How Clean is the River?

An Examination of the Water Quality of the Upper Mississippi River

June 1989

Prepared by the
Upper Mississippi River Basin Association

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

In the late 1800's and early 1900's the Mississippi River was used for many purposes: river commerce; log transport; commercial fishing, trapping, and hunting; water supply; and disposal of waste. Assuming that the river had an unlimited capacity for waste disposal, municipalities and industries dumped their refuse directly into the river. These waste disposal practices soon backfired as riverfronts and backwaters became smelly, unsightly, and unhealthy places. Eventually water quality laws and regulations were instituted to change waste disposal practices and the river water quality improved. (Merritt, 1984)

Today the river still supports multiple uses and is considered a nationally significant ecosystem as well as a nationally significant commercial navigation system. Through the implementation of federal and state laws regulating discharges to the river, the construction of sewage treatment plants, the introduction of erosion control programs, and increased public awareness and understanding of our river resource, the Mississippi River has been cleaned up so that the smelly, unsightly, and unhealthy conditions of the early 1900's no longer exist. While there are no longer open cesspools, there are, however, still water quality issues that need to be resolved.

Since many of the existing programs pertaining to river water quality are relatively new, state and federal agencies are constantly working to understand and protect water quality. Effects of pollutants on aquatic life and humans, effects of man's activities on river water quality, the relationships between pollutants within the river environment, the suitability of existing regulations, and the development of new regulations are all issues of prime concern. Water quality programs evolve over time as issues are resolved and new questions arise.

The Mississippi River, called the "Muddy Mississippi" by early river travelers, has never been a pristine river. The large amounts of silt the river transports have created the large delta at the river's mouth. While the river is still affected by erosion and sedimentation from adjacent lands, it is now also affected by man's activities. So what is the quality of the river today? How clean is the water? As this report attempts to answer these questions, it will become apparent that this task is not as easy as it may appear.

This report examines the water quality of the Upper Mississippi River from Lock and Dam 1 in Minneapolis, Minnesota to the confluence of the Ohio River at Cairo, Illinois. Since there are five states bordering the river (Minnesota, Wisconsin, Iowa, Illinois, and Missouri) there are five different sets of rules governing activities that affect the river. Each of the states decides on acceptable discharge levels and uses of the river based on their definition of acceptable water quality. Water quality is thus examined on a state-by-state basis as well as on a basinwide basis. Water quality standards of the five states bordering the river are compared and the water quality of the river system is examined.

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WATER QUALITY STANDARDS

Determining the quality of a water body is a fairly difficult and subjective exercise. Perceptions of water quality vary depending on the purposes for which water is used. Public health concerns, fish and wildlife concerns, or industry needs will all likely result in different assessments of the quality of water. To provide a consistent assessment of water quality, it is necessary to have a quantitative means by which to measure water quality. This is done through the use of both numeric and narrative standards.

The standards are derived through research, past experiences, and expert opinions. The Environmental Protection Agency (EPA) has published guidelines for developing standards based on their research efforts. Some states have conducted their own research or have utilized information from neighboring states. Epidemiologic studies and past experiences with such things as fish kills, health problems, or algae outbreaks, have given resource managers a good idea of minimum acceptable standards for the commonly monitored parameters. Expert opinions are utilized to determine the margin of safety and to produce standards for substances which are just presently being found in the water column or might potentially exist.

Since different uses of a water resource require different degrees of water quality, the states have designated uses for water bodies and have developed variable standards based on the use. The standards for using the water as a drinking water supply are much more restrictive than the standards for industrial use. Thus the states have had to decide for what uses they will regulate water quality in different streams, lakes, and rivers. In most cases the designated use of a water body is simply the existing or historic use and is determined by the existing water quality. The designated uses are listed in Table 1.

Each state designates uses in a slightly different way. Illinois has one designated general use with one set of standards. However, this "general" use and its standards include four different specific types of uses. The other states designate specific uses with each use having its own set of standards. Iowa, Missouri, and Wisconsin go further than the classification of "aquatic life" by delineating between warm water aquatic communities and cold water aquatic communities. Minnesota has the most detailed use designation and standards. As shown by the designated use codes in Table 1, Minnesota has degrees of standards within a use. Examining the "1D" classification, the 1 stands for domestic consumption and the D stands for a degree of domestic consumption. "1A" represents the highest quality water for domestic consumption and therefore these waters are subject to more restrictive standards. "1D" is the lowest quality water acceptable for domestic consumption and thus it has less restrictive standards. The fisheries, industrial, and agricultural use classifications for Minnesota utilize this same type of designation.

The different use designations each have their own distinct water quality standards. The parameters regulated for one use though, are not always the same parameters regulated for the other uses. For example, while dissolved oxygen levels are critical to aquatic life they do not directly affect the use of the water for recreation. Thus dissolved oxygen levels are not regulated for the recreation use. When the same parameter is regulated for two or more uses the standard usually differs since different uses require different quality. In addition, the same designated use in the five states does not always have the same regulated parameters.

The designated uses of the Upper Mississippi river vary geographically. The most restrictive use for which the entire river is protected is aquatic life. The river is designated as a drinking water supply in Minnesota and Missouri and in parts of Iowa where there are drinking water intakes. While the river reach in Minnesota by the Metro treatment plant is designated as a drinking water supply it is not a recom-

Table 1. Designated Use(s) for the Mississippi River

	Designated Use(s)	Designated Use Code	Affected River Reach
Illinois	General (Primary and Secondary Body Contact, Aquatic Life, Agriculture, Most Industrial Uses)	---	Entire river
Iowa	Primary Body Contact Recreation Wildlife, Warm Water Aquatic Life, and Secondary Body Contact	A B(w)	Entire river except 3 municipal water works intakes
	Raw Water Source of Potable Water Supply	C	Keokuk, Fort Madison and Burlington Municipal Water Works Intakes
Minnesota	Domestic Consumption Fisheries and Recreation Class B Industrial Consumption Class B Agriculture and Wildlife Class A Aesthetic Enjoyment and Navigation Other uses	1D 2B 3B 4A 5 6	Entire river from Lock and Dam 1 to the Iowa border except reach from Metro Plant to River Mile 830
	Domestic Consumption Fisheries and Recreation Class C Industrial Consumption Class B Agriculture and Wildlife Class A Aesthetic Enjoyment and Navigation Other uses	1D 2C 3B 4A 5 6	Metro Plant to River Mile 830 (Rock Island Railroad Bridge)
Missouri	Protection of Aquatic Life Drinking Water Supply Livestock/Wildlife Watering Whole Body Contact Recreation	I II IV V	Iowa-Missouri Border to confluence of Missouri River
	Protection of Aquatic Life Drinking Water Supply Irrigation Livestock/Wildlife Watering	I II III IV	Missouri River confluence to confluence of Ohio River
Wisconsin	Warm Water Sportfish Communities Recreation Wild and Domestic Animals Public Health and Welfare	C --- --- ---	Entire river

mended use and the water quality must only be "generally comparable" to the standards for domestic consumption. Since there are no drinking water intakes on the river in Wisconsin, this use is not designated.

Since the standards for the different uses vary, the strictest standard in water bodies with more than one use is the maximum acceptable value. For example, in Missouri the allowable concentration of arsenic in water used as a drinking water supply is 50 ug/l whereas the allowable concentration for protection of aquatic life is 20 ug/l. Since the river is designated for both uses, the maximum allowable concentration of arsenic is 20 ug/l since this is more restrictive.

Tables 2 and 3 list the most restrictive water quality standards for the designated uses of the Mississippi River in the five states. The standards for uses that are not designated for the Mississippi River may be more restrictive but are not listed in the tables since they do not apply to the Mississippi River. For example, in Missouri the most restrictive standard for antimony levels in the Mississippi River is 146 ug/l. In Wisconsin, however, the most restrictive standard for antimony is 7800 ug/l. The 146 ug/l standard in Missouri applies to water bodies used as a drinking water supply. The 7800 ug/l standard in Wisconsin applies to a human threshold level for ingestion of aquatic organisms. Since the two states' standards are designed for different uses, the standards vary considerably. Wisconsin does not designate the Mississippi River as a drinking water supply. But if they did, the drinking water supply standard for antimony would be 0.00012 ug/l which is considerably more restrictive than the drinking water supply standard in Missouri.

Cumulatively there are a total of 136 numeric water quality standards. There are standards for 51 inorganic parameters and for 85 organic parameters. The five states have standards for only 13 of the same parameters (arsenic, cadmium, chromium, copper, cyanide, dissolved oxygen, fecal coliform, lead, pH, phenols, selenium, silver, and temperature). The standards for only 4 of these parameters (dissolved oxygen, fecal coliform, pH, and temperature) are similar in all the states. Only the states of Missouri and Wisconsin have numeric standards for the organic parameters. Minnesota is presently reviewing standards for organic parameters. Following is a comparison of each state's numeric water quality standards for the parameters that are applicable to the Mississippi River.

Inorganic Parameters

Illinois has numeric standards for 31 inorganic parameters. Overall the standards are either less restrictive or similar to the other states'. In only one case (fluoride) is the standard more restrictive. Illinois has standards for two parameters (total phosphorus and strontium 90) that are not regulated in the other states.

Iowa has numeric standards for 27 inorganic parameters. Overall the standards are very similar to those in the other states. However, there are four parameters that are applicable to Mississippi River water used as drinking water supplies for which Iowa has standards but the other states do not. These include beta particle and photon radioactivity, gross alpha particle activity, radium 226 and 228, and tritium. Iowa's water quality policy states that while the Mississippi River does not meet their existing high quality waters criteria, the resource is considered to be of exceptional state and national significance and therefore all activities are to be directed towards improvement of water quality.

Minnesota has numeric inorganic standards for 27 parameters. Overall Minnesota's standards are comparable to the other states' but are more restrictive for pH and boron. Minnesota has standards for 6 parameters (bicarbonates, hardness, hydrogen sulfide, total dissolved salts, specific conductance, and sodium) that are not regulated in the other states' standards.

Missouri has numeric standards for 84 parameters -- 32 for inorganic parameters

Table 2. State Water Quality Standards Pertinent to Mississippi River*

Inorganic Parameters**

		ILLINOIS	IOWA		MINNESOTA		MISSOURI		WISCONSIN+
			A & B(w)	C	1D, 2B, 3B, 4A, 4B, 5, 6	1D, 2C, 3B, 4A, 4B, 5, 6	I, II IV, V	I - IV	
Ammonia Nitrogen	mg/l	15(c)	2-5 (seasonal)						
Ammonia, Unionized	mg/l	0.04			0.04	0.04	(c)	(c)	0.04
Antimony	ug/l						146	146	7,800
Arsenic	ug/l	1,000	100	50	50	50	20	20	50
Barium	ug/l	5,000	1,000	1,000	1,000	1,000	1,000	1,000	
Beryllium	ug/l						5	5	0.2
Beta Particle and Photon Rad.	mrem/yr			4					
Bicarbonates	meq/l				5	5			
Boron	ug/l	1,000			500	500		2,000	
Cadmium	ug/l	50	10	10	10	10	10	10	0.81
Chlorine, Total Residual	ug/l		25		5	5	2	2	7.06
Chloride	mg/l	500		250	100	100	250	250	
Chromium	ug/l	50 (hexavalent) 1,000 (trivalent)	50 (hexavalent)	50 (hexavalent)	50	50	50	50	9.74 (hexavalent) 79.06 (trivalent)
Cobalt	ug/l						1,000	1,000	
Copper	ug/l	20	20	1,000	10	10	20(Diss.)	20(Diss.)	17.88
Cyanide	ug/l	25	5	20	20	20	5	5	4.96
Fecal Coliform	#/100 ml	200	200	200	200	200	200		200
Fluoride	mg/l	1.4		2.0	1.5	1.5	2.2	2.2	
Gases, Total Dissolved	% sat.						110	110	
Gross alpha particle activity	pCi/l			15					
Gross beta	pCi/l	100							
Hardness	mg/l				250	250			
Hydrogen Sulfide - S	mg/l				0.02	0.02			
Iron, Dissolved	ug/l						1,000	1,000	
Iron, Total	ug/l	1,000					300	300	
Lead	ug/l	100	100	50	50	50	50	50	18.66
Manganese	ug/l	1,000					50	50	
Mercury	ug/l	0.5	0.05	2			0.5	0.5	0.002
Nickel	ug/l	1,000					100	100	97.79
Nitrate - N	mg/l			45			10	10	
Oil	mg/l	15			0.5	10			
Oxygen, Dissolved	mg/l	6 (16 hrs.) 5	5 (16 hrs.) 4 (24 hrs.)		5	4(b) 5 (24 hrs.)	5	5	5
pH	standard units	6.5-9.0	6.5-9.0	6.5-9.0	6.5-8.5	6.5-8.5	6.5-9.0	6.5-9.0	6.0-9.0
Phenols	ug/l	100	50	50	10	100	1	1	160,000
Phosphorous, Total	mg/l	0.05							
Radium 226	pCi/l	1							
Radium 226 and 228	pCi/l			5					
Salts, Total Dissolved	mg/l				700	700			
Selenium	ug/l	1,000	100	10	10	10	10	10	7.07
Silver	ug/l	5		50	50	50	5	5	3.48
Specific Conductance	us/cm				1,000	1,000			
Sodium	meq/l				60% of total cations	60% of total cations			
Solids, Total Dissolved	mg/l	1,000	750	750					
Strontium 90	pCi/l	2							
Sulfate	mg/l	500					250	250	
Temperature	°F	not >89°(a)	5.4° above normal, not >86°	5.4° above normal, not >86°	5° above normal, not >86°	5° above normal, not >90°	not >89°(a)	not >89°(a)	5° above normal, not >89°
Thallium	ug/l						13	13	11
Tritium	pCi/l			20,000					
Turbidity	NTU		not >25 increase by point source	not >25 increase by point source	25	25			
Zinc	ug/l	1,000	1,000	1,000			345	345	73.37

* The units have been standardized between the five states.
** Iowa, Minnesota, and Missouri have different designated uses for various river reaches. The key for the designated use codes (e.g. A, 1D, I) is shown in Table 1.
+ See Appendix A for more detail.
(a) Maximum allowable water temperature varies monthly and spatially on the river.
(b) Reach of river from the outlet of the metro treatment plant in St. Paul to Lock and Dam 2 -- not less than 5 mg/l as a daily average from April 1 to November 30, and not less than 4 mg/l at other times.
(c) Dependent on pH and temperature.

Key: meq/l - milliequivalents per liter
mg/l - milligram per liter (10^{-3})
ml - milliliter
mrem/yr - millirem per year
ng/l - nanogram per liter (10^{-9})
pCi/l - picocurie per liter
ug/l - microgram per liter (10^{-6})
us/cm - microohms per centimeter

Source: Illinois Title 35 Part 302-303
Iowa Chapter 61
Minnesota Rules Chapter 7050
Missouri 10CSR 20-7.031 and revisions effective 4/15/89
Wisconsin Chapters NR102 and NR105

Table 3. State Water Quality Standards Pertinent to Mississippi River

Organic Parameters*
(All units are in ug/l except Dioxin which is measured in ng/l)

Parameter	Missouri I, II IV, V	Missouri I - IV	Wisconsin+
Acenaphthene	20	20	
Acrolein	320	320	470
Acrylonitrile	0.058	0.058	4.7
Aldrin	0.000074	0.000074	0.00057
Alpha; beta, delta - BHC	0.0022	0.0022	
Benzene	5.0	5.0	140
Benzidene	0.00053	0.00053	0.0038
Benzo(a)pyrene			0.1
BHC, alpha			0.15
BHC, beta			0.27
BHC, technical grade			0.2
Bis (2-chloroethyl) ether	0.03	0.03	8.8
Bis (2-chloroisopropyl) ether	35	35	1,100
Bis (chloromethyl) ether			0.0034
Carbon Tetrachloride	5.0	5.0	31
Chlordane	0.00046	0.00046	0.0044
Chlorobenzene	20	20	14,000
Chloroform (trichloromethane)			87
2-Chlorophenol	0.1	0.1	
Chlorpyrifos	0.033	0.033	
2,4 - D	100	100	
DDT	0.000024	0.000024	0.00014
Demeton	0.1	0.1	
Di-n-butyl phthalate			65,000
Dichlorobenzene	400	400	
1,2 - Dichlorobenzene			10,000
1,3 - Dichlorobenzene			13,000
1,4 - Dichlorobenzene			100
3,3'- Dichlorobenzidene	0.01	0.01	0.16
1,1 - Dichloroethane			48
1,2 - Dichloroethane	5.0	5.0	370
cis - 1,2 - Dichloroethene			15,000
trans - 1,2 - Dichloroethene			15,000
1,1 - Dichloroethylene	7	7	
Dichloromethane (methylene chloride)			3,600
2,4 - Dichlorophenol	7	7	10,000
Dichloropropene(s)	87	87	3,200
Dieldrin	0.000071	0.000071	0.00057
Di-2-ethylhexyl phthalate			30,000
Diethyl phthalate			1,100,000
Dimethyl phthalate			1,700,000
4,6 - Dinitro-o-cresol			220
Dinitrophenols			3,000
2,4 = Dinitrotoluene			260
Dioxin - 2,3,7,8 - TCDD	0.000014	0.000014	0.0001
1,2 - Diphenylhydrazine			2.4
Endosulfan	0.056	0.056	0.321
Endrin	0.0023	0.0023	0.069
Ethylbenzene	320	320	10,000
Fluoroanthene	40	40	32
Guthion	0.01	0.01	
Halomethanes			87
Heptachlor	0.00028	0.00028	0.0014
Hexachlorobenzene	0.00072	0.00072	0.0055
Hexachlorobutodiene	0.45	0.45	160
Hexachlorocyclopentadiene	0.5	0.5	7,100
Hexachloroethane	1.9	1.9	65
Isophorone	5,200	5,200	170,000
Lindane - Gamma BHC	0.0022	0.0022	0.3
Malathion	0.1	0.1	
Methanes, halogenated	0.19	0.19	
Methoxychlor	0.03	0.03	
Mirex	0.001	0.001	
Nitrobenzene	30	30	540,000
N-Nitrosodi-n-butylamine			1.9
N-Nitrosodiethylamine			1.1
N-Nitrosodimethylamine	0.0014	0.0014	1.8
N-Nitrosodiphenylamine			120
N-Nitrosopyrrolidine			29
Parathion	0.04	0.04	0.0141

Table 3. (Continued)

Parameter	Missouri I, II IV, V	Missouri I - IV	Wisconsin+
Pentachlorobenzene			51
Pentachlorophenol	3.2 - 39 (varies with pH)	3.2 - 39 (varies with pH)	(varies with pH and temperature)
Polychlorinated Biphenyls - PCBs	0.0000079	0.0000079	0.00049++
Polynuclear Aromatic Hydrocarbons			0.1
1,2,4,5 - Tetrachlorobenzene			28,000
1,1,2,2 - Tetrachloroethane			64
Tetrachloroethene			49
Tetrachloroethylene	0.8	0.8	
Toluene			110,000
Toxaphene	0.000073	0.000073	0.0057
2,4,5 - TP	10	10	3,700
1,1,1 - Trichloroethane	200	200	33,000
1,1,2 - Trichloroethane			140
Trichloroethene			360
Trichloroethylene	5.0	5.0	
2,4,6 - Trichlorophenol			18
Vinyl Chloride	2	2	10

* Illinois, Iowa, and Minnesota do not have numeric standards for the organic parameters.

\+ See Appendix A for more detail.

++ Includes Aroclors 1254 and 1260

Source: Missouri 10OCSR 20-7.031 and revisions effective 4/15/89
Wisconsin Chapters NR105

and 52 for organic parameters. Overall Missouri's standards for the inorganic parameters are comparable to the other states'. However, Missouri has standards for 3 parameters (cobalt, total dissolved gases, and dissolved iron) that are not regulated by the other states. Missouri has just revised its standards to include both chronic and acute toxicity numbers for protection of aquatic life. The standards for many of the metals are based on the hardness of the water.

Wisconsin has numeric standards for 93 parameters -- 21 for inorganic parameters and 72 for organic parameters. The inorganic standards are comparable to the other states for most parameters but are considerably less restrictive or more restrictive in a few cases. The standards for antimony and phenols are exceedingly less restrictive than those standards for the other states. This is due to the fact that the standard is based on a designated use (human threshold level for consumption of fish) which is not represented in the other states' standards. The exceedingly more restrictive standards are primarily for the toxic metals (cadmium, chromium, lead, mercury). These standards are based on chronic toxicity to aquatic life which may not be represented by Illinois', Iowa's, or Minnesota's standards. As with the state of Missouri, many of the standards for the metals are dependent on water hardness. Wisconsin has recently revised its standards to include different effect levels on aquatic life, domestic animals, and humans. Since this approach is unique to Wisconsin, the Wisconsin standards are detailed in Appendix A.

Organic Parameters

Two states, Missouri and Wisconsin, have standards for organic parameters. The organics include such substances as pesticides, herbicides, solvents, and cleaning agents. Many of these substances bioaccumulate in the food chain and are very persistent in the environment. Even minute quantities such as nanograms/liter (10^{-9}) are not acceptable in the river. Missouri's standards are based on the 10^{-6} cancer risk level (1 additional cancer case per 1 million people) for long term fish and water consumption. Wisconsin's standards are based on effects to humans, aquatic life, and domestic animals. The standards for public health include 1) a human threshold criteria that is based on effects to the reproductive or nervous system from ingestion of water or aquatic organisms and 2) a human cancer criteria based on a 10^{-5} cancer risk level for contact with or ingestion of surface waters or aquatic organisms. The protection of aquatic life is based upon both an acute and chronic toxicity standard. The standards for the organic parameters are shown in Table 3.

The standards for many of the 88 organic parameters were determined by extrapolation of data from animal studies in which a "no observable effect level" was determined. Many of the standards determined through this method are for minute quantities of a substance like a nanogram/liter (10^{-9}) or less. Since the current levels at which a substance can be detected (detection limit) are in the micrograms/liter (10^{-6}) range, many of the standards are below the detection limit. Therefore any detect of these substances is considered above the standard and not acceptable.

In addition to the numeric standards each of the states have narrative standards that address water quality regardless of use. Basically, these standards prohibit:

- unnatural sludge, bottom deposits, floating debris, oil, grease, or scum,

- materials producing color, odor, taste, or unsightliness, and

- substances or conditions in sufficient amounts to have a harmful effect on human, animal, or aquatic life.

Summary

The water quality standards are used as a quantitative measure of water quality and also as a criteria for determining the allowable level of contaminants in discharges to water bodies. Facilities such as public wastewater treatment plants or industrial plants which discharge into the river are required to have a permit which limits the allowable concentration of substances in the discharge or at some downstream point. If the water quality standard for a substance is very restrictive, the allowable concentration of that substance will be small or possibly disallowed. For the purposes of this report, water quality standards are used to describe ambient quality. Their regulatory use in the states' permitting process is not examined in this report.

