikes, and known standards.

2.5 TOXICITY TESTING

Two standardized procedures were used for the toxicity tests, with Ceriodaphnia dubia, a microcrustacean, and Selenastrum capricornutum, a green alga. Both organisms have been widely used by the U.S. EPA (Lewis et al., (1992)) to evaluate toxicity of ambient surface water/sediments and effluents.

Source of Ceriodaphnia was from the (Environmental Research Laboratory at Duluth, Minnesota (ERL-D) laboratory cultures. The animals of known parentage were ≤ 24 hours old when the tests were begun. Acute toxicity tests (48 hours in duration) were conducted only with the September 1989 surface water samples following procedures given in Lewis et al. (1992). All remaining toxicity tests were chronic life cycle tests. For the chronic tests, one animal was placed into each of ten, 30 ml cups containing 15 ml of test water. The same procedure was repeated for a set of 10 replicate controls containing either Lake Superior water or dilute mineral water solution (DMW). The daphnids were fed a yeast-cerophyll-trout chow (YCT) and algae daily, and test solutions were changed (renewed) on days 2 and 4 of the 7-day test period. Survival and young production during the 7-days were analyzed for significant differences ($P < 0.05$) from the controls using a pair-wise multiple range comparison procedure. Additional test details are given in Lewis et al. (1992).

The source for Selenastrum cells was from ERL-Duluth cultures. Dilution water consisted of stock culture medium containing 100 μg/l EDTA. Water samples were filtered through a 0.45 μ millipore filter and fortified with media mineral salts to a concentration equal to the synthetic dilution water. A dilution series was prepared with 30, 60 and 100 percent sediment pore water and a dilution control. Each test received a starting inoculum of 10,000 cells per ml; tests were cultured under continuous illumination of 400 ± 50 foot candles, at 24 ± 2 °C.

The test containers were continuously shaken at 100 RPM. Algal growth was determined at 48 hours and at the end of the 96-hour test with an electronic particle counter. Test results were expressed as percent of the control growth (i.e. test/control X 100 = percent stimulation or inhibition).

2.6 MACROINVERTEBRATE PROCEDURES

Characteristics of the macroinvertebrate communities were determined by using artificial substrate (Hester-Dendy samplers) and instream dip net and hand-picking sampling procedures. The multiplate Hester-Dendy samplers were selected (using specifications according to the Ohio Environmental Protection Agency ,1987) to provide a consistent uniform substrate for macroinvertebrate colonization.

Each Hester-Dendy artificial sampler consisted of eight 3x3 inch, one-eighth inch thick tempered masonite hardboard plates fastened together with an eye-bolt. The plates were separated by one-inch square hardboard spacers. Three samplers were attached by threaded rod to a concrete patio block, placed on the stream bottom at a depth of 0.75 to 1.5 m, and left for 6-weeks of colonization. During retrieval, to minimize loss of organisms, a 0.15 mm mesh drawstring net was placed over the submerged samplers. Sampler plates were scraped and organisms retained on a 40-mesh sieve screen (0.425 mm mesh) and preserved in 70 percent ethanol.

Macroinvertebrate kick samples were collected by disturbing (agitating and kicking) the stream bottom while positioning an A-frame dip net downstream to collect dislodged organisms. Samples were also taken by hand-picking organisms from shoreline objects such as boulders, logs, and bridge abutments. A standardized time period of thirty minutes was used for handpicking collection procedures at each location. The collected organisms were preserved in 70 percent ethanol.

Organisms were sorted and tabulated in a glass tray over a lighted glow box. Initial sample examination was done with a magnifying lens and the final sorting was done with a stereomicroscope. Samples were periodically further checked for sorting completeness. Large numbers of a taxonomic group (generally > 300) were subsampled in a glass tray divided into equal quadrants. Macroinvertebrates were generally identified to the genus taxonomic level. Midges were identified by mounting the larval head capsule on glass slides for microscopic examination. A reference collection of the organisms was

assembled to maintain consistent and uniform identifications.

All count information was placed into a computerized format to classify the community into structural and functional groupings according to feeding habits, after Merritt and Cummins (1987). The standard metrics used to classify structural features were richness, diversity (Shannon-Weaver), equitability, and percentages of Ephemeroptera-Plecoptera-Tricoptera (Weber, 1973). An Index of Community Integrity (ICI) was calculated according to the Ohio EPA (1987). Qualitative field collections were not made in 1991-1992, therefore ICI metric 10 could not be determined and the final ICI score was derived using the first nine metrics.

2.7 DATA MANAGEMENT AND STATISTICAL ANALYSIS

Individual survey data sheets were kept in bound notebooks. Each analysis and sampling location had separate unique identifications. All surveys were sequentially numbered and data compiled into computerized spreadsheets. Data was converted to ASCII formats for the multivariate analyses.

Descriptive statistics were used to determine the habitat, chemical, toxicity, and macroinvertebrate associations. Multiple regression analyses were used to determine the toxicity relationships with the sediment pore water measurements and the habitat, nutrient, and macroinvertebrate findings. The levels of high, medium, and low significance were set at $P<0.01$, $P<0.05$, and $P<0.1$, respectively. Canonical correspondence analysis (CCA) was used to associate all the taxa and the dominant macroinvertebrate groups to eight environmental variables (ter Braak, 1986). The eight variables were surface water and sediment pore ammonia, nitrite-nitrate and total phosphorus, and QHEI habitat score, and drainage area at the sampling site. All macroinvertebrate counts were log transformed to reduce the potential effect of extremely abundant taxa and downweighing the influence of rarer taxa. Forward selection and Monte Carlo permutation tests were used to determine the environmental variables having the greatest influences.

3. EVALUATION OF WATERSHED QUALITY

3.1 HABITAT ASSESSMENT

Habitat quality (based on the QHEI scores) was the highest at the main tributary sampling sites. Overall, the QHEI scores at the mainstem and upper watershed sites were 20 percent lower (Table 3-1). Lowest scores (≤ 50) were found in the lower 25 miles of the mainstem and at 3 of 8 upper watershed sites. Factors contributing to poor quality at these sites were a lack of substrate heterogeneity (diversity), unstable substrates, and excessive amounts of fines (particles < 2.4 mm). An open dominant riparian cover was present at the poor quality upper watershed sites. A wooded land cover was commonly found at most tributary and mainstem locations.

Most samples were collected in relatively shallow water (< 3 ft). Samples collected downstream from Jordan were taken near the edges of the barge channel in deeper water. River bottom samples from the mainstem stations sediments downstream from Delhi, in the reservoirs and at some of the upper watershed sites were embedded with fine particles (> 50 percent by volume) and with a mixture consisting of sand and gelatinous muck. Mainstem stations upstream from Jordan were generally shallow and exhibited moderate amounts of overhanging bank vegetation (Figure 3-1). The main tributary sediments were characterized by having greater proportions of gravel and stones, and fine particles amounted to < 50 percent by volume (Table 3-1). The tributary streams had more variable water depths and greater proportions of overhanging vegetation (Figure 3-2). Higher average QHEI habitat scores and lower amounts of substrate embeddedness were found at the main tributary stations.

A greater degree of bank erosion was observed at the mainstem locations. Slumping banks, and a lack of associated vegetation and large rip rap for erosion protection were commonly observed. The main tributary sites appeared to have the best bank stability. A mixture of open grassland and wooded area were found at most of the upper watershed sites. The upper watershed sites typically had the least amounts of overhanging vegetation and channel obstructions. A general absence of aquatic macrophytes (both submerged and emergent) was noticed at all the sampling locations.

Baker (1988) concluded that watershed size has a major influence on pollutant loading and instream water quality. Watershed size affects the seasonal export of particulate

TABLE 3-1. HABITAT CHARACTERISTICS.

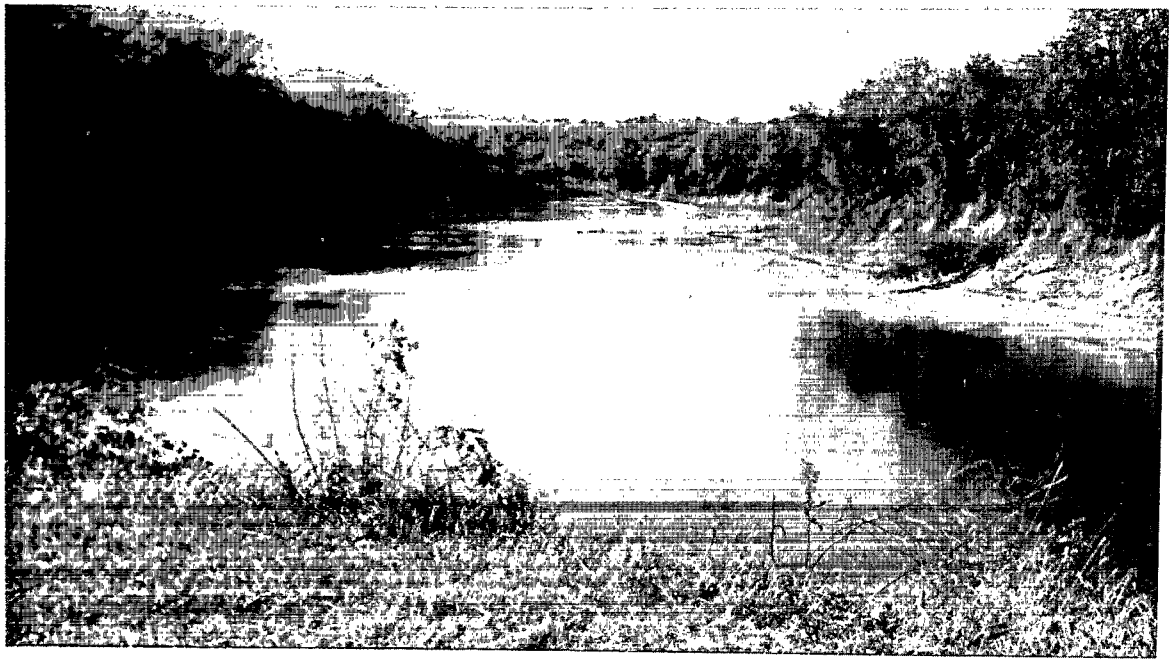
Location	Dominant Cover	Sample Depth [a]	QHEI Score	Degree Eros [b]	Percent Embedd [c]	Dominant Substrate Characteristics
Mainstem Locations						
Fort Snelling	wooded	4-15	46	II	I	sand, mud
35 W Bridge	open	3-10	-	-	I	sand, mud
Jordan	wooded	1-3	48	II	I	sand
Henderson	wooded	1-4	60	I	-	sand, silt, mud
St. Peter	wooded	2-3	64	II	I	sand, silt, mud, woody debris
Judson	wooded	2-3	61	II	I	sand, mud, grvl, woody debris
Courtland	wooded	1-2	60	II	I	sand, silt
Morton	wooded	2-6	65	II	I	sand, mud, grvl, woody debris
Delhi	wooded	2-3	70	III	III	sand, silt, gravel
Upper Sioux	wooded	1-2	67	III	III	sand, slt, grvl, woody debris
Average			60	II	I	
Reservoirs						
Rapidan	-	3-4	-	-	I	sand, mud
Chippewa	-	3-4	-	-	I	mud
Lac Qui Parle	-	4-6	-	-	I	mud
Average					I	
Main Tributaries						
High Island Cr.	wooded	1-2	68	III	II	sand, slt, grvl, woody debris
Rush Riv.	wooded	1-2	70	III	II	sand, silt, gravel
Blue Earth Riv.	wooded	1-3	60	III	III	sand, gravel
Le Sueur Riv.	wooded	1-2	73	II	II	sand, grvl, cbble, wdy debris
Watonwan Riv.	wooded	1-3	76	III	-	sand, silt, gravel, cobble