The water quality standards are an important first step in understanding the quality of the Mississippi River since they affect the way the states determine and describe water quality. A state with less restrictive water quality standards will likely consider the water quality of the river to be better than that described by a state with more restrictive standards. With less restrictive standards, there will likely be fewer exceedances of the standard. Similarly, a state with fewer standards for a designated use will likely find fewer exceedances since there are fewer standards to exceed. Thus the states' descriptions of water quality vary depending on the number, type, and severity of the standards.

DETERMINATION OF WATER QUALITY

Since water quality is a subjective and complex issue there are various ways to assess the quality of a water body. A monitoring network can be developed that will provide representative samples of the water body. Evaluations or surveys by resource managers can be used. Some states even use citizen complaints about water quality in their assessment of the resource. Since water quality monitoring and regulatory programs vary among the states, two states sharing the same body of water can describe the quality of that same resource differently.

This section of the report will examine the water quality of the Upper Mississippi River. Since no single approach is sufficient to understand the complex and dynamic nature of water quality, river water quality will be examined through five different methods. Water quality will first be examined by looking at exceedances of water quality standards and guidelines. Second, the water quality of the Upper Mississippi River as discussed in the states' 305(b) Water Quality Reports will be examined. This examination will look at how well the Mississippi River supports the national goal of fishable/ swimmable uses. Third, the quality of the fishery resource will be examined since this resource is affected by water quality. Fourth, the quality of the sediment in the river will be discussed in terms of its relation to water quality. Fifth, water quality trends will be examined based on data from federal and state monitoring networks.

Exceedances of Water Quality Standards/Guidelines

Comparison of Past and Present Exceedances

Water quality standards and guidelines provide one mechanism by which to assess the condition of the resource. As more information is gained about contaminants, water resources, and relationships within the aquatic environment, the standards are revised to more adequately protect the designated uses of the resource. This section of the report discusses water quality based on exceedances of standards and guidelines in the 1970's and in the 1980's.

In 1981, a study of the water quality of the Upper Mississippi River was conducted for the water years (October to September) 1977 and 1979. (Chesters, et al., 1981) Data from various sources covering 48 monitoring sites on the river was used for the study. Besides the conventional water quality parameters which include among others, temperature, turbidity, and dissolved oxygen, the study also examined PCBs, pesticides, and toxic metals and organics in fish tissue. The most stringent water quality guidelines of the states bordering the Mississippi River and the EPA water quality standards were used for the examination.

As shown in Table 4, the most pervasive problems that were discovered on the river in 1977 and 1979 were high levels of phosphorous, mercury, and fecal coliform. The phosphorous levels were considered to be associated with high sediment loads in the river since phosphorous load is closely associated with sediment. The high mercury levels were attributed to possible contamination during analysis since they were much higher than expected. (A comparison with present day mercury levels shows that the 1977 and 1979 values are consistent with existing mercury levels.) Insufficient treatment of sewage and agricultural nonpoint pollution were considered to be the causes of the high fecal coliform levels.

The most serious problems on the river in 1977 and 1979 occurred between Minneapolis and Lock and Dam 2 and downstream of Clinton, IA. The Minneapolis-St. Paul region had problems with excessive amounts of toxic metals, turbidity, pH, and low dissolved oxygen levels. Downstream of Clinton, toxic metals and turbidity values were high and some local problems existed with low dissolved oxygen levels and high PCB levels in fish.

Table 4. Areas of the UMRS Having Water Quality Problems, 1977 and 1979

Location	Parameter Exceeded
Minneapolis-St. Paul, MN (Pools 1-2)	dissolved oxygen, toxic metals, turbidity
Below St. Paul to Hastings, MN (Pool 2)	pH, dissolved oxygen, toxic metals, turbidity
Red Wing, MN (Pools 3-4)	copper
Lake Pepin area (Pool 4)	PCBs in fish, copper
Alma, WI (Pool 4)	dissolved oxygen
Pool 5	turbidity, copper
Winona, MN (Pool 6)	toxic metals
La Crosse, WI (Pool 8)	PCBs in fish, copper
Lynxville, WI (Pool 9)	pH, PCBs in fish, copper
Cassville, WI (Pool 11)	PCBs in fish
Clinton, IA to Thebes, IL (Pool 14- Reach 4)	toxic metals, turbidity
Cape Girardeau, MO (Reach 4)	PCBs in fish
Thebes, IL (Reach 4)	dissolved oxygen
All areas except Pools 3-4, 9-12	fecal coliform
All areas	total phosphorous, mercury

Source: Chesters et al., 1981

The number of exceedances and the parameters that were exceeded in 1977 and 1979 can be compared to exceedances of the states' standards in the 1980's. Minnesota, Illinois, and Iowa utilize the EPA STORET computer program to produce an exceedance report which lists the water quality parameters that exceed the state standards. Wisconsin and Missouri do not routinely use exceedance reports in their water quality determinations. [For a review of Wisconsin's ambient monitoring program see Sullivan, 1989.] The existing state standards are the same or less restrictive than those used in the 1981 study.

Table 5 lists the water quality exceedances by state (MN, IL, IA) for the 1980's. Clinton and Keokuk are listed twice in the table since both Iowa and Illinois utilize the data from these stations to determine water quality. The periods of record range from six years to nine years.

[Iowa has listed exceedances for the dissolved form of the toxic metals although there are no standards for these parameters. Since some of the state agencies only sample for dissolved metals the Iowa DNR uses this data to supplement their sampling program for total metals. Since the level of the dissolved metal is lower than the level of the total metal, an exceedance of the standard by a dissolved metal is considered an exceedance of the total metal standard. Thus dissolved metals are used to determine exceedances of the total metal standards.]

The parameter which exceeds the state standard at every station is fecal coliform. The highest frequency of exceedances is at Thebes, IL (100 percent) and St. Paul, MN (61 percent). pH and total copper are the only other parameters for which exceedances are found in all three states. Dissolved oxygen exceedances occur occasionally at almost all the stations below Clinton, Iowa.

Table 5. Violations of State Water Quality Standards
Percent Violations (Total Number of Samples)

	Period of Record	Ammonia, Unionized	Cadmium, Dissolved	Cadmium, Total	Copper, Dissolved	Copper, Total	Cyanide, Total	Fecal Coliform	Iron, Total	Lead, Total
MINNESOTA										
STANDARD		0.04	NS	10	NS	10	20	200	NS	50
St. Paul, MN	1980-1988	3.3%(90)				12.1%(33)		61%(66)		
Lock and Dam 5	1980-1988							15.2%(66)		
La Crosse, WI	1980-1988	1.3%(80)						20%(66)		
La Moille, MN	1980-1988							15.7%(51)		
ILLINOIS										
STANDARD		0.04	NS	50	NS	20	25	200	1000	100
Clinton, IA	1983-1988					6.3%		31.6%	62.5%	
Keokuk, IA	1983-1988							38.1%	70.6%	
Below Alton, IL	1980-1988					36%		51%	76%	4%
Thebes, IL	1983-1988			15%		35%		100%	100%	15%
IOWA										
STANDARD		NS	10*	10	20*	20	5	200	NS	100
Lock and Dam 9	1980-1986							7%(58)		
Clinton, IA	1980-1988		2%(43)	4%(27)	2%(43)	7%(27)	11%(19)	30.4%(23)		
Davenport, IA	1980-1986							53%(17)		
Keokuk, IA	1980-1988					14%(29)	5%(20)	38%(32)		

Table 5. (Continued)

	Period of Record	Manganese, Total	Mercury, Dissolved	Mercury, Total	Oxygen, Dissolved	pH	Silver Total	Turbidity
MINNESOTA								
STANDARD		NS	NS	NS	4/5	6.5 - 8.5	50	25
St. Paul, MN	1980-1988					1.1%(91)		23.5%(17)
Lock and Dam 5	1980-1988					9.9%(81)		
La Crosse, WI	1980-1988					20%(80)		
La Moille, MN	1980-1988					19%(63)		
ILLINOIS								
STANDARD		1000	NS	0.5	5/6	6.5 - 9.0	5	NS
Clinton, IA	1983-1988				4%	7.7%		
Keokuk, IA	1983-1988				4.2%			
Below Alton, IL	1980-1988			4.2%	5.0%			
Thebes, IL	1983-1988	5%			3.6%		10%	
IOWA								
STANDARD		NS	0.05*	0.05	4/5	6.5 - 9.0	NS	not >25 increase
Lock and Dam 9	1980-1986		35%(23)	36%(28)	4%(56)			
Clinton, IA	1980-1988		21%(24)	33%(27)	4%(55)	2.3%(84)		
Davenport, IA	1980-1985			8%(13)		2.3%(44)		
Keokuk, IA	1980-1988				1%(100)	2.8%(107)		

NS - No Standard
* - The number used for the dissolved metals is the standard for total metals.

Of the 16 parameters which had exceedances, only 7 of the parameters have standards in all three states. Of those 7 parameters, only one parameter, fecal coliform, has the same standard in all three states. Since the fecal coliform standard is the only consistent standard among the states, it is the only exceedance that is directly comparable along the length of the river. Although the three states all have standards for the 6 other parameters, the standards vary and thus the exceedances of these standards are not directly comparable. Unless a comparable set of standards is used by the states, examination of water quality exceedances on a basinwide level is difficult and can be misleading.

The same limitations hold true when the exceedances in 1977 and 1979 are compared to exceedances in the 1980's. When the results from the 1981 study and present day exceedances are compared they look similar in that fecal coliform is still a problem on the entire river and there are still occasional exceedances of the pH, dissolved oxygen, and toxic metals standards. The fecal coliform comparison is the only truly valid comparison which can be made since the fecal coliform standard of 200 colonies/100 ml is used in both the present and in the past study. Fecal coliform exceedances have continued over the years and are still a major water quality problem on the river.

In 1977 and 1979 mercury standards were exceeded in Iowa and Illinois. However, the mercury problem in the 1980's does not appear as widespread as it was in the 1970's. This is likely because the standard used for comparison is different. The standard for mercury is 0.05 ug/l in Iowa and 0.5 ug/l in Illinois as compared to the more restrictive 0.0017 ug/l value used in the 1981 study. Since Minnesota does not have a standard for mercury, its mercury levels could not be compared. Thus, the apparent decreased mercury problem in the 1980's is likely only the result of differing standards or nonexistent standards.

Phosphorous was a problem in the 1981 study but it does not show up as an exceedance in the 1980's. This is partly due to the fact that neither Minnesota nor Iowa have a standard for phosphorous levels in the river. Illinois has a standard but had no exceedances in the 1980's. It is possible that the phosphate bans instituted in the 1980's have alleviated the phosphorous problem.

Water Quality of Major Metropolitan Areas

There are two major metropolitan areas on the river, Minneapolis/St. Paul, Minnesota and St. Louis, Missouri. Since these two areas have an effect on the quality of the river, this report examines the special water quality problems in the metro areas. A 1988 toxics study of the Minneapolis-St. Paul area and studies conducted in 1981, 1982, and 1988 of the St. Louis area are discussed.

Minneapolis/St. Paul Metro Area

In 1988, the Minneapolis/St. Paul Metropolitan Waste Control Commission (MWCC) published a Toxics Assessment Report on the river in the Twin Cities. The report examines toxics monitoring data from 1981-1987 and compares the data to draft water quality standards proposed by the Minnesota Pollution Control Agency for 47 toxic inorganic and organic compounds. The compounds examined in the study are listed in Appendix B.

The MWCC report indicates that three stations on the navigable portion of the river in the Twin Cities area (St. Paul - River Mile 839.1, Grey Cloud - River Mile 826.7, and Hastings - River Mile 815.6) had levels of inorganics and organics that would have occasionally exceeded the draft water quality standards if they had been in effect. A total of seven metals (cadmium, copper, hexavalent chromium, lead, mercury, silver, zinc) and phenols were found at concentrations exceeding the draft standards in various years. Five pesticides (chlordane, dieldrin, endrin, endrin aldehyde, heptachlor) and PCBs would have exceeded the draft standards. All the pesticide exceedances occurred in 1981 but there was no pesticide sampling from 1982 to 1987 so it is not known whether there were exceedances in those years. None of the other draft standards for the organics were exceeded.

If the 1981-1987 concentrations of the metals and organics are compared to the existing standards, the water quality would look better. Only the occurrences of phenols and copper would still be over the standard. The draft standards are more restrictive than existing standards for six of the seven metals which had exceedances (excluding copper), and contain criteria for the organics for which there are presently no definitive standards. It is interesting to note how different the water quality appears when based on more restrictive standards which are designed to protect human and aquatic life and to protect against bioaccumulation, a problem in the Twin Cities area under the existing standards.

While there are no recent exceedances (1982 to 1987) of the draft water quality standards for the organics, this does not mean that there is no release of pesticides or other substances into the river in the metro area. Many organic compounds are not yet regulated since there are no standards for these compounds. Nonpoint source pollution from the Minnesota River is considered a major problem due to its detrimental effect on the Mississippi River. Combined sewer overflow is gradually being eliminated but is still a problem in the metro area. Overall, there is still a considerable pollutant load from the Twin Cities area as compared to non-metro portions of the river.

St. Louis Metro Area

In 1981, the Illinois EPA conducted a study of the water quality in the Mississippi River at St. Louis and the effect of the wastewater effluent from seven wastewater treatment plants. The water quality portion of the study consisted of sampling on a transect across the river at seven sampling stations. Each transect consisted of a sample site on the west side of the river, the center, and the east side of the river. Because of the influx of the Missouri River north of St. Louis, the Mississippi River flow past St. Louis is typically characterized by three flow streams. Flow on the western side of the river is predominantly Missouri River water and flow on the eastern side is predominantly the Upper Mississippi River. The flow in the center is a mixture of the two rivers. Thorough horizontal mixing of the two rivers may occur more than 30 miles downstream. (Black and Veatch, 1982) The sampling stations extended from river mile 184 (above St. Louis) to river mile 168.5 (below St. Louis and all the metro treatment plant outfalls). Samples were analyzed for four field parameters (temperature, pH, conductivity, dissolved oxygen), 14 non-metal constituents, 22 metals and metalloids, and several organic contaminants.

In 1982, a study was conducted by Black and Veatch for the Metropolitan St. Louis Sewer District to determine the impact of toxic materials upon the Mississippi River near St. Louis. The study examined both water and sediment for 126 priority pollutants. Sampling was conducted upstream of St. Louis near river mile 195, downstream near river mile 167, at wastewater treatment plant influent and effluent points in the St. Louis metro area, and at the combined sewer outlets. Due to the horizontal stratification of the river in St. Louis, samples were collected at three points along a transect at the upstream and downstream stations.

In the 1981 study, eight inorganic pollutants were in violation of Illinois water quality standards -- dissolved oxygen, fecal coliform, phenols, total copper, total dissolved solids, total iron, total manganese, and total silver. In addition three organics (pentachlorophenol, alachlor, and chlordane) were detected in some river transect water samples, but not at concentrations considered toxic to aquatic life. In general, temperature, conductivity, total suspended solids, fecal coliform, total phosphorus, and sulfate were higher on the west side of the river. Dissolved oxygen, pH, nitrate plus nitrite, and chloride were higher on the east side of the river.

Out of all the water samples collected at the river in the 1982 study, a total of 31 different pollutants were identified: 22 pollutants at the upstream station on the west side of the river, 27 on the upstream east side and center of the river, 26 downstream on the west side of the river, and 28 on the downstream east side and center of the river. Appendix C lists the identified priority pollutants and their frequency of occurrence. Four of the pollutants (phenols, cadmium, copper, zinc) on the west side of the river exceeded the Missouri standards and seven of the pollutants (phenols, cyanide, cadmium, chromium, copper, nickel, zinc) on the east side and center exceeded the standards. One pollutant ((bis 2-ethylhexyl) phthalate) was found at concentrations above the EPA aquatic life limit. Missouri does not have a water quality standard for this parameter.

The flow on the west side of the river receives the discharges from St. Louis' treatment plants and the combined sewer overflows. The 1981 study reported that the Bissell Point treatment plant effluent impacted the river by increasing concentrations of ammonia nitrogen, fecal coliform bacteria, and chemical oxygen demand. In the 1982 study, 40 to 45 different pollutants were found in the Bissel and Lemay treatment plant effluents, yet only 26 pollutants were found downstream in the river. The report states that it is likely the assimilative capacity of the river, mixing zones, chemical reactions, and other related variables are responsible for the far fewer detected pollutants in the river. Pollutant loadings determined in the 1982 report show that the input of pollutants from St. Louis discharges is minimal as compared to the number and concentration of pollutants in the water above the city. The report concluded that while the discharges did add pollutants to the river the impact was hardly noticeable.

The flow on the east side of the river receives the discharges from numerous treatment plants on the Illinois side of the river. The 1981 study reported increases in ammonia nitrogen, chloride, chemical oxygen demand, and fecal coliform due to the combined impacts from four municipal wastewater discharges. The 1982 report did not quantify discharges from the Illinois side of the river. However, since the number of pollutant occurences and the types of pollutants differed upstream and downstream on the Illinois side of the river, it is apparent that the discharges do affect river water quality.

In 1988, the Illinois EPA conducted a low flow water quality analysis of the Mississippi River in the St. Louis area. The sampling stations were located at the same approximate locations as the stations in the 1981 study. Samples were analyzed for the four field parameters analyzed in 1981 plus 40 inorganic parameters and over 100 organic compounds. Due to the drought conditions and the decreased precipitation, nonpoint source agricultural loadings and point loadings from the wastewater treatment plants were minimal. Since the wastewater treatment facilities were not overloaded, they provided the best effluent quality possible with available hardware. Even though the low flow conditions in the river minimized the water available for wastewater dilution, the river water quality was considered optimal for the St. Louis metro area. Even with this optimal water quality, however, problems with quality still remained. Fecal coliform levels were very high and dissolved oxygen levels were low downstream of the Bissel Point treatment plant on the Missouri side of the river. The only inorganic parameter which exceeded the Illinois standards (besides fecal coliform and dissolved oxygen) was total iron. High levels of aluminum were found but Illinois has no standard for aluminum. Five organics (pentachlorophenol, alachlor, atrazine, cyanazine, and metolachlor) were detected at low levels. Although the type and number of pollutants found in the 1988 study are similar to those found in the 1981 study, it must be remembered that the 1988 study did not represent normal river conditions but rather represented the optimal water quality for the river in the St. Louis area due to the drought.

Summary

One indication of water quality is whether the levels of various contaminants in the water exceed the standards set by the states. This approach can obviously be complicated by the fact that standards may differ among states and may also change over time. However, a number of general conclusions can be made based upon available data.

Based upon 1980's data from monitoring stations in Minnesota, Iowa, and Illinois, the standards that are mostly frequently exceeded are those for fecal coliform, pH, total copper, and dissolved oxygen. The fecal coliform exceedances are a continuing problem as evidenced by the pervasiveness of fecal coliform problems on the river in both 1977 and 1979 and in the 1980's. Exceedances of the pH, dissolved oxygen, and metals standards occur occasionally as they did in the 1970's.

While mercury and phosphorous exceedances were common in 1977 and 1979, they very seldom occur in the 1980's. The more recent lack of mercury exceedances is primarily due to differences in standards over time which do not allow for accurate comparisons. The decrease in phosphorous exceedances on the river is due to lack of standards, change in standards over time, and/or possibly lowered phosphorous levels in water bodies due to phosphate bans.

The Minneapolis/St. Paul and St. Louis metro areas both affect water quality through permitted and unpermitted (e.g. runoff) pollutant loadings to the river. As indicated by recent studies in these metro areas, there may be several pollutants detected in the river but few of them exceed the standards and draft standards. If the standards are made more restrictive, as proposed in Minnesota, the assessment of water quality may change even though the actual level of pollutants may not.

Support of Uses

In compliance with Section 305(b) of the federal Clean Water Act, each state prepares a biennial report which addresses, among other things, the water quality of its surface waters and the extent to which these waters support fishing and swimming (goals of the Act) and their designated uses. These reports are sent to the EPA which utilizes the information to produce the National Water Quality Inventory. The Inventory is a report to Congress on the condition of the waters in the United States since enactment of the Clean Water Act in 1972. As such, the 305(b) reports provide determinations of water quality that can be used to examine the quality of the Mississippi River.

While all states are required to determine the percent of fishable/swimmable waters, all five states in the Upper Mississippi River Basin conduct their determinations differently. First, the five states have not conducted the same amount of monitoring of the river. Thus each state relies upon monitored data and other means of evaluation to differing degrees. Second, the parameters which determine whether a water body supports fishing or swimming vary among the states. Third, the criteria used to determine full, partial, or no support varies among the states.

Determinations of use support are based on monitoring data and evaluations by professsional resource managers. According to the EPA guidelines, monitoring data is considered to be current and usable if it is less than five years old. All the states have several monitoring sites where they have sampled water quality, fish tissue, and sediment over the years. In addition there are monitoring sites which are used for specific studies and then are discontinued. Each state determines which river reaches are represented by the monitoring data and conducts their use support determinations based on this data. River reaches that are not represented by monitoring data are evaluated by resource professionals. Table 6 lists the percent of river miles with use support determinations based on monitoring data and evaluations.

As shown in Table 6, the states divide the river into different numbers of river reaches to present the use support data. Illinois divides the river into the most reaches and Wisconsin divides the river into the least number of reaches. The water quality within a reach is considered to be fairly homogenous. Illinois and Minnesota utilize the EPA's River Reach System and Iowa uses a similar system. The EPA system divides the river into reaches based on watershed boundaries and tributaries. A river reach usually extends from one tributary

Table 6. Basis for Use Support Determinations on the Mississippi River

			Use Support Based on: (Percent River Miles)		
	Mileage	Reaches	Monitoring	Evaluations	Method Unknown
Illinois	581	79	73%	27%	
Iowa	313	12	31%	69%	
Minnesota	174	34	52%	15%	33%
Missouri	362	2	100%		
Wisconsin	231	1		100% (nonpoint sources)	For point sources

Source: State 305(b) reports and Wisconsin Nonpoint Source Assessment Report, August 1, 1988.

to another tributary or from a tributary to a watershed boundary. Minnesota further divides some of the reaches due to locks and dams or changes in water quality classifications. Through use of the River Reach System it is theoretically possible to examine water quality changes over short distances and determine the source of degradation or improvement. For example, if a river reach above a tributary has better water quality than a river reach below a tributary, it is likely that the tributary or a point source in the lower river reach has caused the degraded water quality. However, since both Illinois and Minnesota have not monitored the water quality in all their river reaches, but rather have extrapolated the water quality from various monitoring sites to the river reaches, this sort of detailed analysis is not presently possible. Nevertheless, both Illinois and Minnesota, and Iowa to a lesser degree, provide more detailed water quality assessments than either Missouri or Wisconsin which basically analyze the river as a single unit.

The level of monitoring also varies among the states. Illinois , Minnesota, and Missouri use the most monitoring data to assess the support of uses. Iowa primarily uses evaluations supplemented by monitoring data. Wisconsin uses evaluations to assess the impacts from nonpoint sources but the method used to assess point sources is not indicated. Since Wisconsin has five monitoring stations on the river it is possible the point source impacts are based on monitoring data from these stations.