Table 3-1 (cont)
HABITAT SUMMARY

Location	Dominant Cover	Sample Depth [a]	OHEI Score	Degree Eros [b]	Percent Embedd [c]	Dominant Substrate Characteristics
Cottonwood Riv.	wooded	1-3	76	III	II	sand, gravel
Hawk Cr.	open	1-2	74	II	III	sand, gravel, cobble
Yellow Medicine Riv.	wooded	1-2	77	III	II	sand, grvl, cbble, boulders
Average Score			72	III	II	
Upper Watersheds						
Beauford	wooded	-	68	II	-	sand, gravel
Blue Earth	wooded	1	64	III	I	clay, silt, woody debris
County Rd 13	wooded	1	63	III	I	sand, silt, boulders
Frost	open	-	57	III	-	sand, silt, gravel
Mountain Lk.	open	-	50	-	-	sand, silt
St. James	open	-	68	-	-	sand, silt, grvl, wdy debris
Wells	open	-	49	-	I	sand, mud, gravel
Camp Pope Cr.	wooded	-	61	III	I	sand, grvl, cbble, wdy debris
Gaylord	open	1	45	III	I	sand, mud
Average Score			58	III	I	

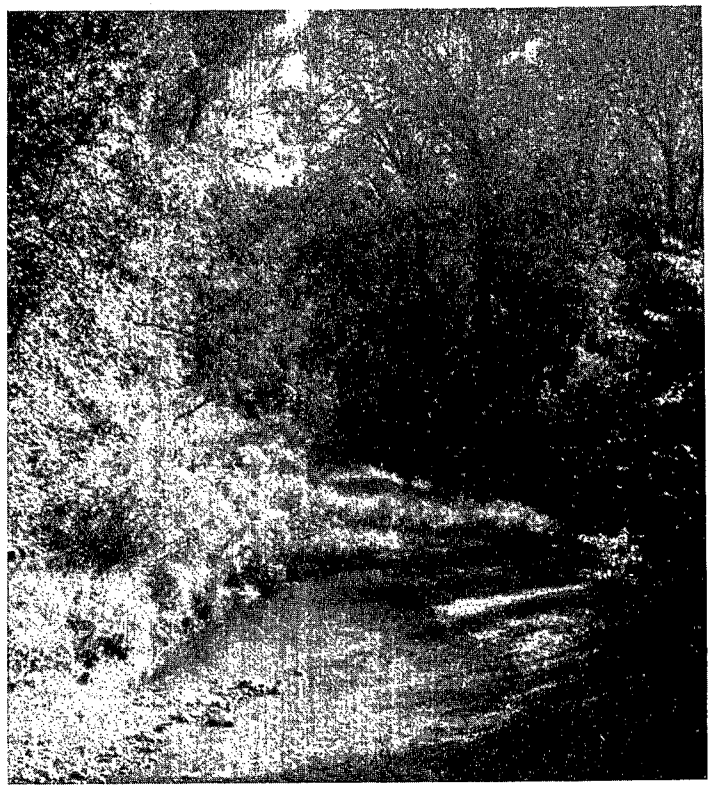
[a] Sampl. Depth = Sampling depth in feet.
[b] Degree Erosion = I - heavy, II - moderate, III - none to slight
[c] Percent Embeddedness = I - > 50 % by volume, II - 11 to 50 %, III - <1 to 10% by volume.
\- No information

Morton (river mile 203)

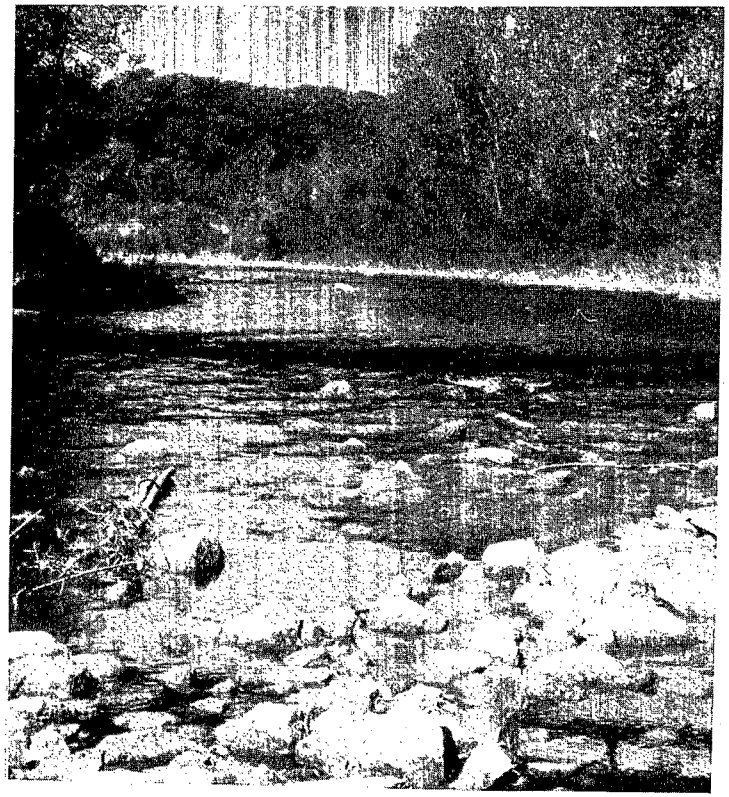


Jordan (river mile 42)

Figure 3-1. Minnesota River mainstem sampling sites at Jordan and Morton.



High Island Creek



Le Sueur River

Figure 3-2. Minnesota River tributary sampling sites at High Island Creek and Le Sueur River.

associated pollutants and sediment. Exposure durations from rainfall events tend to be more short-term in smaller watersheds, but lower and longer-term in larger watersheds. Lenat (1984) in a study of agricultural streams found that the amount of substrate (< 2 mm) was related to farm management practices.

Although many of the stations listed in Table 3-1 showed a general association between greater bank erosion and substrate embeddedness, insufficient information was gathered in this study to directly relate the occurrence of fine particles in the river substrate to land use management practices.

3.2 STREAM CHEMISTRY PROFILES

Except for ammonia-nitrogen, similar nutrient concentrations were generally found between the surface water and sediment pore water samples (Table 3-2). Total ammonia-nitrogen (as N) concentrations were highest in the mainstem and reservoir sediment pore waters. Reservoir sediment pore water had about 10 times higher concentrations of ammonia nitrogen than at the other sites. Concentrations of nitrite-nitrate nitrogen were 5-10 times higher in the main tributary than at the upper watershed sites. Ammonia-nitrogen, nitrite-nitrate and iron concentrations progressively increased at the downstream mainstem locations. Arthur et al. (1994) report supplied a summary of surface water anion and cation characteristics in the Minnesota River Basin. Five cations, namely cadmium, chromium, copper, lead, and zinc, were uniformly at or below the analytical limits of detectability in the sediment pore waters. No differences were found by location for the anion and cation concentrations or for surface water total organic carbon and conductivity values.

The surface water nutrient concentrations reported in Table 3-2 are similar to those reported by Baker (1988) in corn/soybean agricultural watersheds. He found higher nitrate concentrations in the smaller watersheds. Although higher nitrate levels were generally present in the upper watershed locations, no comparable samples were collected in the low to higher order streams to follow the nutrient changes after episodic rainfall events.

Amounts of land use devoted to agricultural activities have been linked to decreased water quality in Minnesota (Fandrei et al., 1988). In the agricultural areas, these investigators suggested that reference (or lowest) surface water values for total ammonia, nitrite-nitrate nitrogen and total phosphorus appear to be between 0.3-0.4, 0.5-4.2, and 0.2-0.3 mg/l, respectively. Surface water ammonia concentrations at all of the

Table 3-2. SURFACE AND SEDIMENT PORE WATER NUTRIENT CHARACTERISTICS (Av. Conc. - mg/l)

	Surface Water			Sediment Pore Water		
	NH_3-N	T-P	NO_2+NO_3	NH_3-N	T-P	NO_2+NO_3[a]
Mainstem Locations						
Fort Snelling	-	-	-	9.5	0.7	1.6
35 W Bridge	-	-	-	7.0	0.7	3.0
Jordan	-	-	-	0.9	0.1	1.6
Henderson	< 0.1	0.2	5.2	1.7	< 0.1	3.4
St. Peter	< 0.1	0.1	4.2	3.5	0.2	3.4
Judson	< 0.1	0.2	2.3	0.3	< 0.1	2.1
Courtland	< 0.1	0.2	1.5	0.8	0.1	1.5
Fort Ridgely	< 0.1	0.3	1.3	0.2	< 0.1	0.3
Morton	< 0.1	0.3	1.0	0.5	0.1	0.1
Delhi	< 0.1	0.2	0.5	1.8	0.2	0.4
Upper Sioux	< 0.1	0.2	0.6	0.2	0.2	-
Reservoirs						
Rapidan	-	-	-	4.8	0.9	1.1
Chippewa	-	-	-	4.0	1.8	< 0.1
Lac Qui Parle	0.1	0.3	0.1	13.2	5.2	< 0.1
Main Tributaries						
High Island Cr.	0.1	0.3	6.4	0.2	< 0.1	3.5
Rush Riv.	0.3	0.4	12.0	< 0.5	0.2	13.9
Blue Earth Riv.	< 0.1	0.2	13.2	0.4	0.6	11.1
Le Sueur Riv.	< 0.1	0.4	15.3	0.2	0.1	12.4
Watonwan Riv.	< 0.1	0.3	14.6	0.3	0.2	7.9
Cottonwood Riv.	< 0.1	0.2	8.8	0.5	0.3	4.1
Redwood Riv.	< 0.1	0.3	3.5	-	-	-
Hawk Cr.	< 0.1	0.4	3.9	< 0.1	0.5	< 0.1
Yellow Med. Riv.	< 0.1	0.2	2.6	< 0.1	0.2	1.6
Upper Watersheds						
Beauford	0.2	0.3	17.7	-	-	-
Blue Earth	-	-	16.8	0.1	0.1	9.5
County Rd 13	-	-	18.6	3.6	0.2	< 0.1
Frost	-	-	17.3	-	-	-
Mountain Lk	< 0.1	0.4	19.4	-	-	-
St. James	-	-	12.9	-	-	-
Wells	< 0.1	0.9	18.9	< 0.1	< 0.1	13.7
Gaylord	-	-	-	1.5	< 0.1	3.2

[a] NH_3-N = Total ammonia nitrogen, T-P = Total phosphorus as (PO_4)
NO_2+NO_3 = Nitrite+Nitrate nitrogen. - No information

Note: Surface water mainstem, reservoir, and tributary water data from Payne (1994), upper watershed data from Proctor (1994).

stations in our study were generally comparable to their reference levels. Most of the nitrite-nitrate concentrations exceeded the reference values, especially in the main tributary locations associated with the Blue Earth drainage (south of Mankato) and at all of the upper watershed sites. Insufficient surface water values were available for comparison with the reservoir stations (Appendix B). The Fandrei et al. (1988) report did not include sediment pore water values.

Water quality values in the Fandrei et al. (1988) report exceeding the 75th percentiles for total ammonia, nitrite-nitrate, and total phosphorus were 0.6, 6.8, and 0.5 mg/l, respectively. Only the nitrite-nitrate concentrations found in Table 3-2 exceeded their 75th percentile value. Making this same comparison with the average sediment pore water, the ammonia nitrogen values exceeded their 75th percentile most often followed by nitrite-nitrate and then total phosphorus. Using these guidelines, stations having the best water and sediment pore water quality were found in the river's mainstem and in the main tributaries entering upstream from Mankato.

Relatively meager information was available on herbicide concentrations. Thurman et al. (1991) have reported on surface water total herbicide concentrations in the Minnesota River, and found that the median concentrations were < 5 μg/l. Atrazine was found to be the most persistent herbicide monitored. Therefore, it appears that herbicides may have played a minor role in our study since it has been recently concluded that concentrations < 20 μg/l do not cause sustained observable ecosystem effects (Huber, 1993).

3.3 TOXICITY FINDINGS

None of the surface water samples collected during September 1989 were toxic to Ceriodaphnia. Only the sediment pore water samples (Table 3-3) showed inhibitory test responses. Samples toxic to Ceriodaphnia were found at 6 of the 26 sampled sites. Mainstem locations upstream from the highway 35 W bridge and 8 of 9 tributary locations were not toxic. The most toxic samples were gathered from the Lac Qui Parle Reservoir and two mainstem locations at the 35 W Bridge and Fort Snelling. Toxicity was found on two of five occasions at the Rapidan Reservoir site and on one sampling period at the Chippewa and High Island Creek sites.

Ceriodaphnia reproduction was the most sensitive test response (Appendix H). The significant test response was final yield where young production was < 50 percent of the controls. In only a few tests did the sediment pore water samples cause complete mortality.

TABLE 3-3. TOXICITY RESULTS - CERIODAPHNIA DUBIA EXPOSED TO SEDIMENT PORE WATER.

	Sampling Period					
	10/89	1/90	6/90	9/90	5/92	7/92
Main Stem Locations						
Fort Snelling	50-100% [a]	NT	25-50%	50-100%	NT	-
35 W Bridge	< 100%	-	25-50%	25-50%	NT	-
Jordan	NT	NT [b]	NT	NT	NT	-
Henderson	NT	-	- [c]	NT	NT	-
St. Peter	NT	NT	NT	NT	-	-
Judson	NT	-	-	NT	NT	-
Courtland	NT	NT	NT	NT	-	-
Morton	NT	NT	NT	-	-	-
Delhi	NT	-	-	NT	NT	-
Upper Sioux	NT	-	-	-	-	-
Reservoirs						
Rapidan	NT	NT	50-100%	50-100%	NT	-
Chippewa	NT	-	50-100%	-	-	-
Lac Qui Parle	50-100%	25-50%	25-50%	-	-	-
Main Tributaries						
High Isl. Cr.	NT	-	-	< 100%	NT	-
Rush Riv.	-	NT	NT	-	-	-
Blue Earth Riv.	NT	NT	NT	NT	NT	-
Le Sueur Riv.	NT	-	NT	NT	-	-
Watonwan Riv.	NT	-	NT	NT	-	-
Cottonwood R.	NT	NT	NT	-	-	-
Redwood Riv.	NT	-	-	-	-	-
Hawk Cr.	NT	-	-	-	-	-
Yellow Med. Riv.	NT	-	NT	NT	NT	-
Upper Watershed						
Blue Earth	-	-	-	-	NT	-
County Road 13	-	-	-	-	NT	-
Wells	-	-	-	-	-	NT
Camp Pope Cr.	-	-	-	-	NT	NT
Gaylord	-	-	-	-	NT	NT

[a] Range between no effect level (50%) and effect level (100%).
[b] NT = No toxicity found.
[c] - = No test conducted.

TABLE 3-4. TOXICITY RESULTS - SELENASTRUM CAPRICORNATUM AND SEDIMENT PORE WATER.

	Sampling Period		
	08/89	10/89	06/90
Main Stem Locations			
Fort Snelling	- [a]	22	30
Jordan	-	-	NT
Henderson	29	30 [b]	-
St. Peter	93	12	74
Courtland	NT	55	NT [c]
Morton	NT	45	-
Reservoirs			
Rapidan	15	24	32
Lac Qui Parle	7	19	5
Main Tributaries			
Blue Earth Riv.	-	-	NT
Le Sueur Riv.	-	-	NT
Watonwan Riv.	-	-	NT
Cottonwood Riv.	-	-	NT
Yellow Med. Riv.	-	-	NT

[a] - = Toxicity test not conducted.
[b] Effect level, as percentage yield in cell numbers against control response.
[c] NT = Not toxic, cell numbers ≥ control response.

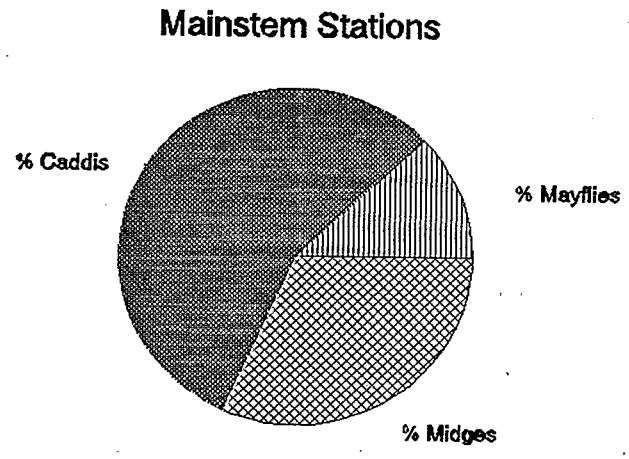
Sediment pore water toxicity to Selenastrum was found at 8 of the 15 sampled locations. Toxicity at the mainstem locations was found beginning at Morton (river mile 203) and, with exception of Jordan, at all downstream stations and both reservoir sites (Table 3-4). Sediment pore water from the two reservoir sites yielded the most inhibitory test responses. None of the main tributary samples were toxic to Selenastrum. Overall, the most toxic locations (in terms of inhibition) were at Fort Snelling, Henderson, and at both of the tested reservoir locations. Samples from the Lac Qui Parle Reservoir showed the greatest toxicity and the most uniform test responses.

More sediment pore water samples were inhibitory (showed a toxic response) with the Selenastrum than the Ceriodaphnia test. Samples from approximately 50 percent (7/13) of the locations were partially inhibitory with the Selenastrum test. By contrast, only about 20 percent (6/31) of the locations were found to be inhibitory with the Ceriodaphnia procedure.

3.4 MACROINVERTEBRATE COMMUNITY CHARACTERISTICS

A total of 135 macroinvertebrate taxa were collected; 81 were found at the mainstem and tributary locations, and 92 taxa at the upper watershed sites (Appendix E). The five groups that accounted for two-thirds of the overall community richness were: Diptera-Chironomidae (midges) at 26 percent, Ephemeroptera (mayflies, 14 percent), Coleoptera (beetles, 10 percent), Trichoptera (caddisflies, 9 percent) and other Dipterans (7 percent). Flatworms, odonates, stoneflies, and hemipterans were more commonly found at the mainstem and tributary locations. Leeches, snails, and isopods were primarily limited to the upper watershed sites.