The parameters used to determine the support of fishable and swimmable uses vary among the states as shown in Table 7. Illinois uses various qualitative indices and fish advisories to determine if the water body will support a fishing use. Iowa and Missouri use fish consumption advisories and the water quality standards that pertain to aquatic life. Minnesota uses water quality standards to determine fishable use support. Wisconsin uses fish advisories and the condition of the fish community to determine fishable use support. All of the states use at least fecal coliform to determine if the swimmable use is supported.

The criteria used to determine the degree of support varies among the states. All five states classify use support into full support, partial support, and no support. Illinois, however, uses full support/threatened impairment as a subclass of full support and divides partial support into minor and moderate impairment. As shown in Table 8, none of the states use the same identical criteria to determine degree of support. Illinois uses the most elaborate criteria and has a flow chart that outlines the steps in determining degree of support. Iowa, Minnesota, and Missouri use percent exceedances of the standards as determiners of the degree of support. Wisconsin has separate criteria for both the fishable use and the swimmable use.

Fishable Use Support

To meet the fishable goal of the Clean Water Act a water body must "provid(e) a level of water quality consistent with the goal of protection and propagation of a balanced population of shellfish, fish, and wildlife." According to the EPA guidance for preparing the Section 305(b) reports, "Fishing advisories, consumption bans, and high incidences of fish abnormalities are indications that waters may not be supporting healthy aquatic populations and do not support the fishable goal." (U.S. EPA, 1987) Strictly interpreted, water bodies with fish advisories do not support the fishable use. (Kohl, April 21, 1989) Nonsupport of the fishable use does <u>not</u> necessarily mean that there are no fish in the water body, it is simply a classification reflecting the health of the aquatic population.

The states have different interpretations of the EPA guidance. For example, Minnesota does not consider fish advisories at all when determining fishable use support. Wisconsin considers fish advisories but has determined that river reaches with fish advisories <u>partially</u> support the fishable use. Missouri does not directly examine fishable use support in its 305(b) report. However, the report does indicate that river reaches that partially support or do not support their designated uses, do not meet the

Table 7. Fishable/Swimmable Use Support Parameters

	Fishable	Swimmable
Illinois*	Fish advisories Consumption bans Index of Biotic Integrity (IBI) Macroinvertebrate Biotic Index (MBI) Biological Stream Characterization (BSC) Water Quality Index (WQI)	Fecal coliform during summer
Iowa	Fish advisories Class B(w) standards: Total dissolved solids, Turbidity, Dissolved oxygen, Arsenic, Barium, Cadmium, Chromium (total hexavalent), Copper, Cyanide, Lead, Mercury, Phenol, Selenium, Total Residual Chlorine, Zinc, Ammonia Nitrogen, pH, Temperature	Class A standards: Fecal coliform Beryllium
Minnesota	Dissolved oxygen, unionized ammonia, pH, 5-day BOD	Fecal coliform Nutrients
Missouri	Fish advisories Class I standards: Chlorine, cyanide, dissolved oxygen, temperature, total dissolved gases, arsenic, beryllium, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, zinc, pH, chloride, and sulfate	Fecal coliform
Wisconsin	Fish advisories Condition of the fish community compared to its potential	Recreation standards: Fecal coliform

*Illinois' water quality indices are explained in Appendix I.

Table 8. Criteria for Determining Degree of Use Support Based on Monitoring Data

	Full Support	Partial Support: Minor Impairment	Partial Support: Moderate Impairment	No Support
Illinois*	Biosurvey Data: <10% modification of aquatic community structure and function; PIBI≤4; MBI≤6.0	10-25% decline in species richness; IBI 31-40; 4<PIBI≤8; MBI 6.0-7.5	25-50% decline in species richness; IBI<30; 8<PIBI-IBI<14; MBI 7.5-10.0	>50% decline in species richness; 14<IBI<23; MBI>10.0
	Water Chemistry: WQI<30; Total Suspended Solids <25 mg/l; Pesticides not detected or only at trace levels; standards not usually exceeded	WQI 30-50; Total Suspended Solids 25-80 mg/l; Pesticides may be at low levels; some standards exceeded	WQI 50-70; Total Suspended Solids >80 mg/l; Pesticides may be at low levels; standards frequently exceeded	WQI>70; Total Suspended Solids >400 mg/l may occur; pesticides may be at levels of concern; standards routinely exceeded
	Fish Tissue: Organochlorines not usually detected	Organochlorines routinely found but at low levels	Organochlorines routinely found and consumption advisories may be issued	Organochlorines consistently found at or higher than USFDA tolerance levels, consumption advisories issued
	Sediment Chemistry: Metals and organochlorines found at nonelevated levels	Metals and organochlorines found at elevated levels	Metals and organochlorines found at highly elevated levels	Metals and organochlorines consistently found at extreme concentrations
Iowa	Standard exceeded in <10% of samples and mean is less than standard	Standard exceeded in 11-25% of samples and mean is < standard or standard exceeded in <10% of samples and mean is > standard		Standard exceeded in >25% of samples or standard exceeded by 11-25% and mean is > standard
Minnesota	Standard exceeded <10% of time	Standard exceeded 10-25% of time		Standard exceeded >25% of time
Missouri	Biology: No evidence of modification of community	Substrate and flow would support diverse benthic fauna but most major taxanomic groups missing. Pollution tolerant fauna abundant.		Substrate and flow would support diverse fauna but benthic fauna absent or present with very low density or diversity.
	Chemistry: Standard exceeded in < 10% of samples and mean is less than standard. Pollutants not found at levels of concern.	Standard exceeded in 11-25% of samples and mean is < standard or standard exceeded in < 10% of samples and mean is > standard. Pollutants not found at levels of concern.		Standard exceeded in > 25% of samples or standard exceeded by 11-15% and mean is > standard. Pollutants found at levels of concern.
	Physical:			Black anaerobic substrate, thick deposits of sludge, tailings or chemical precipitates which bury or heavily embed normal substrate.
Wisconsin	Swimmable: Standards not exceeded	Swimmable: Standards occasionally exceeded		Swimmable: Standards exceeded, does not support use
	Fishable: Potential uses fully met based on existing fish community or water quality.	Fishable: Not fully supporting potential uses based on the existing fish community, water quality, or fish advisories.		Fishable: Potential uses absent based on the existing fish community or water quality.

* See Appendix I for complete description of Illinois indices.

Source: State 305(b) reports

fishable/swimmable goals of the Clean Water Act.

Minnesota and Wisconsin classify the Mississippi River as partially or fully supporting the fishable use. Iowa classifies the river as supporting the fishable use except near Clinton, Iowa and the Quad Cities. These two reaches have problems with priority pollutants and metals. Illinois classifies the river from the Wisconsin border down to Lock and Dam 21 as supporting the fishable use. The rest of the river is considered not supporting. Missouri splits the river into two major sections. Above the Missouri River confluence the river supports the fishable use and below the confluence it does not support the use.

Based on a cumulative assessment of the states' determination of fishable use support, of the 848 navigable miles of the Upper Mississippi River, 508 miles (60 percent) support the fishable use and 340 miles (40 percent) do not support the use. Basically the river from Lock and Dam 1 to Lock and Dam 13 is considered to be fully or partially supporting the fishable use, the river from Lock and Dam 13 to Davenport, Iowa is a mixture of support and nonsupport of the fishable use, the river from Davenport, Iowa to Lock and Dam 21 supports the fishable use, and the river from Lock and Dam 21 to the confluence of the Ohio River does not support the fishable use. Figure 1 shows the fishable use support on the river.

As shown in Figure 1, states across the river differ in their determination of fishable use support. Iowa classifies two river reaches by Clinton and the Quad Cities as not supporting the fishable use while Illinois classifies them as supporting. Illinois classifies the river from Lock and Dam 21 to the confluence of the Missouri River as not supporting while Missouri classifies it as supporting the fishable use. These differences in classification are due to the differences in the states' criteria for determining support, the interpretation of the EPA guidelines for preparation of the 305(b) reports, and the states' water quality monitoring programs.

Swimmable Use Support

The goal of the Clean Water Act is not only to achieve fishable waters, but also to insure that waters of the United States are swimmable. In all five states the primary determiner of whether the water body is swimmable is the number of fecal coliform in the water. Since not all the states monitor fecal coliform values for the river, determination of swimmable use support varies. Of the 174 miles of river in Minnesota only 57.7 miles or 33 percent are classified based on the swimmable use. Of the 581 river miles in Illinois only 38.7 miles or 7 percent are classified. The remainder of the river in Minnesota and Illinois is designated "unknown." Iowa and Wisconsin on the other hand classify the entire river along their state. However, Wisconsin's evaluation is based on little or no monitoring data.

Missouri assessed swimmable use support for only the river reach from the Iowa border to the Missouri River confluence. Since the Mississippi River downstream of the Missouri River confluence is not used for swimming due to physical limitations (e.g. barge traffic and steep banks), Missouri has not assessed swimmable use support for this part of the river.

Based on a cumulative assessment of the states' swimmable use support the river supports the swimmable use except in the Minneapolis-St. Paul metro area and at Thebes, Illinois. Of the 848 navigable miles of the river, 26 miles or 3 percent of the river is considered as not supporting the swimmable use. This figure may be misleading since much of the river was not assessed for the swimmable use. Figure 2 shows the swimmable use support on the river.

Designated Use Support

In addition to the fishable/swimmable use, the states also examine the degree to which the river supports the uses which the state itself designates. Use support is based on the water quality standards for the designated uses. As with the fishable/swimmable use deter-

Figure 1 Fishable Use Support

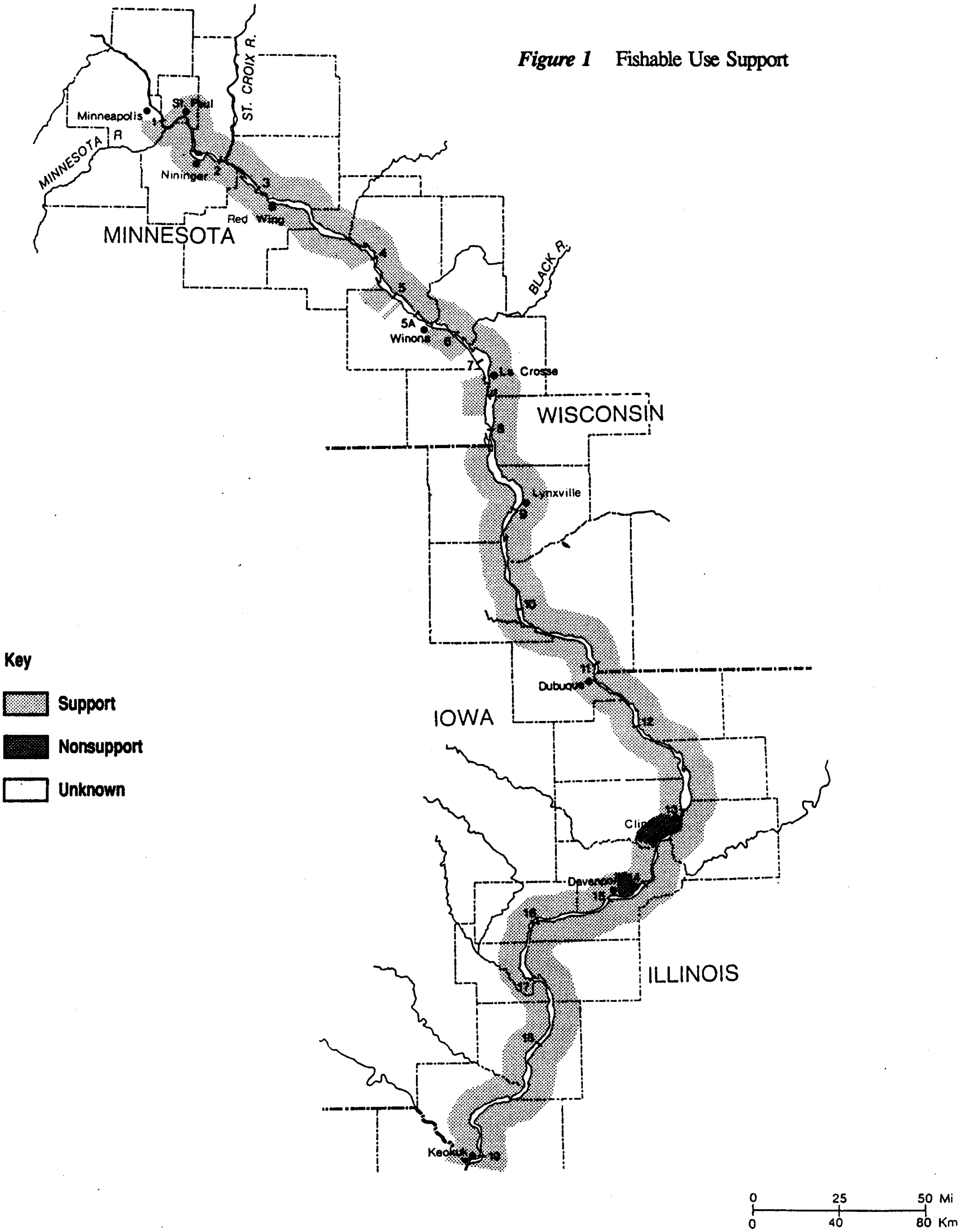
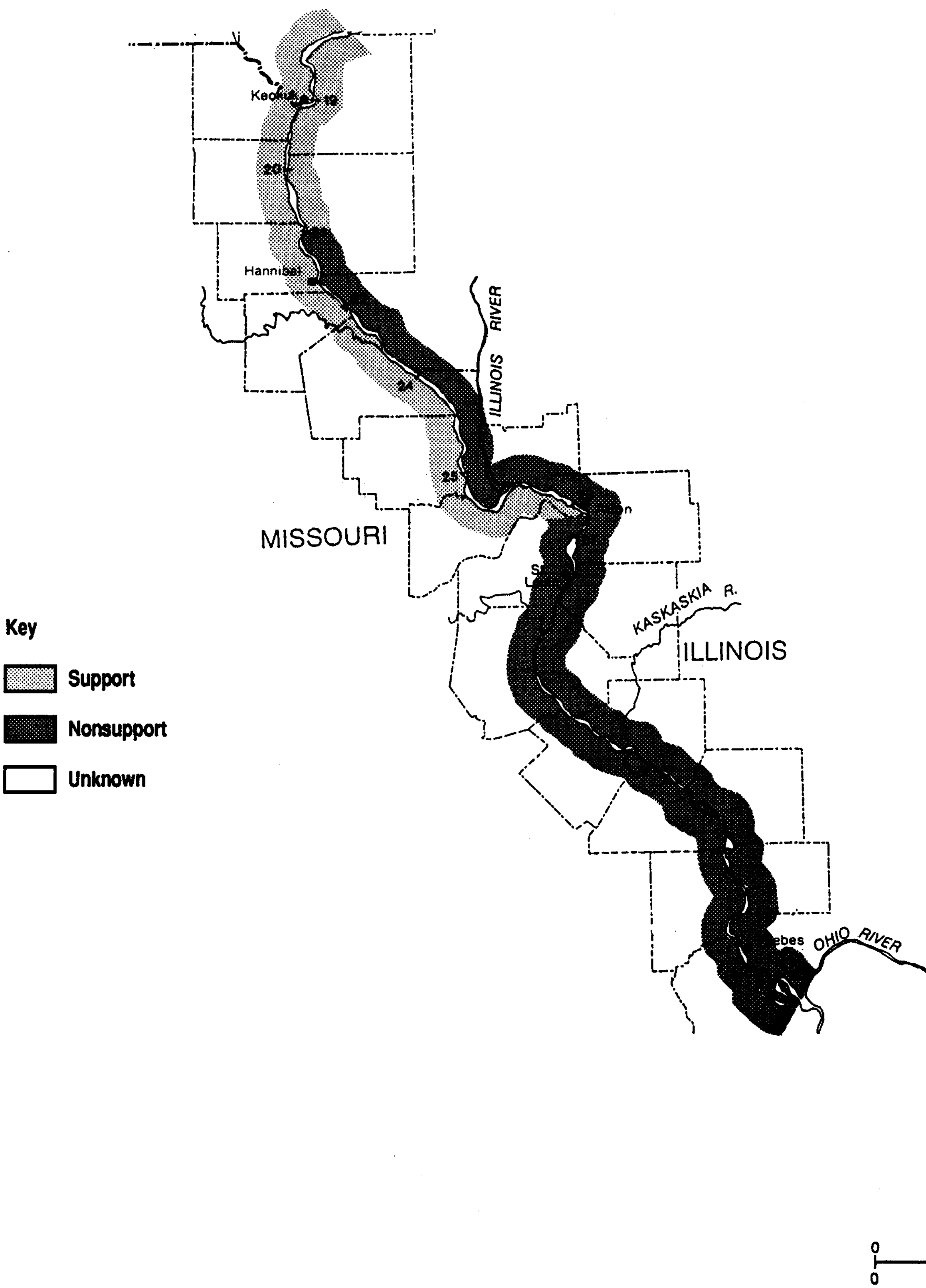


Figure 1 Fishable Use Support *(continued)*



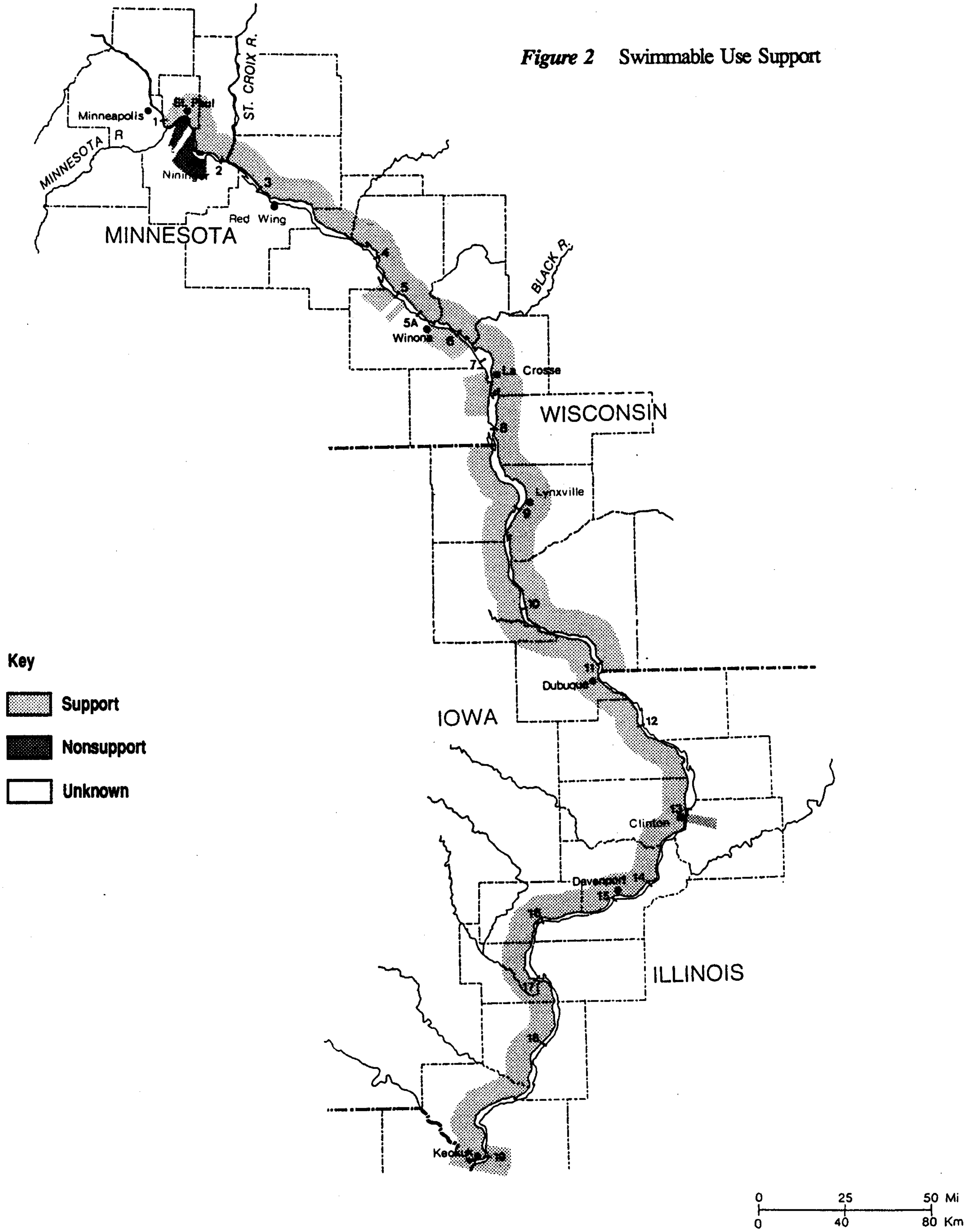
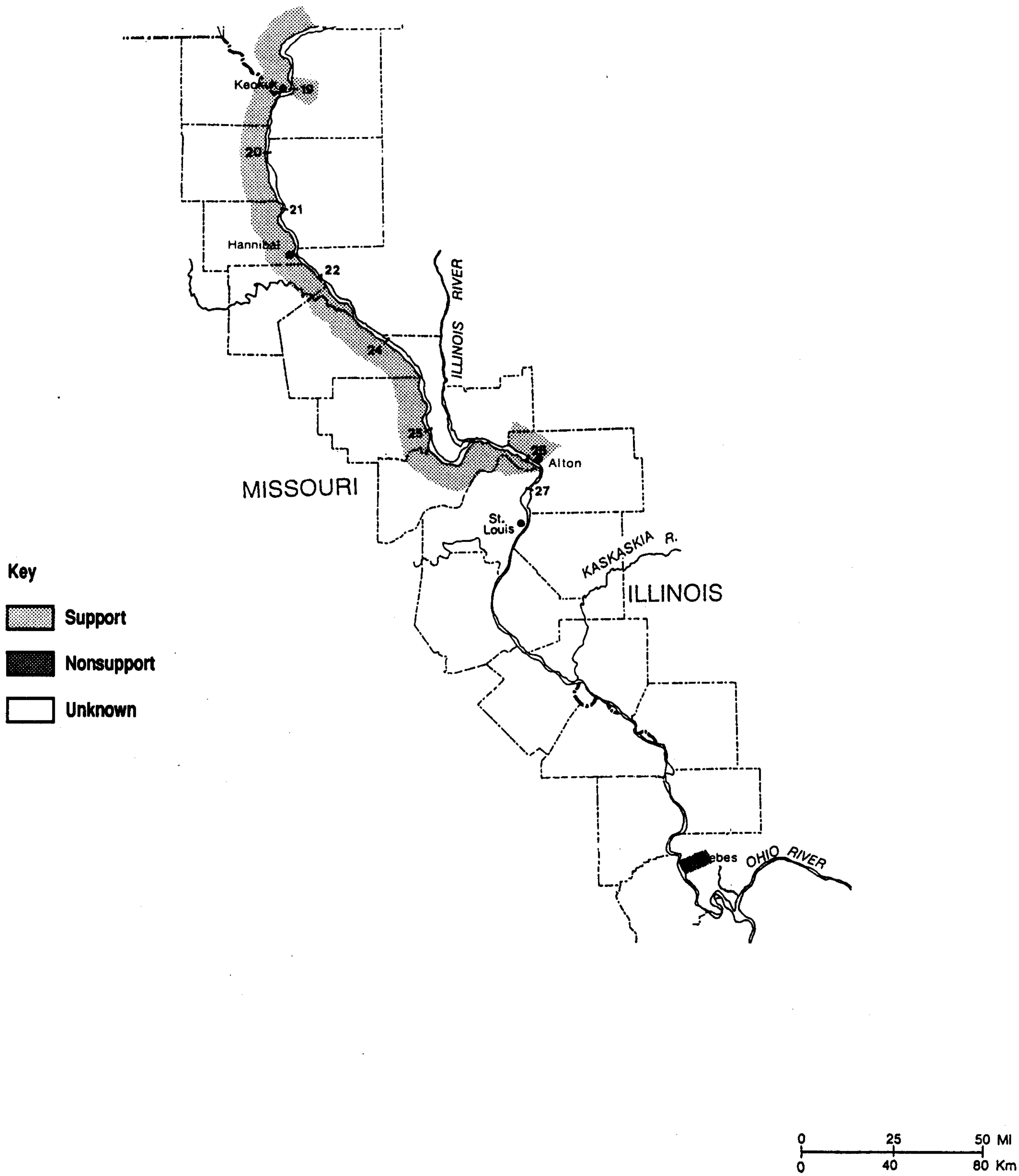


Figure 2 Swimmable Use Support

Figure 2 Swimmable Use Support *(continued)*



minations, the parameters used to determine water quality vary, the acceptable values for the parameters vary, and the degree of use support vary. In addition, the designated uses of the river vary from state to state. Designated use support determinations therefore, only represent each state's best judgment on how well the river supports the uses they have designated.