The most abundant macroinvertebrates (in terms of numbers counted) were mayflies, caddisflies and midges (Appendix C). These three groups accounted for 98 percent of all the individuals collected at all the mainstem sites, 87 percent at the tributary locations, and 71 percent at the upper watershed sites. Caddisflies comprised the largest proportion of the communities on the mainstem and tributaries; midges were most common at the upper watershed sites (Figure 3-3). Common mayfly genera were Baetis, Caenis, Stenonema, Stenacron, Potomanthus, and Tricorythodes. Common midges were Glyptotendipes, Polypedilum, and Tanytarsus, and the most abundant caddisflies taxa were Hydropsyche, Cheumatopsyche, Potamyia, and Cyrnellus. By comparison, in a survey of the Minnesota River's mainstem from Le Sueur (river mile 78) to Ortonville (river mile 333), Kirsch (1985) reported collecting



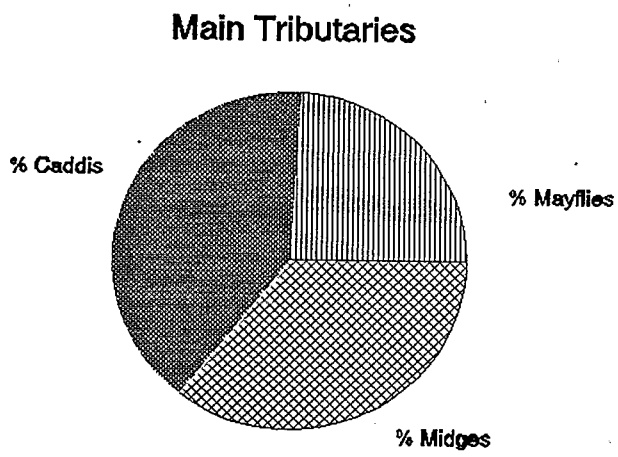


Figure 3.3. Macroinvertebrate structural community characteristics.

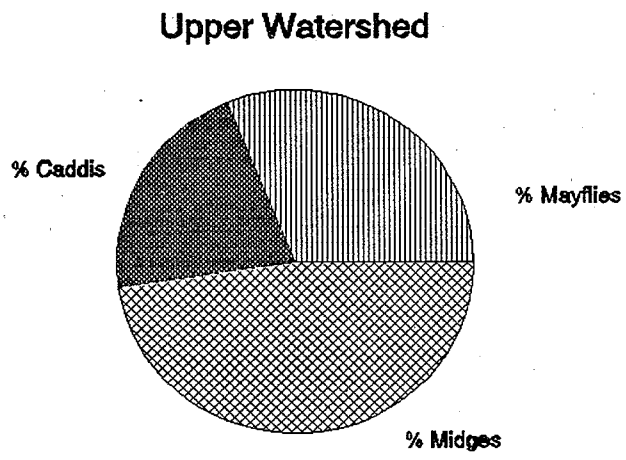


Figure 3.3 (Cont). Macroinvertebrate structural community characteristics.

212 benthic taxa; insects comprised 90 percent of the total collected. The dominant insect groups in their study were mayflies, caddisflies, and midges.

Similar numbers and kinds of major insect groups were collected with both the artificial substrates and qualitative sampling procedures (Appendix F and G). Mayflies, caddisflies and midges were the dominant groups collected with both procedures. Flatworms, oligochaetes, annelids, snails and amphipod crustaceans were commonly collected only with the qualitative procedures. Insect genera found only in the qualitative samples were the water boatman Cymatia, and the damselfly Argia. More midge taxa were collected from the artificial substrates. Hester-Dendy samples from the upper watershed sites had a more diverse assemblage of taxa than samples from the mainstem and tributaries.

There were major differences between sampling locations in richness and in indices of diversity and equitability (Appendix D). The greatest deviations in richness values were with the mainstem stations while ranges in diversity and equitability were greater in the upper watershed sites. Least variations in these indices were found in mainstem locations upstream from St. Peter. Weber (1973) has suggested that diversity values ≥ 3.0 and equitability ≥ 0.5 may be representative of relatively nonimpacted conditions or clean water quality. Three main tributary sites (Le Sueur River, Watonwan River and Hawk River) and two upper watershed sites (Camp Pope Creek and Gaylord) met or exceeded these conditions. Equitability values exceeding 0.8 were recorded at two other upper watershed sites (Beauford and Wells).

Changes in abundance of macroinvertebrate groups in agricultural drainages have been documented by others. Lenat (1984) found that there were both shifts and declines in the abundance of EPT taxa with a replacement by more tolerant trichoptera and dipteran forms. Gammon (1981) noted that as stress from nonpoint source pollutants increased, chironomids (midges) became more abundant, trichoptera and ephemeroptera groups less numerous and irregular in appearance. However, some studies have not been able to document these changes (Marsh and Waters, 1980; King, 1985). The King study was limited to benthic collections along the Minnesota river's mainstem. Marsh and Waters (1980) attributed the few benthic differences they found to local site-specific factors.

Location differences were found in the functional classification of the macroinvertebrate community (Appendix C). Collectors were especially common at the mainstem sites (between

86-99 percent) indicating a good supply of fine particulate organic matter. Scrapers progressively increased in higher proportions upstream from Mankato. At the main tributary sites, collectors remained dominant but were less abundant and replaced by predators and scrapers. Shredders occurred mainly in the upper watershed locations Figure 3-4). Some of these distributions may naturally occur as a function of stream size and order. Camargo (1992) found shredders were more abundant in headwaters, scrapers in the middle reaches, collectors most commonly found in the lower reaches, and predators were distributed throughout the stream. Also, these functional distributions appear to follow the river continuum theory (Cummins, 1979). Menzel (1984) noted that in Iowa prairie streams, collectors and scrapers were the dominant, and predaceous insects less frequently collected. In agricultural streams, the shredder species were replaced by noninsect groups such as Asellus, Hyalella, and Orconectes and others tolerant of soft stream substrates. In our study, a shift occurred in dominant taxa from principally EPT forms to crustaceans and chironomids (Appendix F).

Indices of Community Integrity (ICI) values were generally higher at the mainstem locations (Figure 3-5). Greatest variation in ICI scores were obtained at the upper watershed sites. Only two locations on the river's mainstem exceeded a recommended eastern cornbelt biocriterion of 38 as derived by the Ohio EPA (1987). The two mainstem sites were at Morton and Delhi. None of the main tributary locations met or exceeded this recommended biocriterion. Overall, the locations with the highest ICI values were the mainstem sites located upstream from Mankato, three main tributaries (Le Sueur, Watonwan, Yellow Medicine Rivers) and the County Road 13 and Camp Pope Creek sites in the upper watershed. Factors contributing to the lower ICI scores were lower numbers of EPT taxa and higher numbers of non-insects and dipteran insects other than the midges.

3.5 INTERACTIVE WATERSHED COMPONENT ANALYSIS

Some strong associations ($P < 0.01$) were found among the nutrient, habitat, and biotic variables (richness, EPT, and ICI) Figure 3-6). ICI was strongly associated with surface water ammonia nitrogen and slightly correlated with pore water ammonia. Taxonomic richness was correlated with the other biotic metrics; however, this would be expected because of the dominance of mayflies, stoneflies and caddisflies in the benthic community composition. Habitat (QHEI) scores showed less strong correlations with the three biotic variables. No correlations were obtained between the biotic variables and the riparian zone QHEI score. A slight association was found between habitat scores and

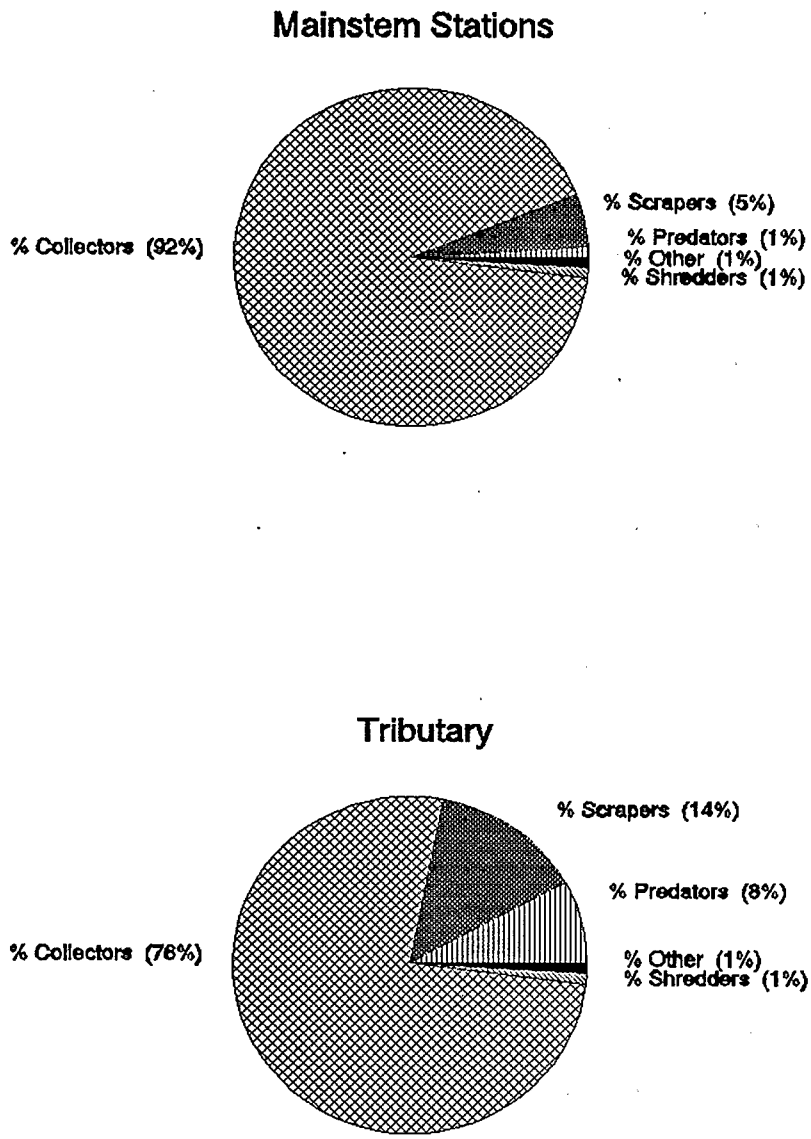


Figure 3-4. Macroinvertebrate functional characteristics.

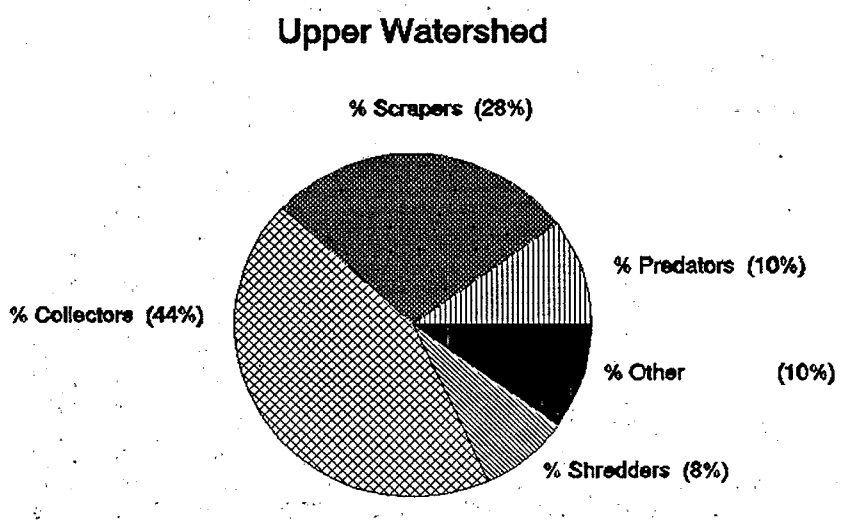
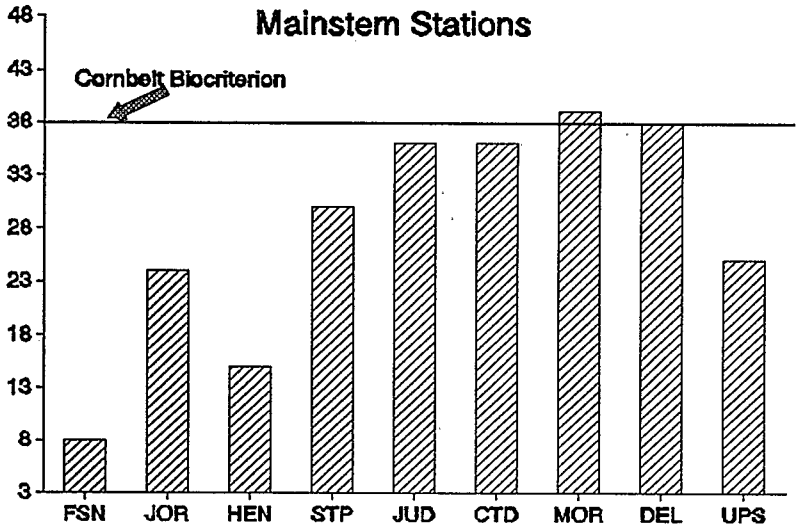


Figure 3-4 (Cont). Macroinvertebrate functional characteristics.



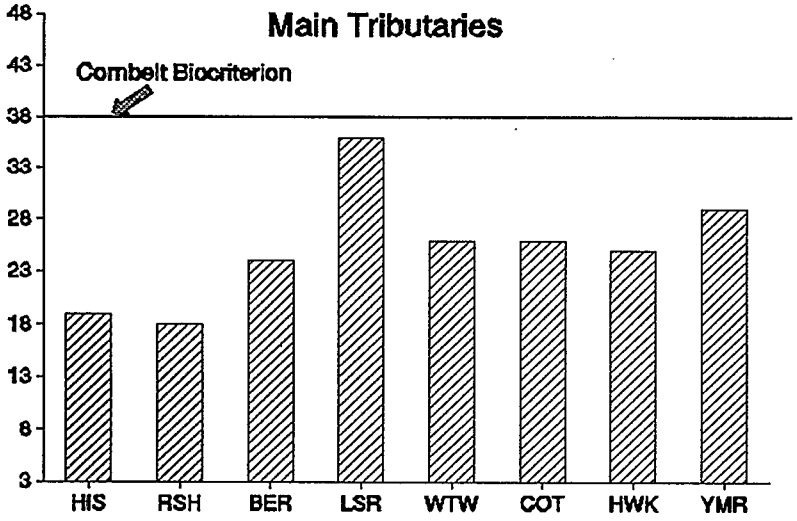


Figure 3-5. Calculated Minnesota River ICI biocriteria.

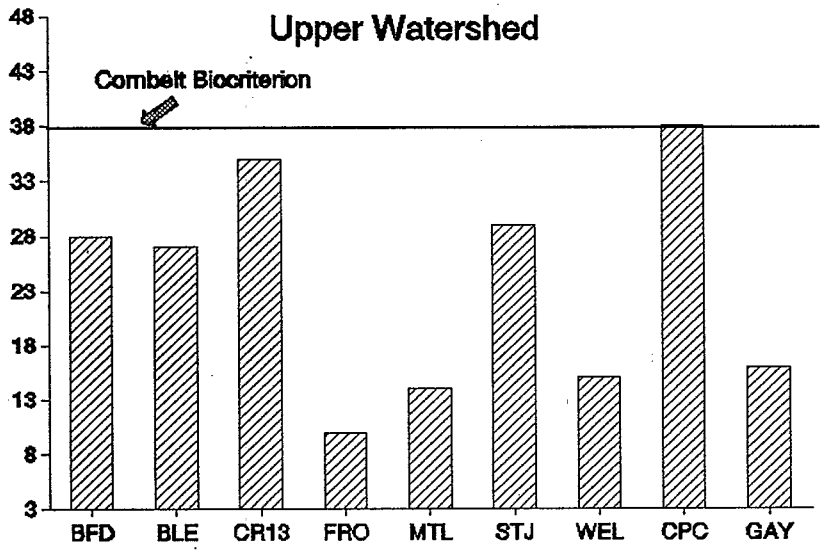


Figure 3-5 (Cont). Calculated Minnesota River ICI biocriteria.

	EPT	ICI	Riparian	QHEI	Drainage Area
Richness	***	***	NS	**	NS
EPT		***	NS	**	NS
ICI			NS	**	NS
Riparian				NS	NS
QHEI					*

* P Between 0.05 - 0.1

** P 0.01 - 0.05

*** P < 0.01

NS Not Significant

	Surface Water NH3-N	Pore Water NH3-N	Surface Water N02+N03	Pore Water N02+N03
ICI	***	*	NS	NS

* P 0.05 - 0.2

** P 0.01-0.05

*** P < 0.01

NS Not Significant

Figure 3-6. Watershed component regression results.

size of the drainage area.

Analyses were also performed using the ICI values with the ammonia and nitrite-nitrate nitrogen concentrations (Figure 3-6). Slight to strong correlations were found with pore and surface water ammonia nitrogen concentrations. No associations occurred with the nitrite-nitrate values.

Regression analyses were conducted to estimate the relationship between the mean pore water chemical values (in Appendix B) and the observed ambient toxicity at the same locations. Level of significance was set at: $P \leq 0.05$. Significant positive associations were found for total ammonia nitrogen at locations toxic to Ceriodaphnia and Selenastrum. Best chemical toxicity associations were obtained with the Ceriodaphnia test. Because the daphnid reproductive yield was the most sensitive response, a comparison of yield was made against the measured total pore water ammonia concentrations. From this analysis ($r^2 = 0.63$, $n = 38$), a 50 percent reduction in reproductive responses was predicted for total ammonia nitrogen concentrations of 8.8 mg/l or higher (Arthur et al., 1994).

Ankley et al. (1990) in a Wisconsin watershed study found that ammonia nitrogen was the chemical responsible for observed ambient toxicity in sediment pore water. Total ammonia nitrogen concentrations generally > 10 mg/l were lethal to Ceriodaphnia; total ammonia concentrations exceeding 20 mg/l affected the growth of Selenastrum. Although the agent(s) responsible for the observed toxicity were not fully characterized, ammonia nitrogen was the the suspected toxicant in this study. Concentrations of heavy metals in the sediment pore waters were uniformly near the limits of detection. No measurements of nonpolar compounds were made on the sediment pore water.

Correspondence analysis added additional information on the interaction of nutrients and habitat quality for the three dominant macroinvertebrate groups (Table 3-5). In general, the Eigenvectors were numerically similar in all four axes, indicating that no particular axis explained the majority of the variations encountered. Poorest correlations were encountered when all the taxa and the midge group were analyzed. For the mayfly and caddisfly groups, the ordinations explained approximately 70 percent of the variation encountered, and the first results found in the first two axes accounted for approximately 50 percent of the variation. Highest correlations were found between the surface water nutrients and the mayfly and caddisfly groups. Best

Table 3-5. Analysis of Biological Community and Environmental Factors.