Table 9 lists the support of designated uses as a percentage of river miles for each of the states. Except for Minnesota, the states classify the majority of the river as partially supporting the designated uses. All states except Missouri and Wisconsin consider some portion of the river as not supporting the designated uses. Minnesota classifies the majority of the river as fully supporting. The use support classifications by river reach are listed in Appendix D.

Summary

Based on fishable use support, 60 percent of the river has acceptable water quality and 40 percent does not. The problem areas are by Clinton, IA and Davenport, IA and from Lock and Dam 21 to the confluence of the Ohio River. The states across the river do not agree on the river reaches that support the fishable use except for the river below the confluence of the Missouri River.

Based on swimmable use support, 97 percent of the river has acceptable water quality and 3 percent does not. The problem areas are in the Minneapolis-St. Paul metro area and Thebes, Illinois. The states across the river do not agree on the river reaches that support the swimmable use. This is due primarily to the fact that the majority of assessments were based on nonquantitative evaluations and that Minnesota, Illinois, and Missouri made no assessments or only partial assessments of the river bordering their states.

Due to the variability in the way in which states determine fishable/swimmable use support, the states' descriptions of water quality vary. As evidenced in Figures 1 and 2, two states can assess the same stretch of river and arrive at different water quality determinations. This does not mean that one description is more accurate than another. In the swimmable use determination the states of Iowa and Wisconsin assessed the entire river, Missouri assessed part of the river, while Minnesota and Illinois assessed almost none of the river. This does not mean that Illinois and Minnesota have inadequate monitoring programs. It only means that Iowa, Missouri, and

Table 9. Support of Designated Uses
As a Percentage of River Miles

	Full Support	Partial Support	No Support	No Data
Illinois	18% (Threatened)*	51% (minor impairment) 28% (moderate impairment)	4%	
Iowa		95%	5%	
Minnesota	65%	19%	13%	3%
Missouri	46%	54%		
Wisconsin		100%		

* Full Support (Threatened) indicates that the waters presently fully support the designated uses but that the use support is likely to change in the future because of changing land use patterns, new point sources, or a continued decline in water quality.

Source: States' 305(b) Reports

Wisconsin consider subjective evaluations an acceptable method and are satisfied to use this approach if monitoring data is unavailable. The variability in use support determinations is inevitable due to differences in assessment methodology, monitoring programs, and water quality standards.

Based on support of the designated uses, the majority of the river is classified as partially supporting the designated uses. Since the designated uses of the river vary by state, this information is most useful as a descriptor of each state's perception of the water quality of the river.

Quality of Fishery Resource

One of the important determiners of water quality is how well the river supports the fishery. Fish can accumulate contaminants from the sediment, from the water column, or through the food chain. Contaminants adsorb to sediment particles which eventually settle out in the river. Fish that feed on aquatic organisms in the sediment, that live near the bottom sediments, or live in an area with high levels of suspended sediment can take up contaminants and accumulate them in their bodies. It has been shown for example, that bottom dwelling fish species which are exposed to high concentrations of PCB contaminated suspended sediments accumulate PCBs more readily than fish species which reside closer to the water surface. (Simons, Li and Associates, 1981) Chlorinated hydrocarbons/pesticides such as chlordane are believed to be derived from the water column since chlordane contaminated sediment has not been found, yet large portions of the river have chlordane contaminated fish. (Ruelle, April 21, 1989) The particular mechanics of how the contaminants are taken up by the fish is still being researched.

Fish Advisories

As discussed previously, cumulatively 340 miles or 40 percent of the river is not considered to be supporting the fishable use. According to a strict interpretation of the 1987 EPA 305(b) guidelines, a river reach is considered as not supporting the fishable use if there are fish advisories for that section of the river. Since the states interpret this guidance differently or devise their own guidelines, not all waters with fish advisories are considered by the states to be not supporting the fishable use. Thus a separate examination of the fish advisories on the river can provide a different perspective on water quality.

Of the 848 miles of the river, cumulatively 519 miles (61 percent) have fish advisories. The advisories are ranked into different groups based on the level of contamination and recommended frequency of consumption. Table 10 explains the different groups of advisories.

Illinois and Missouri use the same group classifications and consumption advisories. Minnesota has one advisory

Table 10. Fish Advisory Groups*

Group I	Lowest level of contaminants -- no advisory	IL, MO, WI
Group II	Moderate levels of contaminants. Children, pregnant women, nursing mothers, and women who may become pregnant should limit consumption to 1 meal/week	IL, MO
	Children under 15, pregnant women, nursing mothers, and women who may become pregnant should not eat these fish.	WI
Group III	No consumption advised	IL, MO, WI

* Minnesota has one advisory level that recommends 1 meal/month but children under 6, pregnant women, nursing mothers, and women who may become pregnant should not eat these fish.

Source: Compiled from state fish advisory brochures level that includes all fish on the Mississippi River from St. Anthony Falls (Minneapolis) to the Iowa border. Both Minnesota's advisory and Wisconsin's Group II advisory recommend no fish consumption for the high risk groups while Illinois and Missouri recommend limited consumption. Iowa has no fish advisories at present.

A total of 10 different fish species are targeted specifically in the consumption advisories: buffalo, carp, channel catfish, crappie, drum, flathead catfish, sauger, sturgeon, walleye, and white bass. Minnesota's advisory pertains to all fish species in the Mississippi River. The consumption advisories for Minnesota and Wisconsin are for PCBs while the advisories in Illinois and Missouri are for chlordane and dieldrin. Recently, dioxin has been detected in fish taken from the river at Red Wing, MN and La Crosse, WI. Discussions are underway to determine if advisories are necessary. (Liebenstein, April 25, 1989) Appendix E lists the advisories by state for the different species of fish in the river. Figure 3 indicates the river segments with fish advisories.

PCBs were first identified in the Minnesota-Wisconsin reach of the Mississippi River in 1970 during Wisconsin's initial fish PCB contaminant analysis. This initial monitoring revealed substantial PCB contamination in fish, especially in carp, walleye, and white bass taken from Pools 3 and 4. In 1975, the U.S. Food and Drug Administration (FDA) detected PCBs in carp fillets that exceeded the commercial tolerance level of 5.0 ug/g. Over 60,000 pounds of carp fillets were destroyed. As a result of this event an Interagency Task Force was formed in 1975 to identify the source(s) of PCB discharge to the Mississippi River and to determine the extent of the problem. After completing a major PCB sampling program the Task Force determined that the highest PCB contamination in fish and sediments was in an area extending from Pool 1 to Pool 4 but that there was no signficant source of PCB discharge to the river. A 1978 report by consultants for the Columbia National Fishery Research Laboratory indicated that the primary sources of PCBs are in the Minneapolis-St. Paul area and that atmospheric input was not believed to be an important source. (Sullivan, 1988)

Since 1975 when the Task Force was formed, state agencies in both Minnesota and Wisconsin have been monitoring the PCB levels in fish. A Minnesota report on the levels of PCBs in carp in the river from 1975 to 1982 states that there is an apparent PCB decrease of 63 percent in the fillet tissue and a 72 percent decrease in the lipid (fat) based concentrations of carp. (MPCA, 1985). A Wisconsin study that compared PCB levels in carp from the late 1970's to the early 1980's found a significant reduction in tissue-based PCB concentrations in carp in Pool 4 and in lipid-based PCB levels in Pools 4, 8, and 9. A comparison was not possible for Pools 5A, 6, and 7 due to insufficient data. The study also examined PCB levels in other fish in Pool 4 and found signficant PCB reductions in white bass, freshwater drum, and walleye. PCB levels have decreased in channel catfish but the reductions are not statistically significant. Overall Wisconsin's data also indicates a decrease in PCB contamination of fish. (Sullivan, 1988)

While the studies show that PCB concentrations in fish have been decreasing since the 1970's, both reports state that the levels are still high in comparison with samples that are not influenced by the Twin Cities metropolitan area. Health advisories for no consumption of various fish apply to the Wisconsin reach of the river from the St. Croix River confluence to Lock and Dam 6.

Since chlordane-contaminated fish are a problem in the Illinois-Missouri reach of the river, Wisconsin has periodically sampled channel catfish in pool 9 to check for chlordane problems. In both 1982 and 1987, chlordane was not detected in channel catfish from pool 9. (Liebenstein, April 25, 1989)

The State of Iowa does not have advisories for fish consumption but the state does conduct fish tissue monitoring in conjunction with the EPA. Since monitoring began in 1980, fish samples have been collected from 13 different stations along the Mississippi River. Contaminants that

Figure 3 River Reaches with Fish Advisories Compared to River Reaches that do not Support the Fishable Use

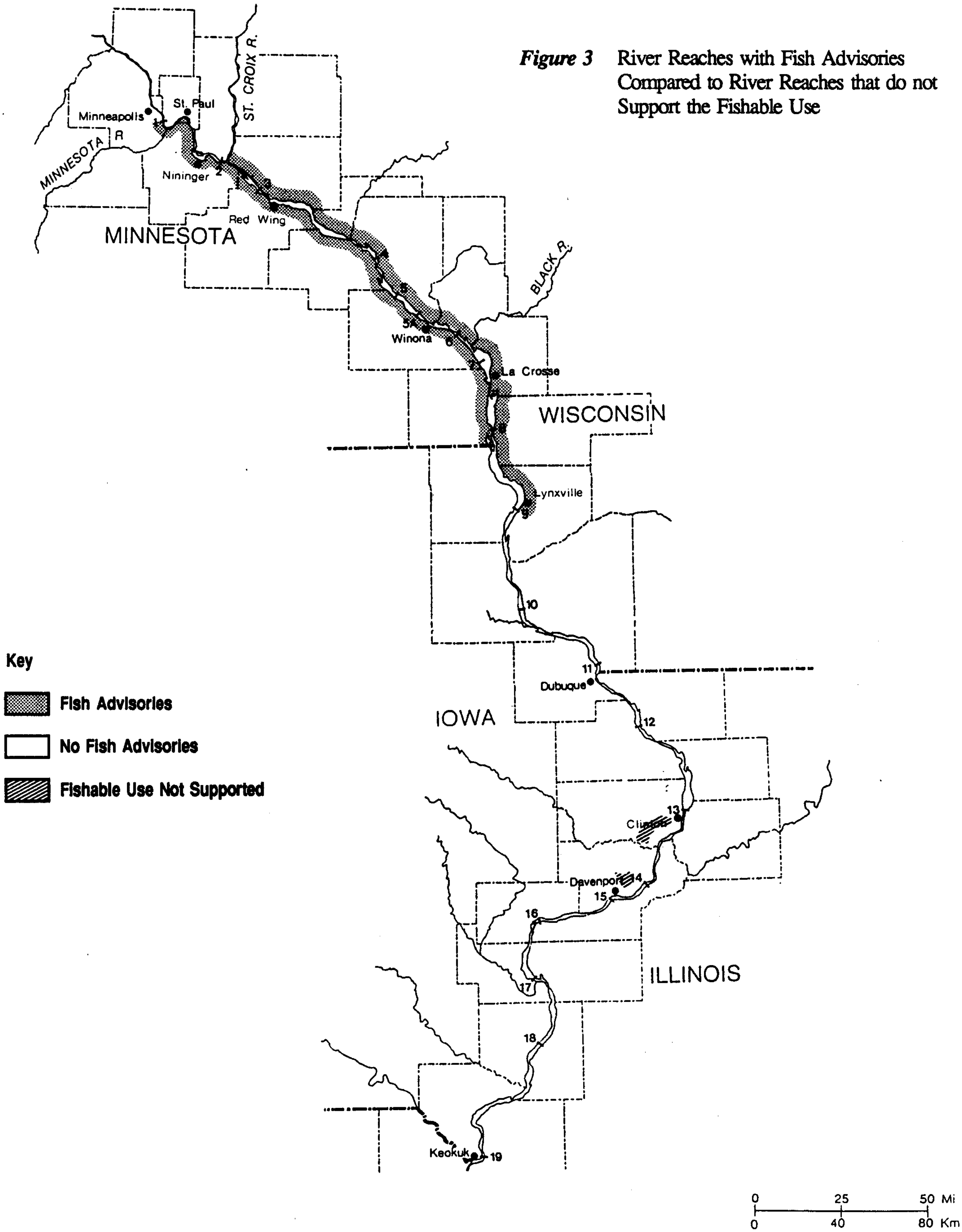
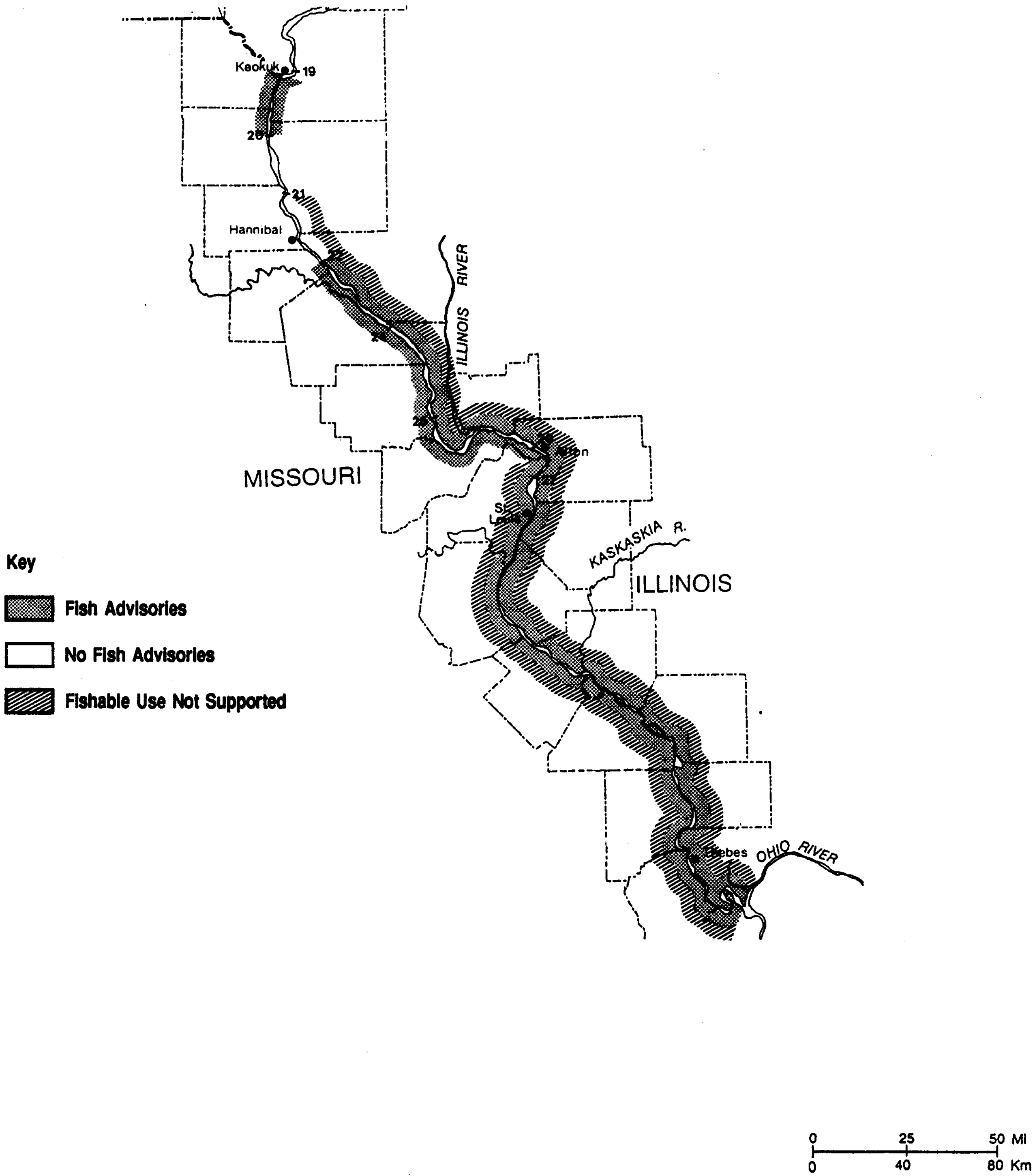


Figure 3 River Reaches with Fish Advisories Compared to River Reaches that do not Support the Fishable Use *(continued)*



have been detected above the Food and Drug Administration (FDA) action level are mercury, chlordane, and PCBs. Mercury was found above the action level (1.0 ppm) at Keokuk in 1980 but has not since been found at that level at any of the stations on the river. Mercury levels in fish in 1987 ranged from 0.051 ppm near Camanche to 0.081 ppm at Montrose. Chlordane has been found above the action level (0.300 ppm) at several sites in the Quad Cities area (Pleasant Valley, River Mile 494, Davenport). The other six stations in the Quad Cities area showed chlordane at levels below the FDA level. PCBs and chlordane both appear to be ubiquitous in the Quad Cities area with all stations reporting occurrences. The only station which had levels of PCBs above the FDA action level (2.0 ppm) in 1987 was upstream of Bettendorf. This station had the highest recorded levels of PCBs in the state. (Olson, October 31, 1988) The Iowa DNR is presently reviewing the fish tissue data to decide whether fish advisories should be issued. (Iowa DNR, 1988)

Chlordane has been found in fish in the Illinois-Missouri reach of the Upper Mississippi River since sampling by the Illinois Department of Conservation (DOC) began in 1978. The Illinois DOC collected samples of carp and at least one other fish species at four locations on the river during 1978, 1979, and 1980. Chlordane was found in fish flesh above the FDA guideline of 0.3 parts per million at River Mile 101 (south of Chester, IL), River Mile 190 (just above Lock and Dam 27), and at River Mile 203 (tailwaters of Lock and Dam 26). The highest concentration of chlordane (1.62 ppm) was found at the Lock and Dam 26 tailwaters site. Fish at this site also contained the pesticide dieldrin at levels over the FDA guideline of 0.3 ppm.

As part of the Basic Water Monitoring Program, the Illinois DOC took fish samples from four Mississippi River locations along the Missouri border in 1980. They found pesticides, metals, one volatile compound, and phthlate compounds (benzene derivatives) in the fish but none of these substances exceeded the FDA criteria. Chlordane was not one of the parameters tested for. The four sample sites were at River Mile 50 (south of Cape Girardeau, MO), 108 (south of Chester, IL), 209 (north of Alton, IL), and 308 (Hannibal, MO). (Missouri DNR, 1984)

Illinois presently has a fish contaminant sampling program where composite fillet and whole fish samples are analyzed for 20 pesticides and PCBs. Other analyses may include mercury, dioxin, or a 50 parameter "wide scan" conducted for special studies or as necessary. On the Mississippi River there are 10 fish monitoring stations at the following approximate river locations (in river miles): 3.0, 101, 133, 190.3, 202.6, 241, 330, 364, 465, and 520. (Illinois EPA, 1988)

Missouri presently has a Fish Tissue Network with 22 stations (2 on the Mississippi River above and below the confluence of the Missouri River) and conducts yearly sampling for priority pollutants in carp. In addition the state conducts special studies specifically on chlordane content in fish. There are no apparent increases or decreases in the chlordane contamination and the problem is not likely to go away in the near future. Chlordane in fish tissue is a concern in the entire Missouri reach of the Mississippi River and will likely continue to be a concern. (Howland, October 18, 1988)

National Contaminant Biomonitoring Program

Since 1967 the U.S. Fish and Wildlife Service has participated in the National Contaminant Biomonitoring Program previously called the National Pesticide Monitoring Program. The program originated in the mid 1960's as a cooperative effort between various federal agencies. While the EPA developed the program, each of the involved federal agencies took the responsibility of monitoring its respective resource. For example, the Fish and Wildlife Service monitors contaminant levels in fish and birds while the EPA and U.S. Geological Survey monitor levels in water and sediment. (U.S. EPA, 1980) The Fish and Wildlife Service analyzes residues of selected organochlorine compounds (pesticides, insecticides, etc.)

and toxic trace metals in samples of fish and birds. There are four stations on the navigable portion of the Upper Mississippi River: Lake City, Minnesota; Guttenberg, Iowa; Dubuque, Iowa; and Cape Girardeau, Missouri.

The monitoring data for organochlorine compounds for the four stations has been presented and analyzed in three reports. The 1981 report presented monitoring results from 1970 - 1974. While no statistical analysis was conducted, an examination of the data shows a general downward trend in the concentrations of DDT and its metabolites (breakdown products) in carp at the Guttenberg and Cape Girardeau stations and an increase in PCB levels at Guttenberg. There was only one year of data for Lake City and none for Dubuque. (Schmitt et al., 1981) The 1983 report examined trends in organochlorine compounds from 1974 - 1979. The Lake City station showed a statistically significant decrease in PCBs while the Cape Girardeau station showed an increase in toxaphene (an insecticide). The Guttenberg station showed no statistically significant changes while the Dubuque station had insufficient data to determine trends. (U.S. Department of Interior, 1983) The 1985 report examined trends from 1976 - 1981. In this report, Lake City showed a statistically significant increase in toxaphene and no change in PCBs. Cape Girardeau showed a significant decrease in PCBs and chlordane and an increase in *cis* Nonachlor and *trans* Nonachlor (components of chlordane insecticides). Guttenberg and Dubuque showed no significant changes in any parameter. (Schmitt et al., 1985) Table 11 summarizes the trends in the three reports.

The decrease in the concentration of DDT and its metabolites at Guttenberg and Cape Girardeau from 1970 - 1974 is consistent with a national trend of decreasing DDT levels since DDT was banned in the United States in 1972. During this same period the Guttenberg station showed an increase in PCBs. This increasing trend appears to stop after 1976 when concentrations generally decreased. The toxaphene increase at Cape Girardeau from 1974 - 1979 was not surprising since by 1971, toxaphene had replaced DDT as the most heavily used insecticide in the U.S. (Schmitt et al., 1981) The decrease in PCBs at Lake City for this time period is consistent with the monitoring results discussed pre-

Table 11. Trends in Levels of Fish Tissue Contaminants

	1970 - 1974*	1974 - 1979	1976 - 1981
Lake City, MN	Insufficient Data	Decrease-PCBs	Increase-Toxaphene
Guttenberg, IA	Decrease - DDT and Metabolites Increase - PCBs	No Change	No Change
Dubuque, IA	No Data	Insufficient Data	No Change
Cape Girardeau, MO	Decrease-DDT and Metabolites	Increase-Toxaphene	Decrease-PCBs Decrease-Chlordane Increase-*cis* Nonachlor Increase-*trans* Nonachlor

* Nonstatistical analysis

Source: Schmitt et al., 1981
U.S. Department of Interior, 1983
Schmitt et al., 1985

viously for Minnesota and Wisconsin, but the levels at Lake City still ranked with the highest PCB concentrations in the country. (Schmitt et al., 1985) The 1976 - 1981 data show an increase in toxaphene at Lake City due to a one time occurence of toxaphene in white suckers sampled in 1981. Toxaphene is not commonly found in the upper reaches of the river and is not considered a problem. (Schmitt, October 13, 1988) Since toxaphene is a difficult compound to measure, the one time occurence of toxaphene is a questionable analytical result. (Sullivan, April 11, 1989) The decrease in PCB and chlordane levels in fish at Cape Girardeau is consistent with national trends. The chlordane concentration at Cape Girardeau, however, still ranks among the highest levels in the country. (Schmitt et al., 1985)

In addition to the organochlorine monitoring, the Biomonitoring Program monitors fish samples for toxic trace metals (arsenic, cadmium, copper, mercury, lead, selenium, and zinc). From 1976 - 1977 the station at Cape Girardeau was the only station sampled on the Upper Mississippi River. Arsenic, cadmium, lead, and mercury were detected in the fish samples with concentrations greater than the national mean. (May and McKinney, 1981) From 1978 - 1981 all four stations were sampled. The Cape Girardeau station showed a significant increase in lead during this period while both the Lake City and Dubuque stations showed significant increases in arsenic. The Guttenberg station showed no trend. (Lowe et al., 1985)

While the Fish and Wildlife Service has continued the Biomonitoring Program up to the present, there are no statistical analyses or reviews for data after 1981. The Service has indicated that they are presently working on a manuscript to update the results of the monitoring. (Schmitt, October 13, 1988)

Summary

There are currently fish advisories for 61 percent of the length of the Upper Mississippi River. There are fish advisories for the river from Locks and Dams 1-9, the Des Moines River confluence to Lock and Dam 20, and Lock and Dam 22 to the Ohio River confluence. The advisories are due to high levels of PCBs, chlordane, or dieldrin in fish tissue.

Besides the PCBs, chlordane, and dieldrin for which the fish advisories are issued, there are other contaminants in the fish that are found below action levels. In the early 1980's, the Illinois DOC found pesticides, metals, one volatile compound, and phthlate compounds in fish tissue and the Fish and Wildlife Service found increasing levels of lead and arsenic. While the levels of these contaminants were not high enough to issue fish advisories, these occurrences show that past and/or present water quality standards and discharge restrictions have not prevented bioaccumulation of contaminants in fish.

Recently, the Wisconsin Department of Natural Resources has detected dioxin in fish at two locations on the river. Wisconsin and Minnesota staff will be meeting to discuss the need for a fish advisory.

While Illinois and Missouri have identical advisories based on fish species, fish size, and river reach, Wisconsin and Minnesota have considerably different fish advisories for the river. Wisconsin's advisory levels vary based on the type of fish, the size of the fish, and the river reach. Nine specific fish species are listed in Wisconsin's advisories. Minnesota, on the other hand, has one advisory that covers all the fish on the river. Minnesota's and Wisconsin's advisories are based on the same fish tissue data, but the states differ in their determination of acceptable risk levels. Iowa is reviewing fish tissue data to determine if the state should issue advisories.

A comparison of river reaches based on fishable use support and fish advisories (see Figure 3) shows little correlation between the two except for the river reach below the confluence of the Missouri River. The river by Clinton and Davenport, Iowa that Iowa considers as not supporting the fishable use due to elevated levels of toxics in fish tissue, does not have fish advisories. The same is true for the river reach between Locks and Dams 21 and 22. Conversely, most of the reaches with fish advisories are considered to be supporting the fishable use. The river reaches from St. Paul to Lock and Dam 9, from the Des Moines River confluence to Lock and Dam 20, and from Lock and Dam 22 to the Missouri River confluence have fish advisories yet these river reaches are considered to be supporting the fishable use.

Based on data from the National Contaminant Biomonitoring Program, the fishery resource at selected stations on the Upper Mississippi River has been affected by toxic metals and organics. DDT and its metabolites, PCBs, and chlordane have been found to be decreasing over time while toxaphene, cis Nonachlor, and trans-Nonachlor (components of chlordane insecticides) have been found to be increasing at only the Cape Girardeau station. Although the levels of PCBs and chlordane were found to be decreasing, these levels are still some of the highest in the country.

Since the trend analysis conducted as part of the National Contaminant Biomonitoring Program ends with 1981 data, it is possible these trends have continued or new trends or substances have been found in the last seven years. According to Minnesota and Wisconsin the PCB levels have continued to decrease but are still very high. Missouri sees no decrease in the levels of chlordane or in components of chlordane and considers it a continuing problem.

The National Contaminant Biomonitoring Program also found toxic trace metals in fish tissue. Increases in lead were seen at the Cape Girardeau station and increases of arsenic occurred at the Lake City and Dubuque stations. Since the analysis for the Biomonitoring Program is based on fish tissue portions which are not covered under the FDA action levels, it is not possible to compare the metals levels to the action levels.

Sediment Quality

Sediment quality is an important component of the quality of the Mississippi River. As discussed previously, fish can be affected by the quality of the sediment. Aquatic plants also take up metals from the sediment which are then assimilated into plant tissue (Buhl and McConville, 1984). Under changing pH or oxygen conditions, metals and other compounds can be released or desorbed from the sediment into the water column. In addition, it has been found that dredging, navigation, or other activities that disturb the sediment can result in releases of the contaminants into the water column that were previously attached to the sediment. (Simons, Li and Associates, 1981). Also, dredging activities could expose previously buried contaminated sediments making the contaminants on these sediments once again available for bioaccumulation or desorption. Thus the quality of the sediment is related to the quality of the water resource.

Sediment particles are the primary transporters of toxic organic and metal compounds. (Simons, Li and Associates, 1981). These compounds adsorb or attach to the sediment and move with the sediment into and/or down the river. Toxic organics and metals primarily attach to clay and silt size particles due to their larger available surface area. These fine-grained particles are easily suspended in the river and can be transported long distances, eventually settling out in low velocity, low energy environments like backwaters.

Presently there are no standards for sediment quality or dredged material disposal in the Mississippi River although the EPA has been in the process of developing national standards for dredged material disposal. Up to the present, most resource managers have used the 1977 EPA guidelines for dredged spoil disposal for Great Lakes harbors as a guide to sediment quality in the Mississippi River. These guidelines classify sediment into not polluted, moderately polluted, and heavily polluted based on the concentrations of 19 different parameters. The guidelines have limitations for use on the Mississippi River sediment because they are based on average background levels of substances in the Great Lakes, not the Mississippi River. The natural background levels of substances can vary due to factors like the geology of an area (e.g. rock with high iron or lead content) or the amount of flow through a water body (e.g. a lake as compared to a river).

The Great Lakes guidelines do not reflect impacts to aquatic life or the environment. The moderately and heavily contaminated categories only represent concentrations of substances over background levels. Sediments that are contaminated according to the Great Lakes guidelines, do not necessarily have an adverse impact on aquatic life in the water body. The elevated levels, however, do indicate that substances have been discharged to the water body raising the levels above normal. The discharges represent existing or past potential sources of pollutants.

The EPA Great Lakes sediment guidelines are used as a benchmark. If an EPA guideline is exceeded, the sediment may have adverse impacts on aquatic life in the water body. In addition, if the sediment is dredged and placed on land, it may adversely impact the environment. If the Great Lakes guidelines are exceeded, toxicity testing may be conducted by state or federal agencies to determine the potential impacts.

Several of the studies referenced in this report have used the Great Lakes guidelines for sediment quality determinations. To maintain consistency, all sediment quality data in this report has been compared to the Great Lakes guidelines. These guidelines are displayed in Appendix F.

State Monitoring Programs

Minnesota does not monitor sediment quality but does conduct case-by-case assessments when necessary. A toxics assessment was conducted on Mississippi River water and sediments within the Minneapolis/St. Paul metro area (Anoka, MN to Hastings, MN). (MWCC, 1988). Sediments were examined for 15 metals and

111 toxic organics including pesticides. Concentrations of contaminants were compared to the Great Lakes harbors guidelines and Wisconsin's NR 347 draft guidelines. [A Wisconsin dredging subcommittee report proposed criteria for dredged material disposal for Great Lakes sediment, but these criteria were not included in the final published code. It is uncertain whether these criteria are applicable to the Mississippi River. (See Appendix F)] Compared to the harbor guidelines, the MWCC study found the sediment was moderately contaminated with arsenic, cadmium, chromium, copper, nickel, and zinc at the St. Paul, Grey Cloud Island, and Hastings sites. The station at Hastings had sediment heavily contaminated with arsenic and chromium. Based on Wisconsin's proposed guidelines the sediment was contaminated with cadmium, mercury, zinc, PCBs, and chlordane.

Wisconsin has a statewide monitoring program and conducts a case-by-case review of sediment quality at dredging sites. Wisconsin classifies the Mississippi River from the St. Croix confluence to the Chippewa River confluence as a known sediment contamination area and the rest of the river as a potential contamination area. (Wisconsin DNR, 1988).

Illinois monitors sediment quality at the ambient water quality monitoring stations throughout the state. The State of Illinois uses a statistical classification by Kelly and Hite (1984) of the Illinois EPA to determine sediment quality. The method compares the concentration of contaminants on sediment to the state mean concentration for 12 parameters. Using the Kelly and Hite statistical classification, Illinois considers 4.4 miles of the river by Fulton, Illinois as having elevated levels of chromium in the sediments (Illinois EPA, 1988). Three other stations on the river where sediment was sampled did not show elevated levels.

Iowa monitors sediment quality only as part of special studies. There are no sediment quality reports on Mississippi River sediment.

Missouri monitors sediment quality only as a part of special studies. Two studies conducted by the Illinois EPA (1982) and Black and Veatch (1982) examined sediments in the St. Louis area for toxic metals and organics. In the studies, the levels of the toxics were not compared to any guidelines. In order to provide a comparison to other similar sediment monitoring on the river (i.e. Minneapolis/St. Paul toxics study), the levels of toxics found in the St. Louis area are compared to the Great Lakes harbor guidelines. When judged against the harbor guidelines, the sediment in the St. Louis area can be described as moderately polluted with arsenic, chromium, copper, lead, and zinc. Some of the sediments were heavily polluted based on high levels of arsenic.

Federal Monitoring Programs

In a 1981 report (Chesters et al.) to the Upper Mississippi River Basin Commission, sediment sampling data from 1977 and 1979 were used to determine the quality of the sediments throughout the length of the Upper Mississippi River. The EPA Great Lakes harbor guidelines were used to determine the degree of contamination. In addition to the 19 parameters used in the Great Lakes guidelines, the study also examined levels of toxic organics not contained in the guidelines. A list of contaminated bottom sediment areas was developed as shown in Table 12.

Out of the 38 sampling locations on the navigable portion of the river, 12 sites had contaminated bottom sediments. Nine of the sites were located between Locks and Dams 1-10 and the other three sites were located downstream from the confluence of the Illinois River. Although there were 13 sampling sites between Lock and Dam 10 and Lock and Dam 21, none of these sites showed contaminated sediments. These findings are generally consistent with the results of the more recent sampling programs.

The U.S. Fish and Wildlife Service has conducted general contaminant surveys of refuge lands on the Upper Mississippi river. A sediment quality survey was conducted in 1985 at 37 sites on a 78-mile river reach from Lock and Dam 10 by Guttenberg, Iowa to approximately Lock and Dam 14 upstream of Davenport, Iowa.

Table 12. Location of Contaminated Bottom Sediment Areas in the UMRS*

Pool/ River	River Mile	Location	Parameter Exceeded
2	839.3	St. Paul, MN	PCBs, chromium, copper, lead
3	813	Hastings Boat Harbor	PCBs, chromium, lead, nickel, zinc, total nitrogen, ammonia, total phosphorous, chemical oxygen demand
3	808	Truedale Slough	total nitrogen
4	791	Redwing Boat Harbor	PCBs, arsenic, chromium, copper, lead, nickel, zinc, total nitrogen, total phosphorous, chemical oxygen demand
4	754	Alma Boat Harbor	nickel, total nitrogen, total phosphorous, chemical oxygen demand
5	741.5	Mt. Vernon Lighthouse	total nitrogen
6	726	Winona Boat Harbor	PCBs, total nitrogen, total phosphorous
8	698	La Crosse, WI	PCBs
10	644.3	Jackson Island	total nitrogen
27	202.7	Alton, IL	arsenic, cadmium, nickel
R_2	158.5	Kimswick, MO	arsenic, cadmium, chromium, nickel
R_4	43.7	Near Thebes, IL	arsenic, copper

* For PCBs, bottom sediments in some areas contain relatively high concentrations but below the pollutional guideline.

Source: Chesters et al., 1981

Sediment samples were analyzed for metals, pesticides, PCBs, and other organic compounds. Of the 37 sites tested, 35 sites (approximately 30 miles of river) had uncontaminated sediment and 2 sites at River Mile 510.2 (Camanche, Iowa) and 561.5 (Bellevue, Iowa) had contaminated sediment as shown in Figure 4.

The sediment contamination near Camanche, Iowa is by an industrial plant effluent outfall. Elevated concentrations of volatile organics (e.g. solvents, cleaners) and polynuclear aromatic hydrocarbons (byproducts in the manufacture of petroleum products) were found in the sediment below the outfall. Bioassays conducted with minnows showed that the sediment from the river was more toxic than the industrial plant effluent. Over the years, even though the industrial effluent was within the permit requirements, the sediment was accumulating hydrocarbons (Ruelle and Kennedy). The site at River Mile 561.5 in pool 12 contains elevated levels of cadmium, lead, and zinc. Levels are considered to be elevated based on the Great Lakes harbor guidelines and/or the professional judgment of the U.S. Fish and Wildlife Service.

Another sediment quality study was conducted in 1988 by the U.S. Fish and Wildlife Service on Clarence Cannon Refuge lands (near Annada, Missouri by River Mile 260) and Delair Refuge lands (near Louisiana, Missouri by River Mile 283). The sediment was analyzed for metals and organochlorine compounds. The results of the study are not yet available. The Service plans to initiate another study in 1989 of river sediment quality from Camanche, Iowa to the Ohio River confluence.

The Army Corps of Engineers analyzes sediment quality as part of its dredging activities. However, due to District Corps policy, there is little sediment quality information for the river below Guttenberg, Iowa. The Rock Island and

St. Louis Districts do not conduct bulk chemical analyses of sediment unless it contains less than 80 percent sand-sized particles. Since most of the Corps dredging involves sand, there is little or no information on sediment quality. The information that does exist in the Rock Island District, is not in a readily usable form.

The St. Paul District has sediment quality data for the river upstream of Guttenberg, Iowa. The computerized data base in the St. Paul office contains sediment monitoring data from the Corps, U.S. Fish and Wildlife Service, and the state agencies in Minnesota and Wisconsin. The data from the Corps is used in this report, to supplement sediment quality information from the states. Concentrations of 6 metals (arsenic, cadmium, chromium, lead, mercury, zinc) in the sediment are compared to the Great Lakes guidelines. Besides the river reaches that Minnesota and Wisconsin classify as having contaminated sediment, the Corps data lists 28 other reaches (approximately 20 miles) with contaminated sediment. The metals which are consistently found to exceed the Great Lakes guidelines are arsenic and chromium. The Corps data is displayed in Appendix G.

Summary

Based on actual sediment sampling and Wisconsin's classification of the river, approximately 148 miles (17 percent) of the Upper Mississippi River have contaminated sediment. Based on Wisconsin's classification of the river as a potential contamination area, another 138 miles (16 percent) of the river have the potential for contaminated sediment. Based on the 1985 U.S. Fish and Wildlife Service study, approximately 30 miles (4 percent) of the river have uncontaminated sediment. Approximately 532 miles (63 percent) of the river contain sediment of unknown quality. Figure 4 displays the areas of the river with contaminated sediment, potentially contaminated sediment, and uncontaminated sediment.

The results of various site specific sediment studies on the river indicate the presence of numerous contaminants. When judged against the Great Lakes harbor classification, these data show that sediment in the river has been contaminated with ammonia, arsenic, cadmium, chromium, copper, nickel, nitrogen, PCBs, phosphorous, and zinc, and has a high chemical oxygen demand. Other contaminants that have been found that are not listed in the Great Lakes guidelines are various volatile organics (e.g. solvents, cleaners) and polynuclear aromatic hydrocarbons.

The source of sediment contamination may be past discharges of pollutants at a time when water quality standards were not as strict or were not being met, existing discharges of substances that are ubiquitous in the environment or unregulated, or nonpoint source pollution. Since the river is constantly changing, contaminated sediment can be transported downstream or into backwaters during normal flows or flood events. Thus, contaminated sediment may not be found near its source.

Determining the quality of sediment in the Mississippi River is difficult since there are no standards specifically for the river. In addition, there has been no determination on the accuracy or inaccuracy of using the EPA Great Lakes harbor guidelines on the Mississippi River. Ideally, guidelines should be developed for the river that take into account the effect of the contaminated sediment on aquatic life.

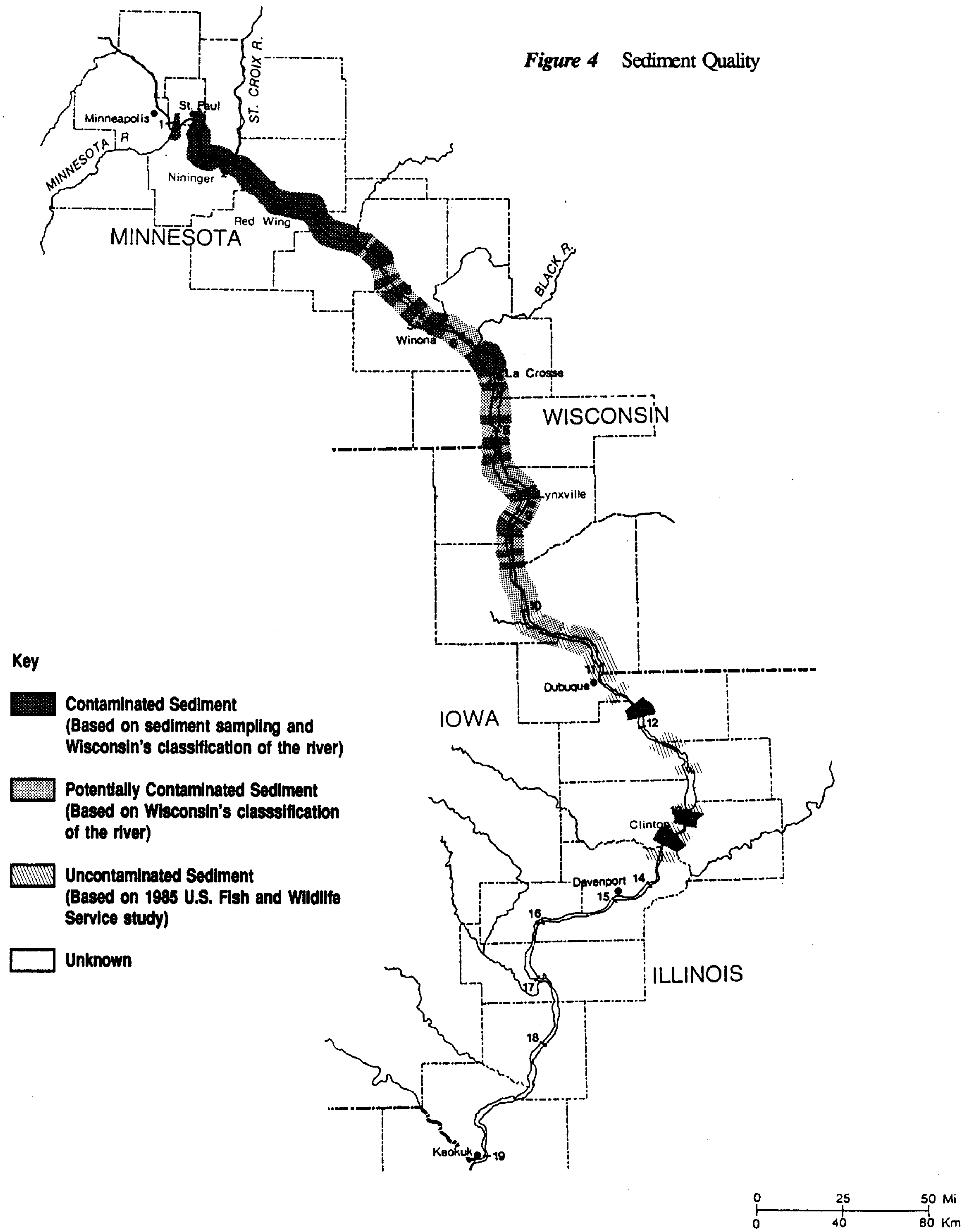
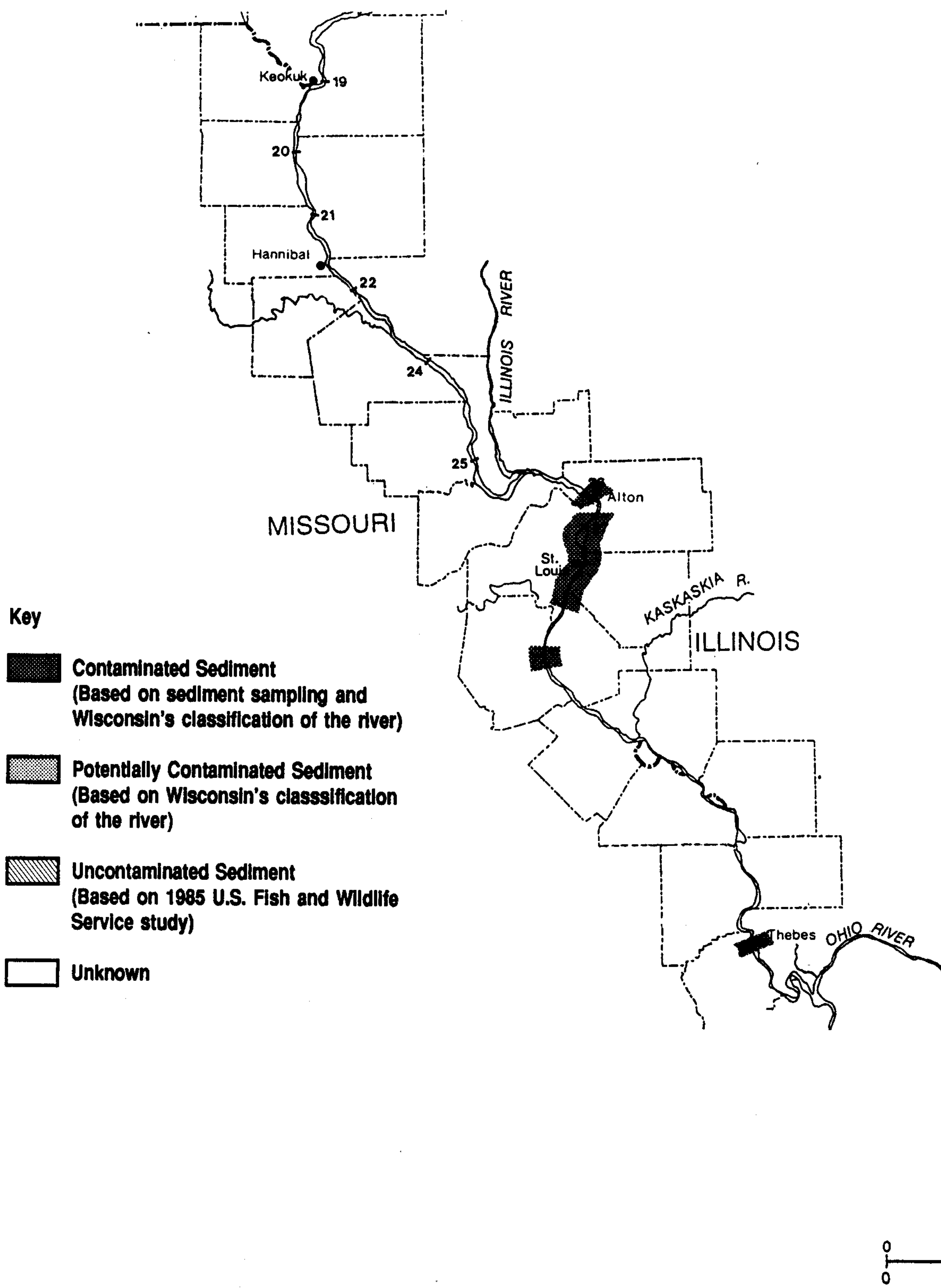


Figure 4 Sediment Quality

Figure 4 Sediment Quality *(continued)*



Water Quality Trend Analysis

Determining trends in water quality is very difficult due to the highly variable nature of water quality. Rivers can be polluted through point discharges and nonpoint sources but they also have a limited ability to assimilate wastes and purify themselves. This balance in water quality varies depending on factors like streamflow and temperature. This variability is a major factor in the difficulty of determining both spatial and temporal trends in water quality.