A. Eigenvalues - Macroinvertebrate and Environmental Variable Associations

	Axis 1	Axis 2	Axis 3	Axis 4
All Taxa				
Eigenvalue	0.183	0.125	0.103	0.085
% Variance explained	17.4	10.5	8.8	7.1
Chironomids				
Eigenvalue	0.221	0.163	0.141	0.113
% Variance explained	17.4	12.2	10.6	7.5
Mayflies				
Eigenvalue	0.208	0.106	0.064	0.050
% Variance explained	34.4	17.1	10.4	8.4
Caddisflies				
Eigenvalue	0.181	0.153	0.097	0.020
% Variance explained	29.0	19.6	9.9	2.9

B. Correlations of Environmental Variables - First two CCA Axes

Variable	All Taxa		Chironomids		Mayflies		Caddisflies	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Surface water NH_3	0.57	- 0.10	0.34	0.10	0.52	0.41	0.16	0.58
Surface water NO_2+NO_3	0.38	0.45	0.18	0.60	0.21	0.58	0.62	0.06
Surface water T-P	0.23	0.66	- 0.49	0.16	0.14	0.78	0.49	0.01
Pore water NH_3	- 0.38	- 0.20	- 0.01	- 0.20	- 0.49	- 0.16	- 0.25	- 0.05
Pore water NO_2+NO_3	0.28	0.34	0.32	0.59	0.12	0.60	0.52	0.13
Pore water T-P	- 0.13	- 0.24	0.24	- 0.19	0.11	0.13	- 0.14	- 0.25
QHEI	0.55	0.29	- 0.20	0.34	0.80	- 0.02	0.48	0.18
Drainage area	- 0.78	- 0.14	- 0.11	- 0.19	- 0.86	- 0.36	- 0.43	- 0.35

associations were obtained with surface water ammonia and nitrite-nitrate nitrogen. Smaller drainage areas were generally associated with increasing nutrient concentrations. No particular associations were evident between the sediment pore water values and the macroinvertebrate community. For the mayfly group, additional associations were found with surface water ammonia, nitrite-nitrate, and QHEI. When biplots were made (not shown), no strong associations were found between any individual taxa, stations, or the eight environmental variables. Although weak taxa associations were found, individual taxa that were identified from the ordination analyses were the midge genera: Microtendipes and Tanypus, the mayfly Stenacron and the caddisfly genus Polycentropus. Findings from the ordination analyses generally paralleled the regression analyses.

This study used procedures similar to an investigation conducted in an agricultural region located in central Michigan (Richards et al., 1993). As in our study, they found that the most important factors affecting the macroinvertebrate community were physical habitat and elevated nutrient concentrations, particularly ammonia. Significant associations were also found between numbers of EPT taxa and substrate quality. These investigators concluded that by increasing substrate and channel heterogeneity and controlling nutrient additions, the macroinvertebrate quality could be enhanced in these streams. Our findings in the Minnesota River Basin appear to corroborate these findings.

4. SUMMARY AND CONCLUSIONS

The Federal Water Act has encouraged the definition of conditions necessary for maintaining physical, chemical, and biological integrity in receiving waters. This study supplies descriptive information on several physical, chemical, and biological components in the Minnesota River Basin. The most important stressor affecting the basin's biological integrity was found to be excessive inputs of nutrients (particularly ammonia and nitrite-nitrate nitrogen) and reaffirms the conclusions by others as to the continual dominance and role of these stressors in degrading the Minnesota River Basin. The dominant habitat characteristics adversely affecting the basin were a general lack of substrate heterogeneity and high substrate embeddedness from fine particles. Highest habitat scores and water quality and least impacted biological communities were found upstream from Mankato on the river's mainstem, the Yellow Medicine tributary, and the upper watershed site at Camp Pope Creek near Redwood Falls.

For most sites, the calculated Index of Community Integrity (ICI) values fell below recommended biocriteria for eastern cornbelt areas in the United States. In many of the more impacted locations, the functional predator and shredder components of the community were depressed.

A good correlation was found between ammonia nitrogen and the macroinvertebrate community. The more impacted sites had fewer numbers of Ephemeroptera/Plecoptera/Tricoptera (EPT) taxa, less richness, and lower ICI scores. Ammonia nitrogen appeared to be a strong predictor of biological quality. Where ambient pore water toxicity occurred (total ammonia nitrogen concentrations > 8 mg/l) a degraded macroinvertebrate biological community was also present.

Additional stream studies are needed to obtain quantitative basin-wide response and exposure indicators (descriptors) for defining stream integrity. Concurrent results by others in the midwestern cornbelt regions need to be interrelated with this study's findings to further describe the kinds and magnitude of stressors affecting agricultural watersheds. Once done, watershed impairment can be linked with dominant habitat characteristics, chemical stressors and macroinvertebrate communities and can bring the nonpoint source pollution problems from agricultural activities into a clearer focus.

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APPENDICES

Appendix A
MINNESOTA RIVER BASIN SAMPLING LOCATIONS.

Location(Abbr.)	Rd. Crossing	County	Drn Ar(mi^2) [a]	R. Mi.
Main Stem Locations				
Fort Snelling(FSN)	State Park	Hennepin	16,100	3
35 W Bridge(35W)	Interstate Hwy.	Hennepin	-	11
Jordan(JOR)	SC Co. 9	Scott	16,000	42
Henderson(HEN)	MN 19	Sibley	15,530	73
St. Peter(STP)	MN 22	Le Sueur	15,020	98
Judson(JUD)	BE Co. 42	Blue Earth	11,200	127
Courtland(CTD)	BE Co. 45	Blue Earth	10,840	140
Morton(MOR)	MN 19	Renville	8,920	203
Delhi(DEL)	RN Co. 21	Renville	7,970	219
Upper Sioux(UPS)	YM Co. 21	Yellow Med.	7,090	237
Reservoirs				
Rapidan	BE Co. 9	Blue Earth	-	
Chippewa	CH Co. 15	Chippewa	-	
Lac Qui Parle	LQP Co. 20	Lac Qui Parle	-	
Main Tributaries				
High Isl. Cr.(HIS)	SI Co. 6	Sibley	240	
Rush Riv.(RSH)	MN 93	Sibley	400	
Blue Erth Ri.(BER)	Sibley Park	Blue Earth	3,450	
Le Sueur Riv.(LSR)	MN 66	Blue Earth	1,110	
Watonwan Riv.(WTW)	US 169	Blue Earth	880	
Cottonwood R.(COT)	Cottwd.St.Br.	Brown	1,208	
Hawk Cr.(HWK)	YM Co. 21	Yellow Med.	470	
Yell. Med. R.(YMR)	MN 67	Yellow Med.	650	
Blue Tributary Upper Watersheds				
Beauford (BFD)	MN 22	Blue Earth	9	
Blue Earth (BLE)	FA Co. 8	Faribault	8	
Cty Rd 13 (CR13)	FA Co. 13	Faribault	10	
Frost (FRO)	FA Co. 13	Faribault	12	
Mountain Lk(MTL)	MN 60	Cottonwood	10	
St. James (STJ)	WA Co. 104	Watonwan	18	
Wells (WEL)	MN 22	Faribault	10	
Camp Pope Cr.(CPC)	RD Co. 9	Redwood	3	
Gaylord (GAY)	MR 22	Sibley	6	

[a] Drn Ar = Drainage area in mi^2

Appendix B

SEDIMENT PORE WATER NUTRIENT ANALYTICAL VALUES - mg/l

	Ammonia Nitrogen (NH_3-N)					Total Phosphorus				
	10/89	01/90	06/90	05/92	06/92	10/89	01/90	06/90	05/92	06/92
Main Stem Locations										
Fort Snelling	11.8	2.2	21.7	2.1	-	0.1	0.4	2.0	< 0.1	-
35 W Bridge	9.4	-	6.2	5.4	-	0.2	1.9	-	0.1	-
Jordan	2.1	0.4	-	< 0.1	-	< 0.1	0.1	-	< 0.1	-
Henderson	3.3	-	-	< 0.1	-	< 0.1	-	-	< 0.1	-
St. Peter	1.7	2.0	7.0	0.3	-	< 0.1	< 0.1	0.3	-	-
Judson	0.3	-	-	-	-	< 0.1	-	-	< 0.1	-
Courtland	0.9	1.2	0.3	-	-	< 0.1	0.2	0.1	-	-
Morton	0.5	0.6	-	-	-	0.1	< 0.1	-	-	-
Delhi	2.8	-	-	0.7	-	0.2	-	-	< 0.1	-
Upper Sioux	0.2	-	-	-	-	0.2	-	-	-	-
Reservoirs										
Rapidan	5.9	1.2	7.4	3.5	-	< 0.1	< 0.1	2.5	< 0.1	-
Chippewa	4.7	-	3.4	-	-	0.3	-	3.3	-	-
Lac Qui Parle	10.6	21.2	7.8	-	-	0.5	6.5	8.8	-	-
Main Tributaries										
High Island Cr.	0.2	-	-	< 0.1	-	< 0.1	-	-	0.1	-
Rush Riv.	< 0.1	-	0.1	-	-	0.1	-	0.2	-	-
Blue Earth Riv.	0.5	0.5	< 0.1	-	-	0.3	0.2	1.1	-	-
Le Sueur Riv.	0.2	-	-	-	-	< 0.1	-	-	-	-
Watonwan Riv.	0.5	-	< 0.1	-	-	< 0.1	-	0.4	-	-
Cottonwood Riv.	-	1.0	< 0.1	-	-	0.1	< 0.1	0.6	-	-
Hawk Cr.	< 0.1	-	-	-	-	0.5	-	-	-	-
Yellow Med. Riv.	< 0.1	-	< 0.1	0.5	-	< 0.1	-	0.3	-	-
Upper Watershed										
Blue Earth	-	-	-	< 0.1	-	-	-	-	0.1	-
County Rd. 13	-	-	-	3.6	-	-	-	-	0.2	-
Wells	-	-	-	-	< 0.1	-	-	-	-	< 0.1
Camp Pope Cr.	-	-	-	1.1	< 0.1	-	-	-	< 0.1	< 0.1
Gaylord	-	-	-	2.3	0.7	-	-	-	< 0.1	< 0.1

- No Information

Appendix C

Macroinvertebrate Community Characteristics - Dominant Structural and Functional Groupings

	% Mayfl.	% Caddis.	% Midg.	% Pred.	% Scrap.	% Collec.	% Shred.
Main Stem Locations							
Fort Snelling	6	41	52	1	< 1	98	< 1
Jordan	7	83	10	< 1	< 1	99	0
Henderson	1	37	62	< 1	< 1	99	0
St. Peter	7	43	48	2	2	96	0
Judson	14	61	22	4	9	85	< 1
Courtland	10	59	27	< 1	8	91	< 1
Morton	29	62	9	< 1	14	86	< 1
Delhi	23	67	9	2	12	86	< 1
Upper Sioux	2	56	39	< 1	2	96	< 1
Mainstem Av.	12	55	31	1	5	93	< 1
Main Tributaries							
High Isl. Cr.	18	35	21	15	12	61	4
Rush Riv.	19	17	43	11	17	68	2
Blue Earth Riv.	7	52	37	1	6	93	< 1
Le Sueur Riv.	20	57	18	9	13	77	< 1
Watonwan Riv.	27	16	35	15	32	49	1
Cottonwood Riv.	12	26	56	6	8	86	0
Hawk Cr.	7	42	42	2	7	90	< 1
Yellow Med. Riv.	35	47	17	4	15	81	0
Tributary Av.	21	35	31	8	14	76	< 1
Upper Watersheds							
Beauford	45	12	13	15	35	33	17
Blue Earth	47	4	39	12	48	34	4
County Rd 13	36	31	22	6	28	31	7
Frost	5	< 1	20	11	4	44	2

Appendix C (cont.)