Trend analysis is based upon evaluation of water samples taken at specific locations at various points in time. The sampling frequency and location affect the representativeness of the sample. Since a flowing river is constantly changing, the water and thus the water quality can be variable. A grab sample taken at one point in time can only indicate the water quality at that moment. Since some parameters like dissolved oxygen can vary considerably in a 24 hour period, a grab sample only represents one snapshot of the changing scene. The location of the sampling station also determines the representativeness of the sampling data since water quality can vary within a small area. The quality of the water in a backwater, side channel, or main channel can vary due to differences in streamflow and disturbance. In addition water quality can vary upstream and downstream of a point due to influx of pollutants or self-purification of the water.

Since there are so many uncontrollable variables in monitoring water quality it is only possible to minimize not eliminate the variability. Programs established to determine trends in water quality try to minimize this variability by consistencies in the monitoring program. Disagreements over trend analysis occur though, as evidenced by a 1981 General Accounting Office report which questioned the usefulness and accuracy of the trend analyses conducted by the federal agencies. Despite the disagreements and difficulties inherent in trend analysis, different federal and state agencies have attempted to examine water quality over time.

In 1972 the U.S. Geological Survey (USGS) established the National Stream Quality Accounting Network (NASQAN) to 1) account for the quantity and quality of streamflow, 2) depict the areal variability of water conditions, 3) detect trends in water quality over time, and 4) provide a nationally consistent data base. There are approximately 500 sampling sites across the country which are generally located at the downstream end of hydrologic accounting units (basins). (USGS, 1988) Up until 1986, there were six stations on the navigable portion of the Upper Mississippi River.

Nininger, MN	#05331570	1977-1988
Winona, MN	#05378500	1963-1986*
Clinton, IA	#05420500	1974-1986
Keokuk, IA	#05474500	1974-1986
Alton, IL	#05587550	1974-1988
Thebes, IL	#07022000	1973-1986

*Includes pre-NASQAN data

Due to program changes, four of the NASQAN stations were discontinued in 1986 -- Winona, Clinton, Keokuk, and Thebes. The Illinois EPA has accepted the responsibility for monitoring at Clinton and Keokuk and conducts the analyses at Thebes. Missouri has assumed partial responsibility for the Thebes station. The Winona station was not picked up by any state and thus data ends in 1986.

In 1974 the EPA initiated the National Stream Quality Surveillance System (NWQSS) to help track progress in pollution control efforts. The program was similar to the NASQAN program in that it was designed to determine trends on river bodies. The program was discontinued in 1981, therefore the data is not used in this report.

In addition to the federal programs, each of the five states has a water quality monitoring program for the river. Minnesota has four sampling stations on the river at St. Paul; Lock and Dam 5; La Crosse, WI; and La Moille, MN. In addition the Metropolitan Waste Control Commission has stations throughout the Minneapolis/St. Paul metro area. Wisconsin has five stations at Hastings, MN; Red Wing, MN; Lake Pepin; Alma, WI; and Lynxville, WI. Illinois has monitoring stations at Fulton, IL (Clinton, IA); Keokuk, IA; Lock and Dam 26; and Thebes, IL. The Clinton, Keokuk, and Thebes stations were previously NASQAN stations. Iowa has two stations at Lock and Dam 9 and Davenport, IA and uses data from the NASQAN stations at Clinton, IA and Keokuk, IA. Missouri has a monitoring station at Hannibal, MO and uses the data from the NASQAN stations at Alton, IL and Thebes, IL.

The trend analysis in this report deals with both temporal and spatial water quality trends of the Upper Mississippi River. Temporal trends are those changes which may occur over time at a given location on the river. Spatial trends are the changes in water quality that may occur as the character and pollutant load of the river vary in its downstream course.

To examine trends, data from the NASQAN stations and the states' monitoring stations was used. Twenty parameters were selected ranging from temperature and dissolved oxygen to metals, nutrients, and sediment. These parameters were chosen because 1) they are conventionally used as water quality indicators, 2) most long term sampling stations at the state and federal level have consistently analyzed for these parameters, and 3) there is historic data available for these parameters that could be used for comparison. The parameters are listed in Table 13.

To evaluate trends for this report, the water quality data was plotted on graphs. Due to limitations with the data only 9 parameters were plotted for the temporal trend analysis. All the parameters were used for the spatial trend analysis.

Temporal Trend Analysis

Temporal trend analysis of water quality in the United States has been primarily conducted by the USGS. Utilizing the data from the NASQAN stations for the period 1974-1981, the USGS has conducted statistical analyses of water quality trends. In 1984, USGS examined trends for dissolved solids, phosphorous, and nitrate plus nitrite (NO_3 and NO_2). (USGS, 1985) In 1987, the USGS conducted a trend analysis for at least 9 parameters but flow-adjusted the data first. It is more accurate to adjust the data based on flow since streamflow variations can potentially cause a trend or act as a confounding influence in trend detection. (USGS, 1987) Four NASQAN stations on the Upper Mississippi River were examined for water quality trends over time: Winona, Keokuk, Alton, and Thebes. The results of the trend analyses are shown in Table 14.

The data shows that the only parameter which had a statistically significant increase at all four stations was chloride. The report attributes this increase to the increased use of salt on highways. Nitrate plus nitrite showed a significant increase at three of the stations. The report states this is likely due to higher levels of atmospheric nitrogen or use of nitrogen fertilizers. No other trends were evident for the stations as a whole.

The Winona station showed increasing levels of alkalinity, chloride, nitrate plus nitrite, dissolved solids, and sulfate. The only decrease was in total phosphorous. Overall, during the period of 1974-1981 the water quality degraded or remained the same for these eleven parameters.

The Keokuk station showed increasing levels of dissolved cadmium, chloride, nitrate plus nitrite, and total phosphorous. Alkalinity showed a decrease. Like the Winona station, the water quality degraded or remained the same for these parameters.

The Alton station showed few trends. Chloride and dissolved solids increased while fecal streptococcus bacteria and dissolved lead decreased. Overall the water quality did not change appreciably.

The Thebes station showed increases in dissolved arsenic, dissolved cadmium, chloride, nitrate plus nitrite, and suspended sediment. The only decrease was in fecal streptococcus bacteria. Overall the water quality degraded or remained the same.

Table 13. Convential Water Quality Parameters Examined

STORET Code	Parameter	Units	Comments
00010	Temperature	°C	Temperature affects dissolved oxygen levels, algae growth, fishery, etc.
00060	Streamflow	cfs	Streamflow can affect water quality by transporting sediment, diluting pollutants, etc.
00061	Instantaneous Discharge	cfs	
00076	Turbidity	FTU	Provides a measure of the suspended particles in the water.
00095	Specific Conductance	us/cm	Measure of the ability of water to conduct an electric current. Indicates the total concentration of ionized substances dissolved in the water. Can be used to estimate dissolved solids.
00300	Dissolved Oxygen	mg/l	Indicates oxygen level in water. Dissolved oxygen is necessary to support most aquatic life.
00400	pH	SU	pH changes can alter the form of inorganic chemicals thereby affecting aquatic life.
00608	Ammonia, Dissolved (NH_3 + NH_4^-)	mg/l	Unionized ammonia is toxic to aquatic life at certain concentrations. The nitrogen in ammonia is a nutrient.
00631	Nitrate plus Nitrite (NO_3 + NO_2)	mg/l	Nitrate plus Nitrite represents a form of nitrogen (a nutrient) in the water.
00665	Phosphorous, Total	mg/l	Phosphorous is a nutrient.
01002	Arsenic, Total	ug/l	Some of these metals are necessary for life in minute quantities but all are toxic in greater concentrations.
01027	Cadmium, Total	ug/l	
01042	Copper, Total	ug/l	
01051	Lead, Total	ug/l	
01092	Zinc, Total	ug/l	
71900	Mercury, Total	ug/l	
31625	Fecal Coliform	#/100 ml	Indicates the bacterialogical quality of water.
70300	Dissolved Solids-Direct	mg/l	Includes all dissolved solids especially bicarbonate which is generally a major dissolved component of water.
70301	Dissolved Solids-Sum	mg/l	
80154	Suspended Sediment	mg/l	Suspended sediment can contain and transport nutrients and toxic metals and organics.

Source: USGS, 1988
Chesters, et al., 1981

Table 14. Temporal Trends in Water Quality, 1974-1981

	Winona, MN	Keokuk, IA	Alton, IL	Thebes, IL
Alkalinity	+	-	No Trend	No Trend
Arsenic, Dissolved	No Trend	No Trend	No Trend	+
Cadmium, Dissolved	No Trend	+	No Trend	+
Chloride	+	+	+	+
Fecal Streptococcus Bacteria	No Trend	No Trend	-	-
Lead, Dissolved	No Trend	No Trend	-	No Trend
Nitrate & Nitrite	+	+	No Trend	+
Phosphorous, Total	-	+	No Trend	No Trend
Solids, Dissolved	+	No Trend	+	No Trend
Sulfate	+	No Trend	No Trend	No Trend
Suspended Sediment	No Trend	No Trend	No Trend	+

Source: USGS, 1985   + statistically significant increasing levels
USGS, 1987   - statistically significant decreasing levels

As shown by the USGS data, water quality improvements were rare during the period 1974-1981. Overall there either was no trend or a trend of degrading water quality.

In addition to the USGS trend analysis, Wisconsin conducted its own evaluation of trends at five stations on the Mississippi River. In their 1986 305(b) Report, Wisconsin lists the results of a trend analysis of four different parameters: total ammonia, fecal coliform, total phosphorous, and total suspended solids. The analysis was conducted with state monitoring data for the period 1978-1985. The five Wisconsin stations on the river were examined for trends as shown in Table 15.

The trend analysis at the five Wisconsin stations primarily showed decreasing levels of the four parameters or no trend at all. Total ammonia showed a statistically significant decrease at all stations except Lynxville which showed no trend. Fecal coliform trends varied. Total phosphorous levels either decreased or remained the same. The trends in total suspended solids varied at the five stations. Overall water quality showed improvement.

The USGS trend analysis covering the period from 1974-1981 overall showed degrading water quality at four stations along the river. The Wisconsin trend analysis from 1978-1985 showed overall improvement in water quality for

Table 15. Trends in Water Quality at Wisconsin Stations, 1978-1985

	Hastings, MN	Red Wing, MN	Lake Pepin	Alma, WI	Lynxville, WI
Ammonia, Total	-	-	-	-	No Trend
Fecal Coliform	No Trend	+	No Trend	-	-
Phosphorous, Total	No Trend	-	No Trend	No Trend	-
Suspended Solids, Total	+	No Trend	-	+	-

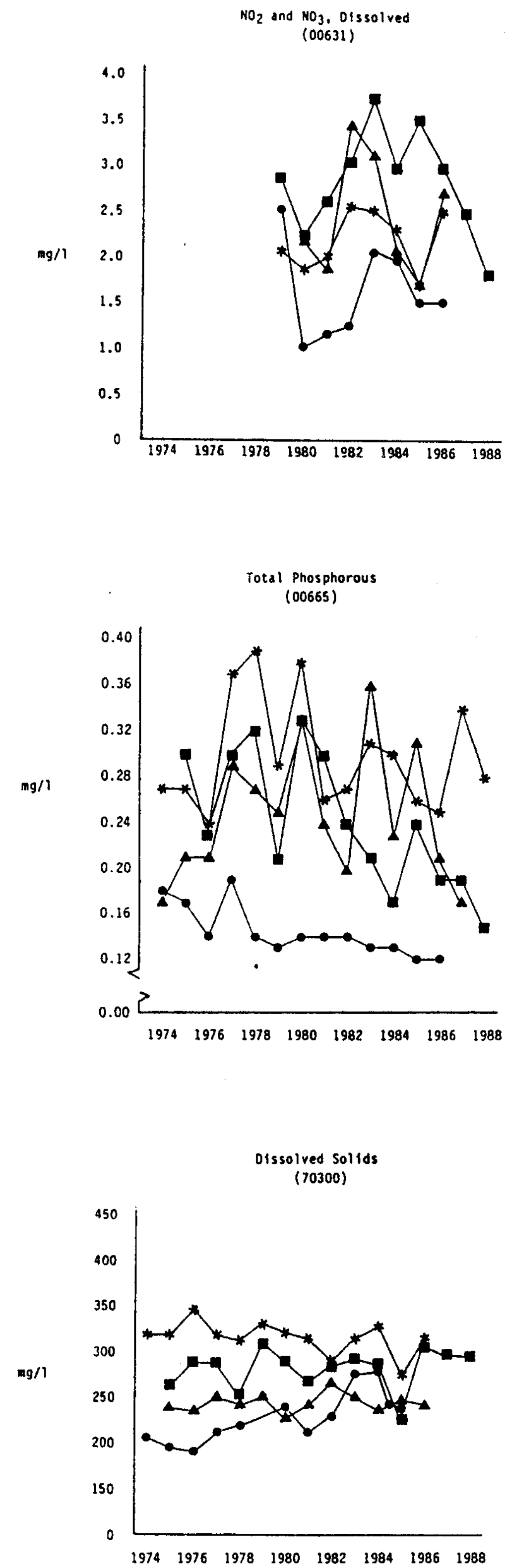
Source: Wisconsin DNR, 1986

the Wisconsin stations. Since the time periods, geographic location of the stations, and the trend analyses techniques are different it is not possible to directly compare the results of the different analyses. But each analysis still provides useful information on trends in water quality.

Since the USGS trend analysis ends with the data from 1981, there is no published information on trends in water quality at the NASQAN stations over the last seven years. To examine potential 1980's trends, recent data from the four NASQAN stations was plotted where available. The annual means were plotted for nine parameters out of twenty parameters available. Specific conductance provides an estimate of dissolved solids thus only dissolved solids was plotted. The metals were not plotted because of data problems due to changing detect levels and sampling schedules.

The trend analysis conducted by USGS was not attempted in this report because it would require various statistical tests and flow adjustment that are beyond the scope of this paper. Rather the data was plotted on graphs and a nonstatistical analysis was conducted. The graphs were examined to see if trends found from 1974-1981 had continued and to see if new trends were apparent with the extra years of data. Since the data in the graphs is not flow adjusted, an "apparent" trend is a trend that is shown by graphs to be increasing or decreasing very obviously and continuously over time. The graphs are shown in Figure 5.

Figure 5 Water Quality Parameters Over Time At Four Monitoring Stations



KEY

- • Winona, Minnesota
- ▲ Keokuk, Iowa
- ■ Alton, Illinois
- * Thebes, Illinois
- --- Data gap

Figure 5 Water Quality Parameters Over Time At Four Monitoring Stations *(continued)*

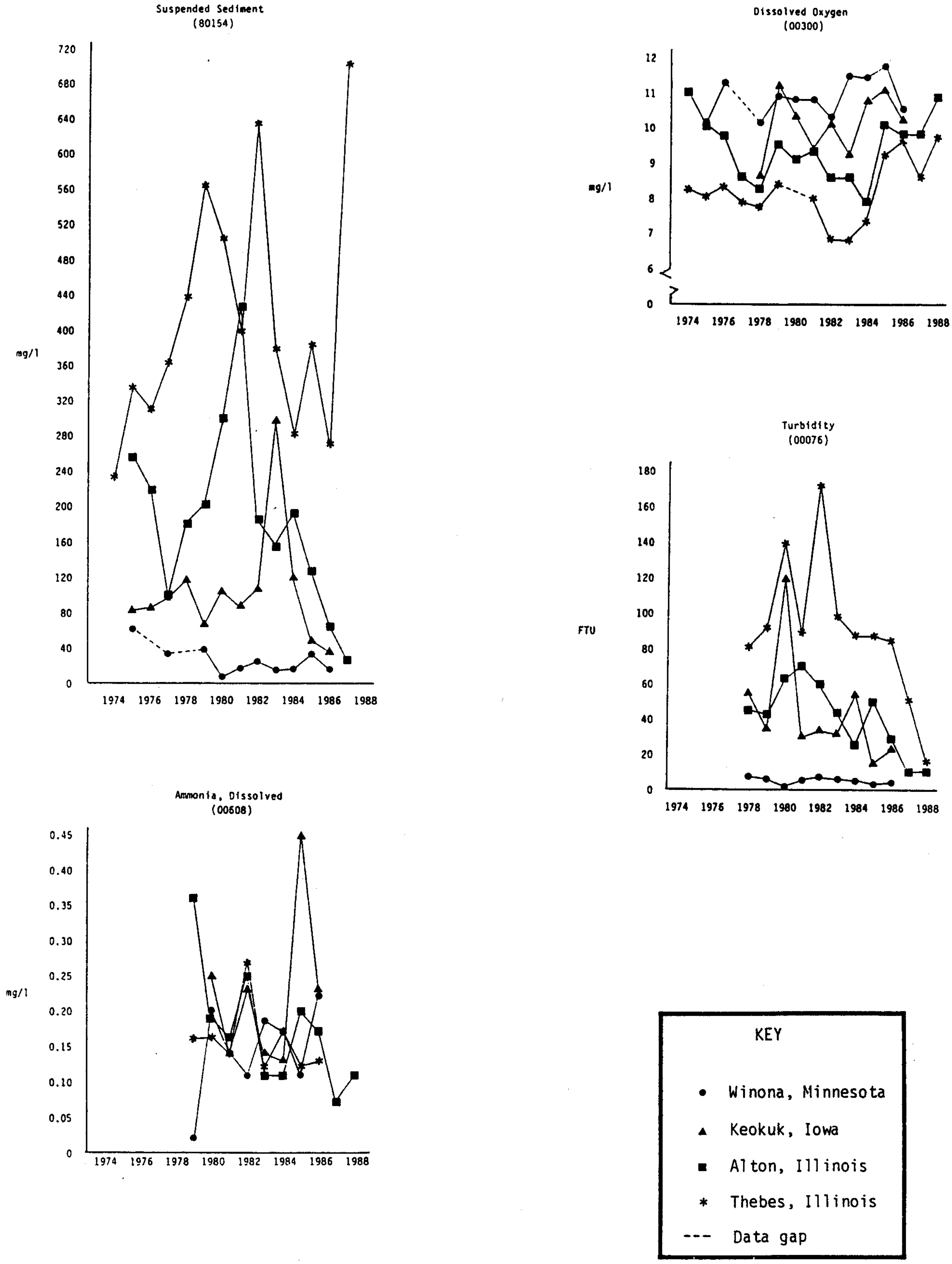
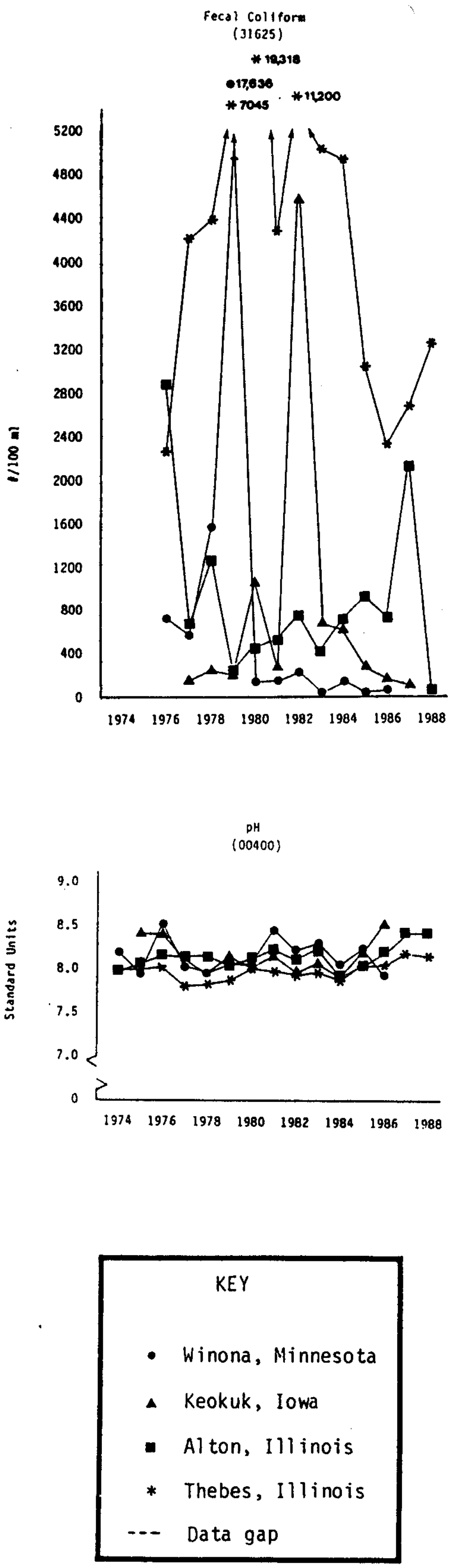


Figure 5 Water Quality Parameters Over Time At Four Monitoring Stations *(continued)*



Four of the parameters analyzed in the USGS trend analysis (nitrate plus nitrite, total phosphorous, dissolved solids, and suspended sediment) were examined in the graphs. The USGS trend analysis noted:

- increasing nitrate plus nitrite levels at Winona, Keokuk, and Thebes,

- decreasing total phosphorous levels at Winona and increasing levels at Keokuk,

- increasing levels of dissolved solids at Winona and Alton, and

- increasing suspended sediment levels at Thebes.

The nitrate plus nitrite trends and the suspended sediment trend did not appear to continue into the 1980's. The decreasing phosphorous levels at Winona did appear to continue but the decreasing levels at Keokuk did not. The increasing dissolved solids levels at Winona continued into the 1980's but the increasing levels at Alton did not. In summary, the only trends for the four parameters that appeared to continue into the 1980's were the decreasing phosphorous levels and the increasing dissolved solids at Winona.

There appear to be new trends in the 1980's for total phosphorous and suspended sediment. From 1974-1981 the USGS found no trend for total phosphorous or suspended sediment levels at Alton. An examination of the graphs for these two parameters in the 1980's shows apparent decreasing total phosphorous levels and suspended sediment levels at Alton.

Water quality data was also plotted for dissolved ammonia, turbidity, and fecal coliform which were not analyzed in the USGS study. The graphs for the 1980's show apparent decreasing levels of ammonia at Alton, decreasing turbidity levels at Alton and Thebes, and decreasing fecal coliform levels at Winona.

Table 16 summarizes the apparent trends in water quality in the 1980's shown in the nine graphs. Of the nine parameters plotted, seven parameters had an apparent trend and thus are listed in the table. Overall the 1980's data showed improving water quality or no trend. In only one instance (dissolved solids at Winona) did the water quality appear to be degrading over time.

Table 16. Temporal Trends in Water Quality, 1980's

	Winona, MN	Keokuk, IA	Alton, IL	Thebes, IL
Ammonia, Dissolved	No Trend	No Trend	-	No Trend
Fecal Coliform	-	No Trend	No Trend	No Trend
Nitrate plus Nitrite	No Trend	No Trend	No Trend	No Trend
Phosphorous, Total	-	No Trend	-	No Trend
Solids, Dissolved	+	No Trend	No Trend	No Trend
Suspended Sediment	No Trend	No Trend	-	No Trend
Turbidity	No Trend	No Trend	-	-

\+ apparent increasing levels
\- apparent decreasing levels

Spatial Trend Analysis

As noted previously, the water quality at a monitoring station is only representative of a specific reach of the river. It may be representative of hundreds of miles of the river or a single mile. Much of this depends on the number of tributaries and point sources, the changes in land use and thus nonpoint sources, and the ability of the river to assimilate wastes and purify itself. Thus to accurately analyze the river for spatial trends in water quality one would likely need significantly more monitoring stations than already exist. But it is possible to examine spatial trends at the location of existing river monitoring stations if the trends are not extrapolated to include the entire river.

Utilizing a combination of the data from the NASQAN stations and the states' monitoring stations, it was possible to select 11 stations on the river which had similar sampling periods and monitored parameters. Most sampling sites were only monitored periodically, or for a short period of time, or for only a few parameters. Thus these stations were eliminated from the selection process. The 11 stations used for the trend analysis in this report are listed in Table 17 and their locations are shown in Figure 6.

To conduct the analysis, the arithmetic mean and minimum and maximum values for each of the 20 parameters listed in Table 13 were obtained for each of the eleven stations. The means are based on an average period of record of 15 years. The number of samples in the period of record ranges from around 100-200 samples for parameters like temperature, conductivity, and dissolved oxygen to 25-50 samples for the metals. The water quality data for the 11 stations is summarized in Appendix H.

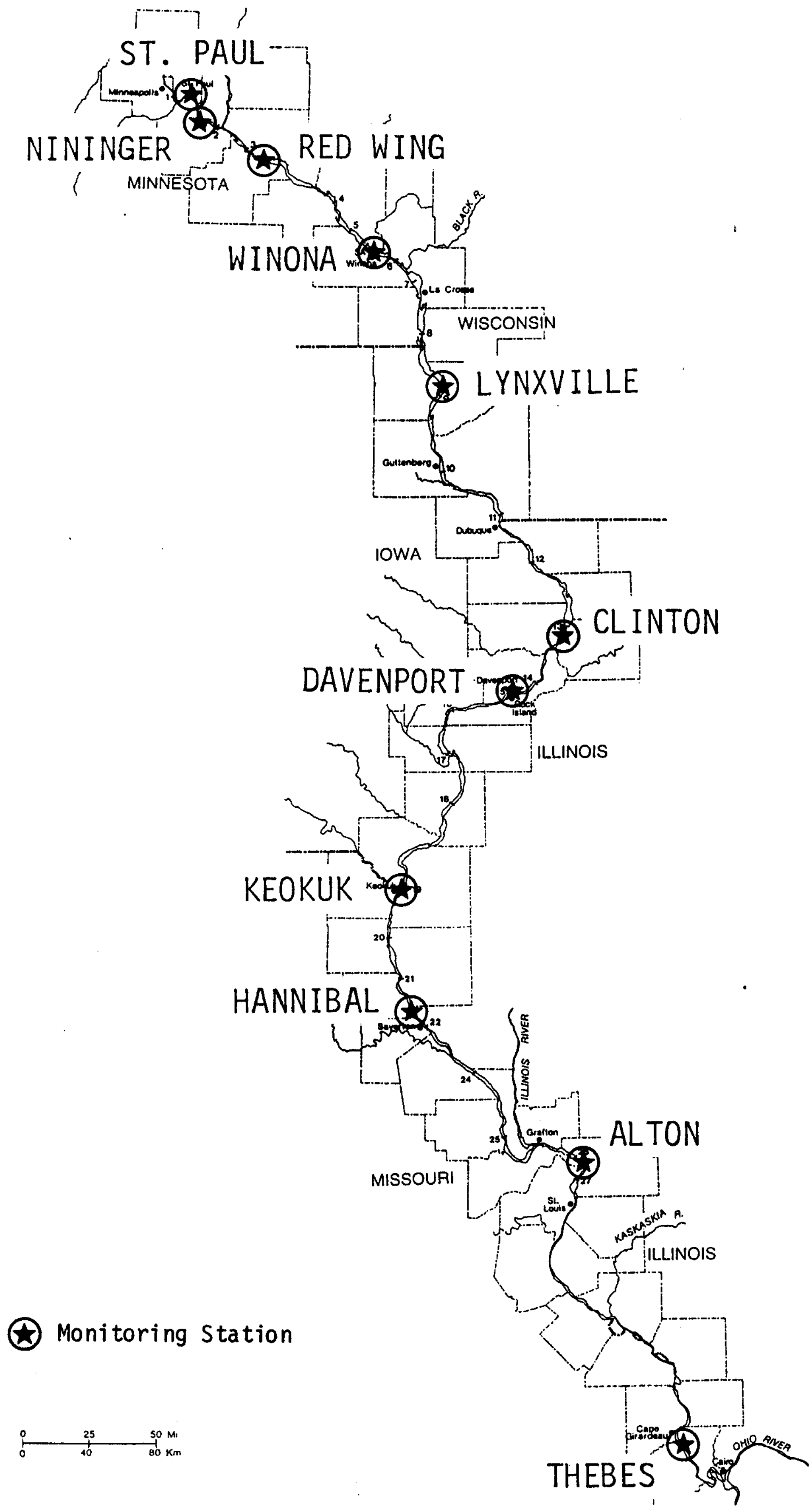
The arithmetic mean proved to be a useful number for all the parameters except fecal coliform and the metals. Since fecal coliform levels can fluctuate considerably (e.g. a range of 64-140,000 coliforms per 100 ml at Thebes, IL) a few extremely high values can skew the arithmetic mean excessively towards the high end, providing an unrealistic picture of average fecal coliform levels. This problem can be minimized by using a different type of mean (i.e. geometric mean). However, the available computerized data contains only the arithmetic mean. While examining the data it is useful to remember this limitation.

The metals data was difficult to use because of the many "less than detect level" values. Each type of analysis or equipment has a detect level which is the smallest concentration of a substance that can be measured accurately. Over time, as equipment and techniques are improved the detect levels decrease and more accurate determinations are pos-

Table 17. Spatial Trend Analysis Monitoring Stations

Monitoring Station	Station #	Period of Record
St. Paul, MN	MN #611	1973-1987
Nininger, MN	NASQAN #05331570	1977-1988
Red Wing, MN	WI #483027	1977-1988
Winona, MN	NASQAN #05378500	1963-1986
Lynxville, WI	WI #123016	1977-1988
Clinton, IA	IL/NASQAN #05420500	1974-1987
Davenport, IA	IA #140690	1972-1985
Keokuk, IA	IL/NASQAN #05474500	1974-1987
Hannibal, MO	USGS/MO #05501600	1967-1988
Alton, IL	NASQAN #05587550	1974-1988
Thebes, IL	IL & MO/NASQAN #07022000	1973-1988

Figure 6 Location of Spatial Trend Analysis Monitoring Stations

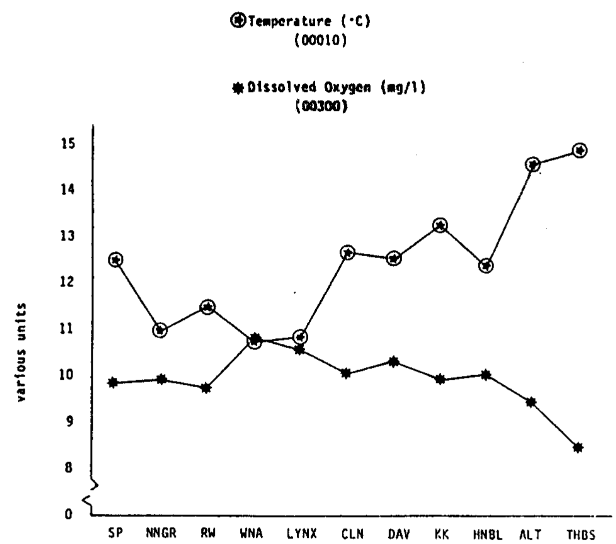


sible. If the concentration of a metal is actually 3 mg/l but the detect level is 200 mg/l, the concentration of the metal is listed as <200 mg/l. As equipment and techniques improve the detect level may drop to values such as 100 mg/l or 50 mg/l. The concentration of the metal will thus be reported as <100 mg/l or <50 mg/l. An actual value for the metal in this example will not be available until the detect level drops down to 3 mg/l or lower.

Since it is not possible to derive an arithmetic mean from a "less than" value, the data must either be discarded or a value must be set for "less than." In this case the value of the "less than detect" was set at the detect level. That is, a sample with <200 mg/l would have a value of 200 mg/l. This method overestimates the mean, but in most cases the value is close enough to the actual mean. In a few instances, however, this method considerably overestimates the mean and the "less than" values were discarded. An example of this occurs at the St. Paul station which used a detect level for cadmium of 10 ug/l from 1973 to 1978. After 1978 the detect level was lowered and actual values for the cadmium concentration were being determined. Using the actual values the mean was 0.59 ug/l. By including the less than values, however, the mean was determined to be 6.65 ug/l. Thus, in this case, the "less than" values were discarded.

The arithmetic means were plotted for each parameter as shown in Figure 7. As expected, due to the warmer air temperatures further south, the mean water temperatures generally increase downstream. The highest mean temperature is at Thebes and the lowest mean temperature is at Winona. Although St. Paul is the northernmost station it has water temperatures comparable to those downstream in Iowa. The mean water temperature upstream of Minneapolis-St. Paul at Anoka, MN is 10.5°C while the temperature at St. Paul is 12.5°C. Due to the inverse relationship of water temperature and dissolved oxygen (oxygen is more soluble in cooler waters) the dissolved oxygen levels generally decrease downstream. The percent oxygen saturation levels (which take into account the solubility of oxygen at different water temperatures) ranged from 85 to 100 percent which is within acceptable levels. The lowest saturation levels are found at the Thebes station.

Figure 7 Water Quality Parameters At 11 Monitoring Stations



KEY	
SP	St. Paul, Minnesota
NNGR	Nininger, Minnesota
RW	Red Wing, Minnesota
WNA	Winona, Minnesota
LYNX	Lynxville, Wisconsin
CLN	Clinton, Iowa
DAV	Davenport, Iowa
KK	Keokuk, Iowa
HNBL	Hannibal, Missouri
ALT	Alton, Illinois
THBS	Thebes, Illinois
---	Data gap

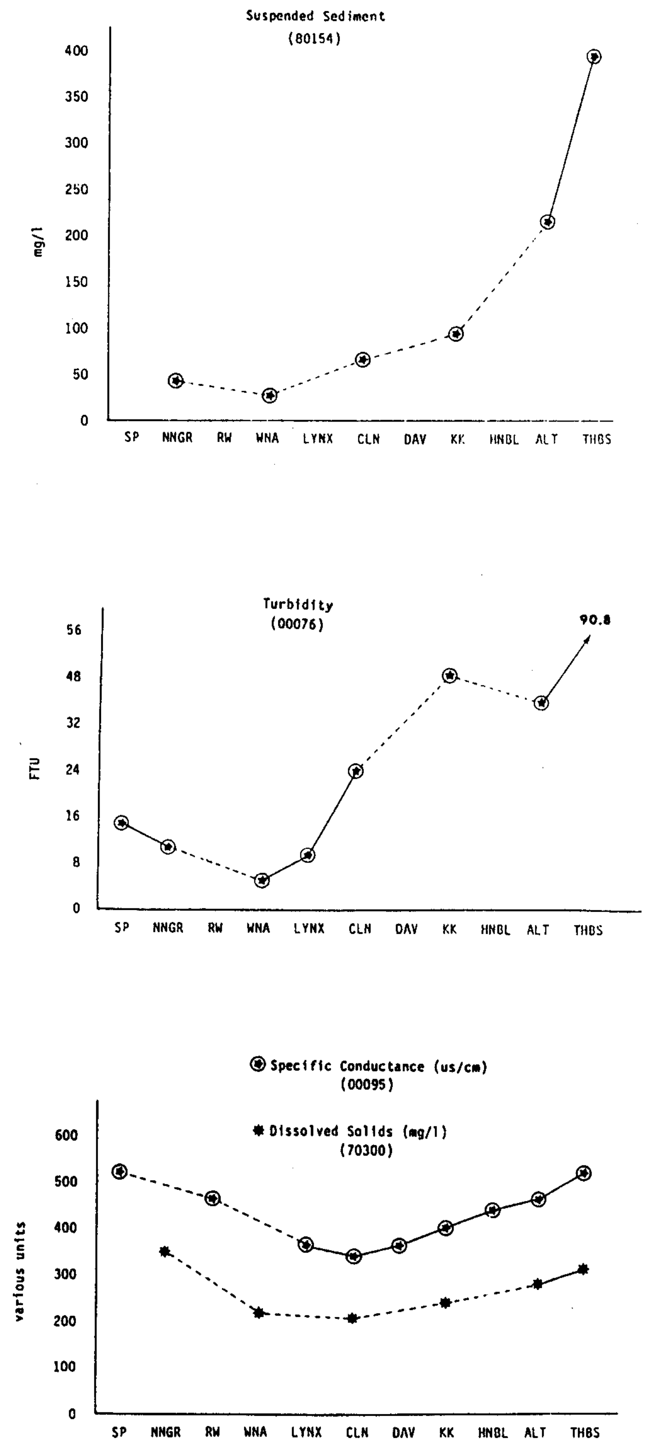
Suspended sediment levels steadily increase downstream from Winona. This would be expected since there is a greater sediment contribution downstream and the increasing streamflow downstream can transport increasing levels of suspended sediment. It is interesting to note that the Upper Mississippi River (minus the Missouri River) discharges approximately 21 million tons of suspended sediment per year. With the additional discharge from the Illinois River (8 million tons/year) and the Missouri River (81 million tons/year), the Upper Mississippi River System discharges a total of 110 million tons/year of suspended sediment. This is 47 percent of the total 235 million tons of suspended sediment discharged from the mouth of the Mississippi River (including the Atchafalaya River) each year. (USGS Project Summary, 1988)

Turbidity levels are moderate at the upstream stations, low at the midstream stations, and extremely high at the downstream stations. The lowest turbidity levels are at the Winona station and the highest are at Thebes. The turbidity levels can be affected by the location of the sampling point. For example, the Winona station is directly downstream of a dam which allows particulates to settle out of the water in the pooled river above the dam. Therefore, the low turbidity levels at Winona could be partially explained by the location of the sampling point.

The levels of dissolved solids and thus specific conductance are lower at the midstream stations and higher at the upstream and downstream stations. The lowest level of dissolved solids is at the Clinton, IA station. One explanation for the lower dissolved solids levels at the midstream stations is the inflow of high quality waters from tributaries such as the St. Croix River.

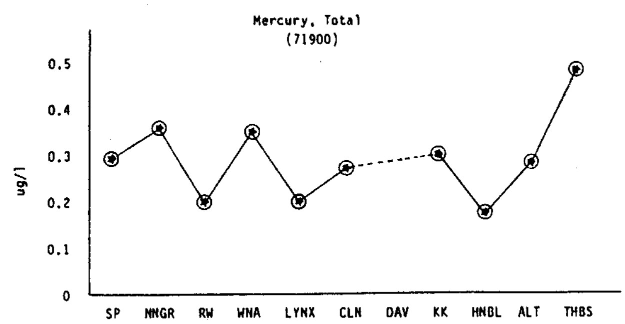
The levels of the six metals (arsenic, cadmium, chromium, lead, mercury, and zinc) vary considerably among the different stations. One explanation for

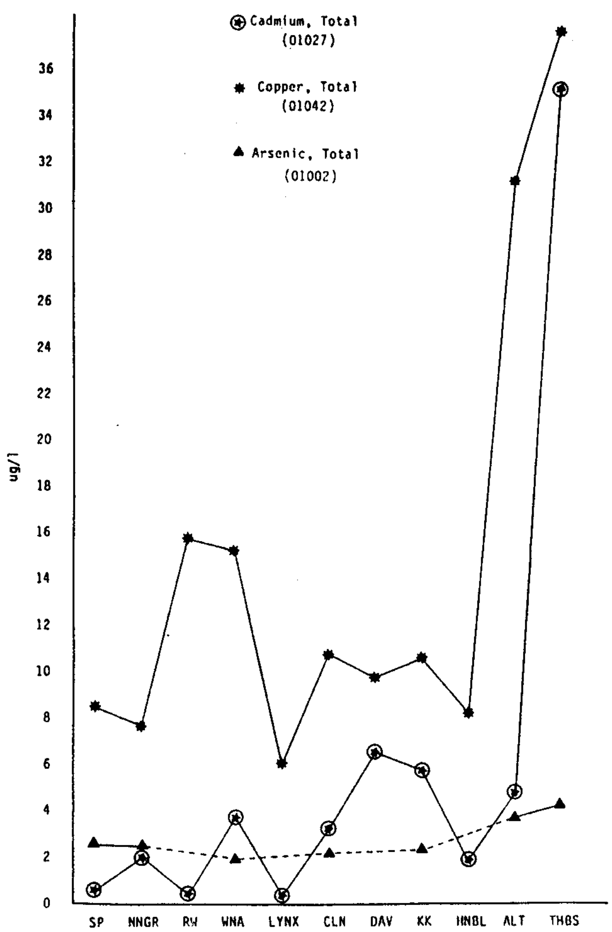
Figure 7 Water Quality Parameters At 11 Monitoring Stations *(continued)*

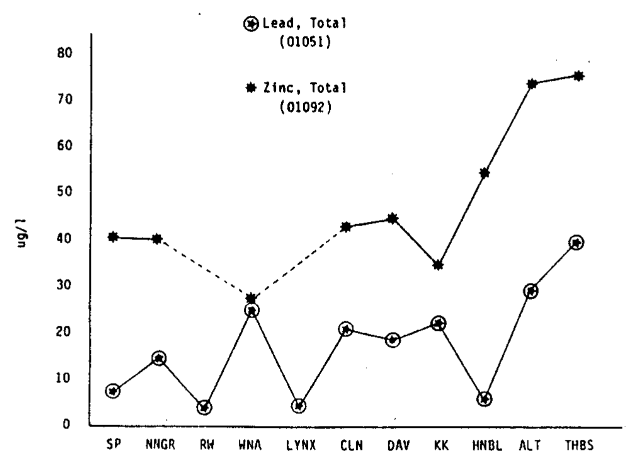


this is that the metals levels at the NASQAN stations are, on the whole, higher than at the non-NASQAN stations. This may represent a difference in sampling or analytical procedures between the NASQAN program and the other programs. Despite this difference, however, one trend that is readily apparent is the high levels of metals at the Alton and Thebes stations. The Thebes station has the highest mean level for all six of the metals and the Alton station has the second highest mean level for four of the six metals. Even considering the problems with the metals data that was discussed previously, Thebes and Alton have considerably higher metals levels than the other stations.

Figure 7 Water Quality Parameters At 11 Monitoring Stations *(continued)*







KEY

SP	St. Paul, Minnesota
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RW	Red Wing, Minnesota
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KK	Keokuk, Iowa
HNBL	Hannibal, Missouri
ALT	Alton, Illinois
THBS	Thebes, Illinois
---	Data gap

Fecal coliform levels vary on the river but are the highest at the Thebes station. While fecal coliform averages can be skewed by rare, extremely high values, the levels at Thebes are actually higher than the other stations as evidenced by the high minimum and maximum values. (See Appendix H.)

The nutrients show differing trends. Ammonia levels are highest at the upriver stations at Nininger and Red Wing and fairly similar for all the other stations. The total phosphorous levels are highest at the downstream stations (except for Hannibal, MO) and lowest at the midriver stations from Red Wing to Clinton. The nitrate levels are also highest at the downstream stations (except for Hannibal, MO) and lowest at the midriver stations. There is no trend in pH levels. All stations have relatively the same levels.