Macroinvertebrate Community Characteristics - Dominant Structural and Functional Groupings

	% Mayfl.	% Caddis.	% Midg.	% Pred.	% Scrap.	% Collec.	% Shred.
Mountain Lk	3	1	26	6	50	23	9
St. James	15	71	11	3	14	78	5
Wells	5	7	53	25	19	43	4
Camp Pope Cr.	36	7	41	4	24	64	5
Gaylord	5	1	79	10	28	44	16
Upper Watershed Av.	22	15	34	10	28	44	8

% Mayfl., Caddis., Midg. = Percent Mayflies, Caddisflies, Midges.
% Pred., Scrap., Collec. Shred. = Percent Predators, Scrapers, Collectors, Shredders.

Appendix D

MACROINVERTEBRATE COMMUNITY CHARACTERISTICS

	Average Index Values			
	Richness	Diversity	Equitability	ICI
Main Stem Locations				
Fort Snelling (FSN)	8	0.5	0.3	8
35 W Bridge (35W)	-	-	-	-
Jordan (JOR)	17	1.1	0.2	24
Henderson (HEN)	11	1.5	0.3	15
St. Peter (STP)	19	2.0	0.3	30
Judson (JUD)	21	2.7	0.4	36
Courtland (CTD)	21	2.7	0.4	36
Morton (MOR)	21	2.3	0.4	39
Delhi (DEL)	19	2.7	0.5	38
Upper Sioux (UPS)	19	2.0	0.3	25
Mainstem Av.	17	1.9	0.3	28
Main Tributaries				
High Island Cr. (HIS)	15	2.9	0.7	19
Rush Riv. (RSH)	15	2.8	0.7	18
Blue Earth Ri. (BER)	16	2.8	0.6	24
Le Sueur Riv. (LSR)	25	3.2	0.5	36
Watonwan Riv. (WTW)	24	3.6	0.8	26
Cottonwood R. (COT)	20	2.6	0.5	26
Redwood Riv. (RWR)	18	2.9	0.6	25
Hawk Cr. (HWK)	21	3.0	0.5	25
Yell. Med. R. (YMR)	14	2.6	0.6	29
Tributary Av.	19	2.9	0.6	25
Upper Watersheds				
Beauford (BFD)	9	2.5	0.9	28
Blue Earth (BLE)	18	2.1	0.3	27
County Rd 13 (CR13)	15	2.4	0.5	35
Frost (FRO)	12	1.8	0.4	10
Mountain Lk (MTL)	17	2.4	0.4	14
St. James (STJ)	13	2.0	0.5	29
Wells (WEL)	11	2.8	0.9	15
Camp Pope Cr. (CPC)	16	3.4	0.9	36
Gaylord (GAY)	13	3.0	0.9	24
Upper Watershed Av.	14	2.5	0.6	24

Appendix E

CHECKLIST OF MACROINVERTEBRATE TAXA COLLECTED.

	Mnstem/ Trib.	Upper Wtrshd.
PLATYHELMINTHES		
Dugesia	x	
OLIGOCHAETA	x	x
HIRUDINEA		
Erpobdella	x	x
Glossiphonia		x
Helobdella		x
Placobdella		x
Theromyzon		x
GASTROPODA		
Ferrisia		x
Fossaria		x
Gyraulus		x
Helisoma		x
Lymnea		x
Physella	x	x
Stagnicola		x
PLECYPODA		
Sphaeriidae	x	x
HYDRACARINA	x	
AMPHIPODA		
Gammaus	x	
Hyalella	x	x
ISOPODA		
Asellus		x
DECAPODA		x
INSECTA		
COLLEMBOLA		
Isotomurus		x
Podura		x
ODONATA		
Anax		x
Argia	x	
Calopteryx	x	
Dromogomphus	x	
Enallagma	x	x
Gomphurus	x	
Hetaerina	x	
Nehalennia		x
Stylurus	x	
PLECOPTERA		
Acroneuria	x	
Isoperla	x	
Paracapnia		x
Paragnetina	x	
Perlesta		x
PLECOPTERA (cont).		
Perlinella	x	
Pteronarcys	x	x
HEMIPTERA		
Belastoma		x
Rhagoylea	x	
Salda	x	
Trichocoria	x	
COLEOPTERA		
Agabus	x	x
Ancyronyx	x	
Berosus		x
Curculonidae	x	
Dineutus		x
Dubiraphia		x
Gyrinidae	x	
Halipus		x
Helichus	x	x
Hydrochus		x
Liodessus		x
Macronuchus	x	
Optioservus		x
Stenelmis	x	x
EPHEMEROPTERA		
Ameletus	x	
Baetis	x	x
Brachycercus	x	
Caenis	x	x
Callibaetis		x
Centroptilum	x	
Ephoron	x	x
Heptagenia	x	x
Heterocloen		x
Hexagenia		x
Isonychia	x	x
Leptophlebia		x
Paraleptophlebia	x	x
Parameletus		x
Potomanthus	x	x
Pseudocleon	x	
Stenacron	x	x
Stenonema	x	x
Tricorythodes	x	x
TRICHOPTERA		
Agraylea		x
Cheumatopsyche	x	x
Chimarra	x	
Cyrnellus	x	

Appendix E (cont.)
CHECKLIST OF MACROINVERTEBRATE TAXA.

	Mnstem/ Trib.	Upper Wtrshd.
TRICHOPTERA (cont).		
Dolophilodes	x	
Hydropsyche	x	x
Hydroptila	x	x
Mayatrichia	x	x
Nectopsyche		x
Nyctiophylax		x
Potamyia	x	
Polycentropus	x	
MEGALOPTERA		
Corydalus	x	
Sialis		x
DIPTERA		
Atherix	x	x
Culiseta		x
Empididae	x	
Hemerodromia		x
Hexatoma	x	
Palpomyia		x
Prionocera		x
Simulium	x	x
Tabanus		x
Tipula	x	x

	Mnstem/ Trib.	Upper Wtrshd.
CHIRONOMIDAE		
Ablabesmyia	x	
Brillia		x
Chironomus	x	x
Conchapelopia	x	
Cricotopus	x	x
Cryptochironomus		x
Dicrotendipes	x	x
Endochironomus		x
Goeldichironomus	x	
Glyptotendipes	x	x
Hydrobaenus		x
Kiefferulus	x	x
Microtendipes	x	
Natarsia		x
Nilotanypus		x
Orthocladius	x	x
Parachironomus	x	x
Parametriocnemus		x
Paralauterborniella	x	
Paratanytarsus		x
Paratendipes		x
Pentaneura	x	
Polypedilum	x	x
Procladius	x	x
Psectrocladius	x	x
Pseudochironomus	x	x
Rheocricotopus		x
Rheotanytarsus	x	x
Smittia	x	x
Stenochironomus		x
Stictochironomus	x	x
Tanypus	x	x
Tanytarsus	x	x
Thienemanniella		x
Thiennemannimyia		x

Total Taxa Encountered = 135

Total Mainstem/Tributary Taxa = 81

Total Upper Watershed Taxa = 92

Appendix F

DOMINANT MACROINVERTEBRATES COLLECTED FROM HESTER DENDY SUBSTRATES.

	Mainstem		Tributary		Upper Watershed	
	1989	1990	1989	1990	1991	1992
PLATYHELMINTHES - Dugesia	x [a]					⊗ [b]
OLIGOCHAETA						
HIRUDINEA						
Erpodella						x
Placobdella						x
GASTROPODA - Physella						⊗
AMPHIPODA - Hyalella					x	x
ISOPODA - Asellus						x
PLECOPTERA - Perlesta						x
COLEOPTERA - Stenelmis		x	x	x		
ODONATA						
EPHEMEROPTERA						
Baetis		x		⊗		⊗
Caenis		⊗	x			
Heptagenia					⊗	⊗
Paraleptophlebia						x
Potomanthus				x		
Stenacron			x	x	⊗	⊗
Stenonema	x	⊗	x	x		
Tricorythodes		x	x	x		
TRICHOPTERA						
Cheumatopsyche	⊗	⊗	⊗	⊗	⊗	⊗
Cyrnellus	x					
Hydropsyche	⊗	⊗	⊗	⊗	⊗	⊗
Hydroptila						⊗
Potamyia	⊗	⊗	⊗	x		
Polycentropus			x			
DIPTERA						
Chironomidae						
Ablabesmyia			x			
Chironomus					x	
Cricotopus					⊗	x
Cryptochironomus						x
Dicrotendipes						x
Glyptotendipes	⊗	⊗	⊗	⊗	x	
Hydrobaenus					x	
Orthocladius					⊗	
Parametriocnemus						x
Paratanytarsus					x	
Polypedilum		x	⊗	⊗		
Rheotanytarsus				x	x	
Tanytarsus	x			x	⊗	⊗
Thienemannimyia					x	x
Other						
Culiseta					⊗	
Hemerodromia						x
Simulium						x
Total Dominant Taxa	7	10	12	14	15	22

[a] Common Taxa (> 1% occurrence); [b] Common Taxon (> 5% occurrence)

Appendix G

DOMINANT MACROINVERTEBRATES COLLECTED FROM QUALITATIVE SAMPLES.

	Mainstem		Tributary	
	1989	1990	1989	1990
PLATYHELMINTHES - Dugesia	⊗	x	x	x [a]
OLIGOCHAETA	x			
GASTROPODA - Physella			x	x
AMPHIPODA - Hyalella		⊗ [b]		
HEMIPTERA - Cymatia	⊗			
COLEOPTERA - Stenelmis	⊗	x	⊗	x
ODONATA - Argia	⊗	x		
EPHEMEROPTERA				
Baetis	⊗	x	⊗	⊗
Caenis	x	x		
Isonychia			x	x
Potomanthus	x	x	⊗	⊗
Stenacron	x		x	x
Stenonema	x	x		
Tricorythodes	x	x	x	x
TRICHOPTERA				
Cheumatopsyche	⊗	⊗	x	x
Chimarra			x	x
Hydropsyche	⊗	⊗	⊗	⊗
Potamyia	x	⊗		
DIPTERA				
Chironomidae				
Chironomus	x			
Glyptotendipes	⊗	x		
Polypedilum	x		x	x
Tanytarsus	x			
Other				
Atherix	x		x	
Simulium		x	x	⊗
Total Dominant Taxa	19	14	14	13

[a] Common Taxa (> 1% occurrence); [b] Common Taxon (> 5% occurrence)
Note: No qualitative surveys performed at the upper watershed locations.

Appendix H

CERIODAPHNIA AND SELENASTRUM TOXICITY RESULTS.

A. Ceriodaphnia dubia Acute Test Results - 48 hour duration

Bioassay	Surface Water Samples Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	890815	100	100	-
Jordan (JOR)	890815	100	100	-
Henderson (HEN)	890815	100	100	-
St. Peter (STP)	890815	100	100	-
Judson (JUD)	890816	100	100	-
Courtland (CTD)	890816	100	100	-
Morton (MOR)	890817	100	100	-
Delhi (DEL)	890817	100	100	-
Upper Sioux (UPS)	890817	100	100	-
Rapidan Reservoir	890814	100	100	-
Chippewa Reservoir	890817	100	100	-
Lac Qui Parle Reservoir	890817	100	100	-
High Isl. Cr. (HIS)	890815	100	100	-
Rush Riv. (RSH)	890814	100	100	-
Le Sueur Riv. (LSR)	890814	100	100	-
Watonwan Riv. (WTW)	890815	100	100	-
Cottonwood Riv. (COT)	890816	100	100	-
Hawk Cr. (HWK)	890817	100	100	-
Yell. Med. R. (YMR)	890817	100	100	-

B. Ceriodaphnia dubia Chronic Test Results - 7-day duration

	Sediment Pore Water Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield[a]
Fort Snelling (FSN)	891023	100	80	4
35 W Bridge (35W)	891023	100	100	12
Jordan (JOR)	891023	100	100	23
Henderson (HEN)	891024	100	100	22
St. Peter (STP)	891024	100	100	22
Judson (JUD)	891025	100	100	24
Courtland (CTD)	891026	100	100	25
Morton (MOR)	891025	100	100	23
Delhi (DEL)	891027	100	100	19
Upper Sioux (UPS)	891027	100	100	22
Rapidan Reservoir	891024	100	100	19
Chippewa Reservoir	891025	100	100	22
Lac Qui Parle Reservoir	891025	100	0	< 1
Lac Qui Parle Reservoir	891025	50	100	20
Lac Qui Parle Reservoir	891025	25	100	24
High Isl. Cr. (HIS)	891023	100	100	24
Blue Earth Riv. (BER)	891024	100	100	23
Le Sueur Riv. (LSR)	891024	100	100	20
Watonwan Riv. (WTW)	891024	100	100	22

Appendix H (cont.)

B. Ceriodaphnia dubia Chronic Test Results - 7-day duration.

Cottonwood Riv. (COT)	891026	100	100	19
Hawk Cr. (HWK)	891027	100	100	20
Yell. Med. R. (YMR)	891027	100	100	18

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	900122	100	100	19
Jordan (JOR)	900123	100	100	20
St. Peter (STP)	900123	100	100	21
Courtland (CTD)	900124	100	100	18
Morton (MOR)	900124	100	100	24
Rapidan Reservoir	900124	100	90	18
Rapidan Reservoir	900124	50	100	21
Lac Qui Parle Reservoir	900124	100	0	0
Lac Qui Parle Reservoir	900124	50	100	5
Lac Qui Parle Reservoir	900124	25	100	19
Blue Earth Riv. (BER)	900123	100	100	23
Cottonwood Riv. (COT)	900124	100	100	18

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	900625	100	0	0
Fort Snelling (FSN)	900625	50	0	0
Fort Snelling (FSN)	900625	100	100	15
35 W Bridge (35W)	900625	100	90	6
35 W Bridge (35W)	900625	50	90	6
35 W Bridge (35W)	900625	25	90	10
Jordan (JOR)	900625	100	100	23
St. Peter (STP)	900625	100	100	17
St. Peter (STP)	900625	50	100	20
Courtland (CTD)	900627	100	100	18
Courtland (CTD)	900627	50	100	18
Rapidan Reservoir	900626	100	80	12
Rapidan Reservoir	900626	50	100	16
Rapidan Reservoir	900626	25	90	15
Chippewa Reservoir	900626	100	100	7
Chippewa Reservoir	900626	50	100	21
Chippewa Reservoir	900626	25	90	25
Lac Qui Parle Reservoir	900626	100	0	0
Lac Qui Parle Reservoir	900626	100	100	12
Lac Qui Parle Reservoir	900626	100	100	17
Rush Riv. (RSH)	900625	100	100	22
Rush Riv. (RSH)	900625	50	90	25
Blue Earth Riv. (BER)	900627	100	100	22
Blue Earth Riv. (BER)	900627	50	100	25
Le Sueur Riv. (LSR)	900627	100	100	21
Le Sueur Riv. (LSR)	900627	50	100	28
Watonwan Riv. (WTW)	900627	100	100	26
Watonwan Riv. (WTW)	900627	50	100	26

Appendix H (cont.)

B. Ceriodaphnia dubia Chronic Test Results - 7-day duration.

Cottonwood Riv. (COT)	900627	100	90	22
Cottonwood Riv. (COT)	900627	50	100	22
Yell. Med. R. (YMR)	900627	100	100	20

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	900924	100	100	17
Fort Snelling (FSN)	900924	50	100	29
Fort Snelling (FSN)	900924	25	100	28
35 W Bridge (35W)	900924	100	100	12
35 W Bridge (35W)	900924	50	100	17
35 W Bridge (35W)	900924	25	100	26
Jordan (JOR)	900924	100	100	24
Jordan (JOR)	900924	50	100	24
Henderson (HEN)	900921	100	100	25
Henderson (HEN)	900921	50	50	24
St. Peter (STP)	900921	100	100	13
St. Peter (STP)	900921	50	100	22
Judson (JUD)	900925	100	80	17
Courtland (CTD)	900926	100	100	16
Delhi (DEL)	900927	100	100	14
Rapidan Reservoir	900925	100	80	3
Rapidan Reservoir	900925	50	100	9
High Isl. Cr. (HIS)	900921	100	90	17
Blue Earth Riv. (BER)	900925	100	100	30
Le Sueur Riv. (LSR)	900925	100	90	22
Watonwan Riv. (WTW)	900920	100	100	26
Yell. Med. R. (YMR)	900927	100	100	17

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	920518	100	100	30
Fort Snelling (FSN)	920518	50	100	31
35 W Bridge (35W)	920518	100	100	29
35 W Bridge (35W)	920518	50	100	32
Jordan (JOR)	920518	100	100	31
Henderson (HEN)	920518	100	100	29
Judson (JUD)	920519	100	100	24
Delhi (DEL)	920519	100	100	28
Rapidan Reservoir	920519	100	90	19
Rapidan Reservoir	920519	50	100	28
Rapidan Reservoir	920519	25	100	30
High Isl. Cr. (HIS)	920518	100	100	28
Yell. Med. R. (YMR)	920519	100	100	26

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Wells (WEL)	920722	100	100	27

Appendix H (cont.)

B. Ceriodaphnia dubia Chronic Test Results - 7-day duration.

Wells (WEL)	920722	50	100	29
Camp Pope Cr. (CPC)	920722	100	100	34
Gaylord (GAY)	920721	100	100	31
Gaylord (GAY)	920721	50	100	30

C. Selenastrum capricornutum Chronic Test Results - 4-day duration

Sediment Pore Water

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield [b]
Henderson (HEN)	890814	100	-	29
St. Peter (STP)	890814	100	-	93
Courtland (CTD)	890814	100	-	100
Morton (MOR)	890814	100	-	100
Rapidan Reservoir	890814	100	-	15
Lac Qui Parle Reservoir	890814	100	-	7

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	891023	100	-	22
Henderson (HEN)	891023	100	-	30
St. Peter (STP)	891023	100	-	12
Courtland (CTD)	891023	100	-	55
Morton (MOR)	891023	100	-	45
Rapidan Reservoir	891023	100	-	24
Lac Qui Parle Reservoir	891023	100	-	19

	Sample Date	Sample Conc.	Bioassay Survival	Bioassay Yield
Fort Snelling (FSN)	900625	100	-	30
Jordan (JOR)	900625	100	-	100
St. Peter (STP)	900625	100	-	74
Courtland (CTD)	900625	100	-	100
Rapidan Reservoir	900625	100	-	32
Lac Qui Parle Reservoir	900625	100	-	5
Blue Earth Riv. (BER)	900625	100	-	100
Le Sueur Riv. (LSR)	900625	100	-	100
Watonwan Riv. (WTW)	900625	100	-	100
Cottonwood Riv. (COT)	900625	100	-	100
Yell. Med. R. (YMR)	900625	100	-	100

[a] Ceriodaphnia Yield - Average number of young produced in test concentration.

[b] Selenastrum Yield - Percentage cell number yield against control response.

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