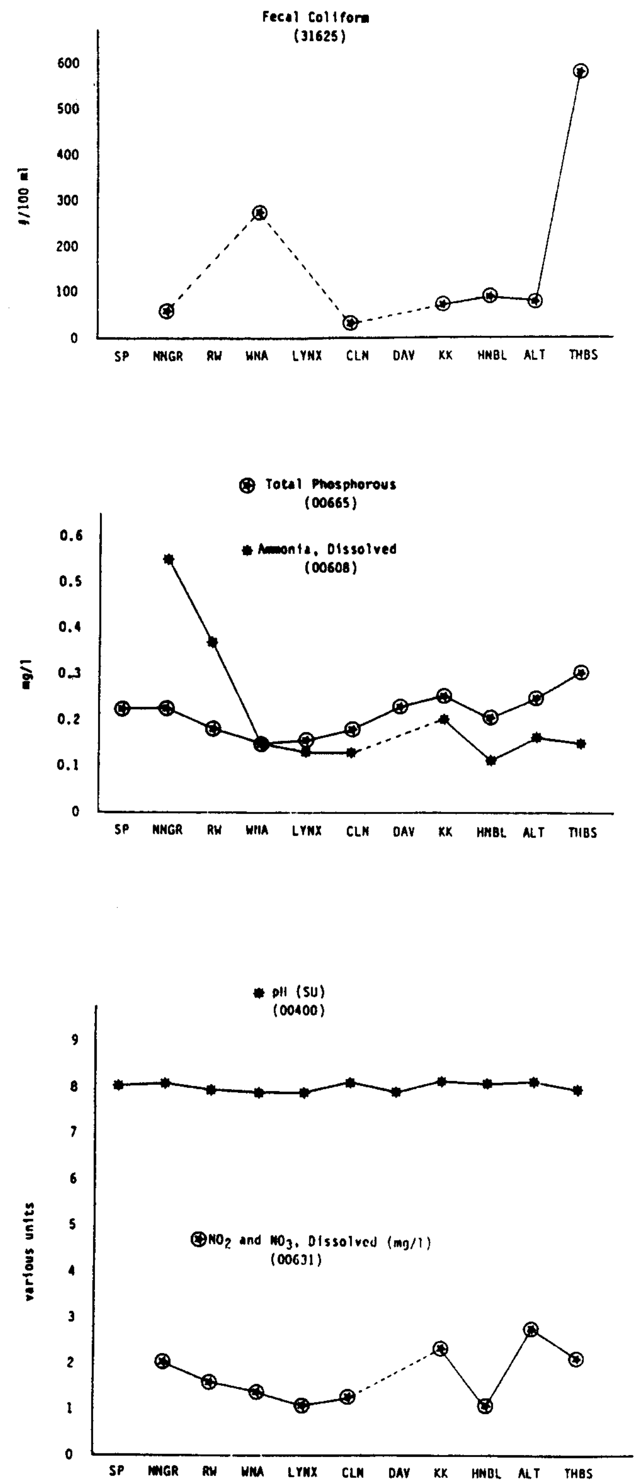
Based on the 20 parameters, two general trends can be noted from this data:

1) the upstream and downstream stations have poorer water quality than the midstream stations and the station at Thebes has the worst water quality, and

2) the midstream stations (approximately Red Wing to Clinton) overall have the best water quality with the station at Winona having the best water quality.

KEY	
SP	St. Paul, Minnesota
NNGR	Nininger, Minnesota
RW	Red Wing, Minnesota
WNA	Winona, Minnesota
LYNX	Lynxville, Wisconsin
CLN	Clinton, Iowa
DAV	Davenport, Iowa
KK	Keokuk, Iowa
HNBL	Hannibal, Missouri
ALT	Alton, Illinois
THBS	Thebes, Illinois
---	Data gap

Figure 7 Water Quality Parameters At 11 Monitoring Stations *(continued)*



Summary

Based on temporal water quality trends from 1974-1981, water quality at four stations on the Upper Mississippi River (Winona, MN; Keokuk, IA; Alton, IL; and Thebes, IL) was overall either degrading over time or showed no trends. There were few trends that showed improving water quality. Based on 1980's data in the Wisconsin river reach, water quality was overall either improving or showed no trend. Using the plotted data for the 1980's for the four stations on the river, water quality primarily improved or showed no trend. The improvements were primarily at the Winona and Alton stations. Based on the 1980's data, water quality appears to have improved in the Wisconsin portion of the river and at Alton, Illinois. Since many parameters showed no trend and since improvements did not occur at all four stations on the river, it is not possible to conclude that water quality is improving on the entire Upper Mississippi River. The data does not suggest, however, that water quality of the river is degrading.

Based on spatial water quality trends from an average of 15 years of data, the water quality is best at the midstream stations (Red Wing, MN; Winona, MN; Lynxville, WI; and Clinton, IA), poorer at the upstream stations (St. Paul, MN and Nininger, MN), and poorest at the downstream stations (Alton, IL and Thebes, IL). The three other midstream stations at Davenport, IA; Keokuk, IA; and Hannibal, MO showed water quality that was better than at Alton and Thebes but not as good as at the other four midstream stations. The impact from the Minneapolis-St. Paul metro area and the Minnesota River can be readily seen at the upstream stations and the impact from the Illinois River, the Missouri River, and the St. Louis metro area can be readily seen at the downstream stations. In addition, the input of high quality waters from tributaries such as the St. Croix River may affect the water quality at the midstream stations.

To determine if the spatial trends hold true over time, the spatial trends were compared with the temporal trends plotted in Figure 5. An examination of the graphs in Figure 5 shows that the Winona station consistently had better water quality than the Keokuk, Alton, or Thebes stations. Examples of this can be seen for all parameters except dissolved ammonia. The graphs also show that the Thebes station has consistently had the poorest water quality. Since the temporal data for St. Paul and Nininger is not plotted, it is not possible to compare their water quality over time. Based on a comparison with the temporal trend graphs, the spatial trends have consistently held true over at least the last ten to fifteen years.

SUMMARY AND CONCLUSIONS

Collective Examination of Water Quality

This report examines the water quality of the Upper Mississippi River based on exceedances of standards, support of uses, quality of the fishery, sediment quality, and spatial and temporal trends. Each of these is only a part of the picture and addresses a different aspect of water quality. Thus, general conclusions about the water quality of the river vary based on the methodology used. Based on the exceedances of the conventional inorganic standards, most parameters are within the standards and water quality is acceptable for most of the designated uses. But exceedances still exist due to high fecal coliform levels, low dissolved oxygen levels, high and low pH levels, and high levels of various toxic metals. Based on support of the fishable use, the downstream end of the river has unacceptable water quality. Based on the support of the swimmable use, the water quality of the river is acceptable except in the Minneapolis-St. Paul metro area and by Thebes, Illinois. Based on fish advisories, a large percent of the river has unacceptable water quality due to high levels of organics in fish. Based on sediment contamination, the water quality is unacceptable for the majority of the Minnesota-Wisconsin reach of the river and the river in the St. Louis metro area. Since each of these methods address a different aspect of water quality, the methods are examined collectively to give a more complete picture of the water quality of the Upper Mississippi River.

Water Quality Problems

The segments of the river that have water quality problems based on exceedances of standards, nonsupport of uses, fish advisories, and contaminated sediment are shown in Figure 8. Collectively, approximately 583 miles (69 percent) of the river have water quality problems. The majority of the problems are concentrated at the upstream and downstream ends of the river. The 265 miles of the river that are <u>not</u> defined as having water quality problems are in the middle of the river from approximately Lock and Dam 10 to Lock and Dam 19 (Guttenberg, Iowa to Keokuk, Iowa) and from Lock and Dam 20 to Lock and Dam 21. Interspersed in this part of the river, however, are localized areas with water quality problems. The longest river reach with no defined water quality problems is the 118 mile stretch from Davenport, Iowa to Keokuk, Iowa.

The river reaches with the best water quality are located in the middle section of the river away from the major metro areas of Minneapolis-St. Paul and St. Louis and the confluences of major tributaries (Minnesota, Illinois, and Missouri Rivers). The water quality studies of the river in the metro areas indicate that there are water quality problems at Minneapolis-St. Paul and at St. Louis. In addition there are sediment contamination problems and fish advisories on consumption of specific fish in the metro reaches of the river. The concentrations of certain toxic pollutants are higher downstream of the two major metropolitan areas. The 1988 toxics study in the Minneapolis-St. Paul area found exceedances of the draft standards for 6 metals, 5 pesticides, phenols, and PCBs. The 1982 St. Louis study found 40 to 45 different priority pollutants in the treatment plant discharges of the city. While most of these pollutants do not exceed the standards, there is a considerable pollutant load from the metro area and continuing water quality problems.

The water quality problems and river mileage corresponding to each of these problems is identified in Table 18. The most pervasive water quality problem on the river is the degradation of the fishery resource as evidenced by the 519 miles of the river with fish advisories. (The river miles with fish advisories may increase if Iowa issues advisories for the river reaches by Clinton and Davenport that contain contaminated fish.) Fishable use is not supported in 340 river miles and swimmable use is not supported in 26 river miles. There are 148 river miles that have identified sediment contamina-

Figure 8 Water Quality Problems of the Upper Mississippi River

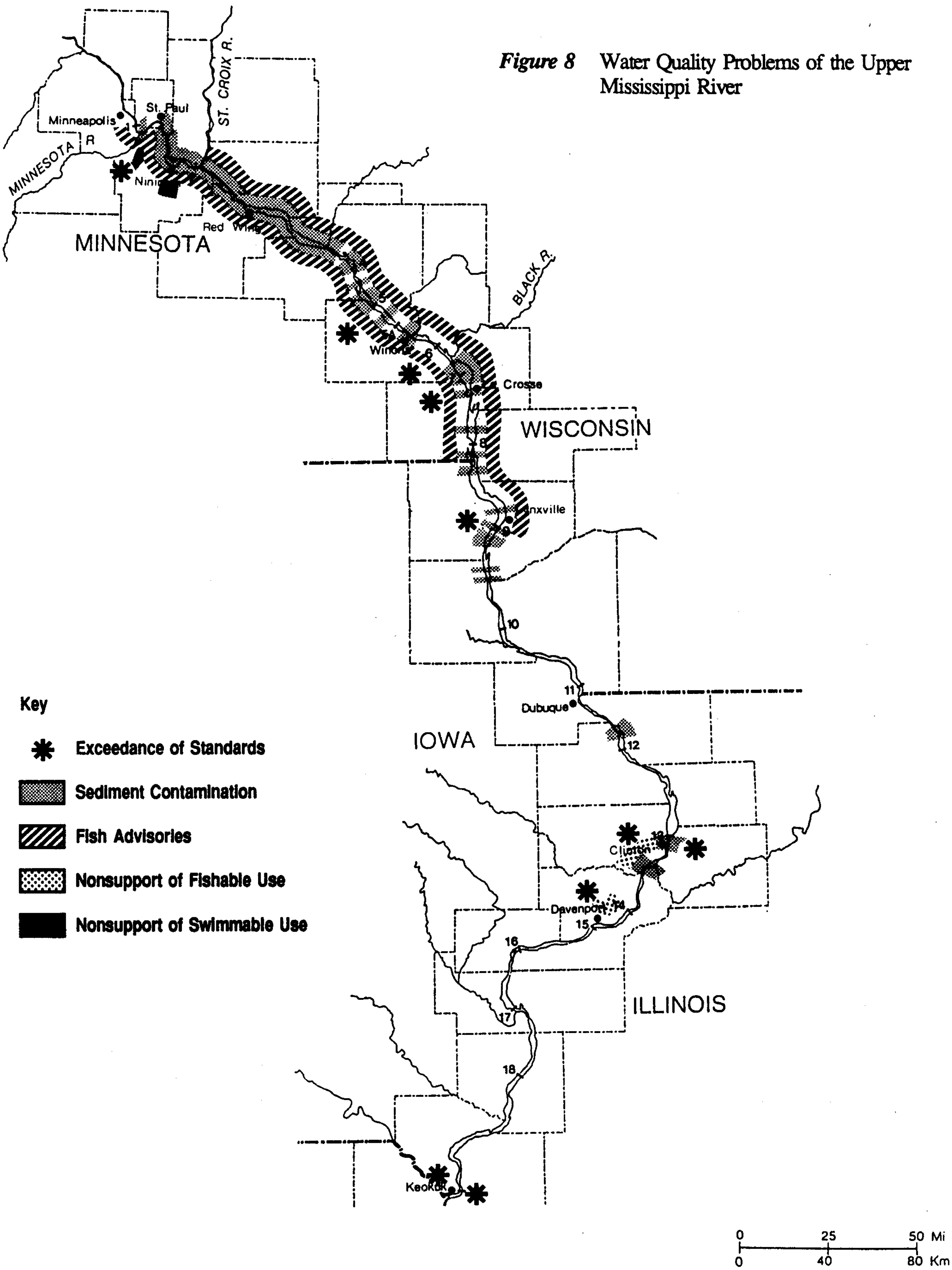


Figure 8 Water Quality Problems of the Upper Mississippi River *(continued)*

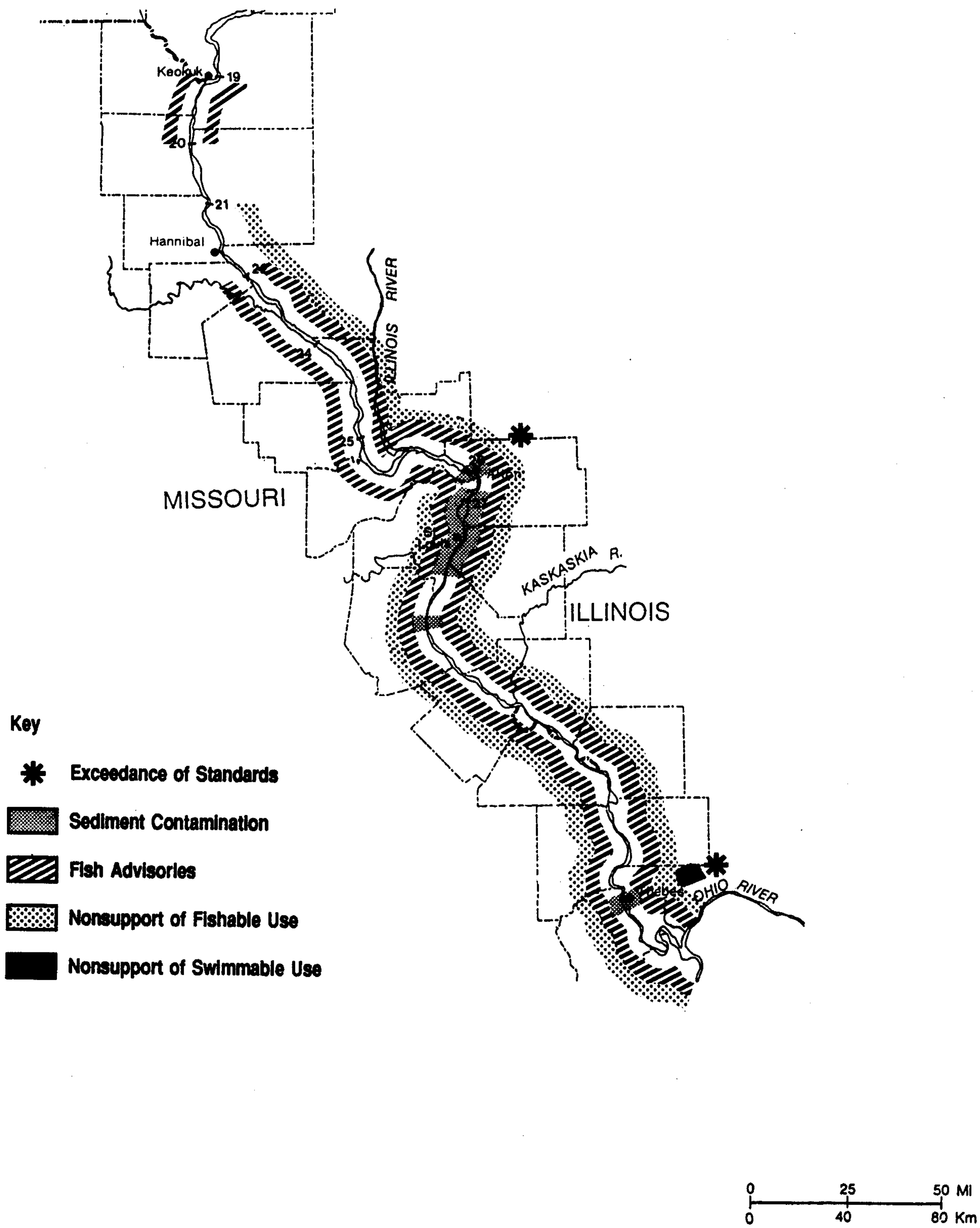


Table 18. River Miles Affected by Water Quality Problems

	Affected River Miles (848 total miles)
Exceedances of Water Quality Standards	(10 locations)
Nonsupport of Fishable Use	340
Nonsupport of Swimmable Use	26
Fish Advisories	519
Sediment Contamination	148

tion. Exceedances of the water quality standards were reported at 10 locations on the river. The river mileage figures for river reaches with contaminated sediment or not supporting the swimmable use may be misleading since there is little data available on either of these problems.

Although 519 miles of the river have fish advisories, only 340 miles of the river are defined as not supporting the fishable use. These 340 miles, however, do not always include river stretches with fish advisories. Thirty-nine river miles that do not support the fishable use do not have fish advisories. Conversely, 222 river miles with fish advisories are considered to be supporting the fishable use. If the mileage of the river stretches that do not support the fishable use and the mileage of the river stretches with fish advisories are combined, a total of 558 miles, or 66 percent of the river, has water quality problems based on degradation of the fishery resource.

A degraded fishery resource indicates potential sediment quality problems since sediment is one of the major sources of contaminants in fish. Bottom feeding fish like carp and catfish take up contaminants like PCBs that are adsorbed to sediment. The 200 miles of river from Lock and Dam 1 to Lock and Dam 9 that have fish advisories due to PCBs in fish, potentially have PCB-contaminated sediment. As shown in Figure 8, 104 miles of these 200 miles are known to have sediment contaminated with PCBs and/or metals. Since sediment monitoring is not extensively conducted on the river, it is not possible to ascertain the quality of the sediment in most of the river.

Sediment contamination in the river is caused by contaminants in the water that adsorb to the sediment or by contamination of the sediment on land and subsequent deposition of the sediment into the river. While the sediment in a river reach may be contaminated, the water quality in that river reach may be within the standards. Contaminants that were deposited in previous years will be adsorbed to the sediment and will likely not show up at problem levels in the water column. In addition, minute concentrations of contaminants which are within the standards for water quality, may accumulate over time and concentrate in the sediment. While discharges to the river and ambient levels downstream from a discharge in the river may comply with permitted levels, the sediment downstream can be concentrating the contaminants to levels that adversely affect aquatic life.

Nonsupport of the swimmable use occurs in 26 miles of the river. All five states base their determination of use support on exceedance of the fecal coliform standard although they may use other criteria as well. All ten stations on the river that had exceedances of standards (see Figure 8) had exceedances of the fecal coliform standard as shown in Table 5. Yet eight of those stations are located in areas that are identified as supporting the swimmable use. This inconsistency is due to the EPA definition of nonsupport, the lack of fecal coliform data on the river, and the use of a geometric mean. Minnesota used the EPA definition of nonsupport which is that a standard is exceeded more than 25 percent of the time. Ten years of data was examined for the Minnesota stations and exceedances did not occur more than 25 percent of the time (except at St. Paul as noted on the map), thus the swimmable use is supported. Iowa used two years of fecal coliform data to determine swimmable use support. Since there was not enough data at the four stations in Iowa to show nonsupport, the river was considered to be supporting the swimmable use. Illinois determined the geometric mean for five years of fecal coliform data and compared this mean to the fecal coliform standard. (The geometric mean reduces the bias that comes from rare, extremely high fecal coliform values.) Since the geometric mean did not exceed the standard, the swimmable use was supported.

Based on the exceedances of the standards, fish advisories, and sediment contamination, there are various contaminants that account for the bulk of the problems. The metals (arsenic, cadmium, chromium, copper, lead, mercury, and zinc), some organics (chlordane, dieldrin, and PCBs), and fecal coliform are the most prevalent contaminants. Exceedances of the standards due to low dissolved oxygen levels and high and low pH levels still occur on the river.

Water Quality Trends

Based on temporal trends at the Winona, Keokuk, Alton, and Thebes stations and five stations in Wisconsin, the water quality of the Upper Mississippi River has been generally improving or has remained the same in the 1980's for the conventional parameters (e.g. total phosphorous, turbidity). This is in contrast to the water quality trends from 1974-1981 determined by the USGS, which showed that generally water quality on the Upper Mississippi River was degrading or had remained the same.

When the exceedances of the standards are examined for the 1980's, the data shows that the exceedances essentially occur each year. Thus the exceedances show that in the 1980's, water quality based on conventional parameters, has remained relatively constant. In addition, many of the problems with high fecal coliform levels, low dissolved oxygen levels, and high and low pH levels identified in the late 1970's (Chesters et al., 1981) have continued into the 1980's. Based on the conventional water quality parameters, water quality has remained relatively the same in the last decade or has improved for a few parameters at various stations. There is no overall trend showing degradation of the resource.

Based on the information from the National Contaminant Biomonitoring Program, the types and levels of contaminants in Mississippi River fish have changed over time. In the 1970's, PCB and chlordane levels decreased while individual components of chlordane insecticides increased. In the 1980's, the states determined that PCB levels were still decreasing but chlordane levels were remaining the same. While there has been improvement in the levels of contaminants in the fish over the years, the Mississippi River still has some of the highest contamination levels in the country based on U.S. Fish and Wildlife Service studies.

Based on spatial trends for 11 stations on the river, the water quality is best at the midstream stations (Red Wing to Clinton), poorer at the upstream stations (St. Paul and Nininger), and poorest at the downstream stations (Alton and Thebes). The stations at Davenport, Keokuk, and Hannibal have better water quality than the downstream stations but not as good as the other four midstream stations. These trends have consistently held true over at least the last ten to fifteen years.

The spatial water quality trends are corroborated by the data on the problem areas of the river. As stated previously, the majority of the water quality problems on the river are found at the upstream and downstream ends of the river.

Problems in Determining Water Quality

The major problem that is encountered when examining the water quality of the 848 navigable miles of the Upper Mississippi River, is that the states along the river have different standards for water quality and different water quality monitoring programs. Since the standards vary and the type and amount of monitoring data varies, states' descriptions of water quality are difficult and sometimes impossible to compare. As shown repeatedly in this report, water quality determinations of the same stretch of river can vary considerably between two neighboring states. The specific problems encountered in comprehensively describing the water quality of the river are listed in Table 19.

These problems in describing water quality make it more difficult to conduct comparisons over time, between states, and between studies. These types of problems were minimized in this paper, however, by selecting data and studies that could legitimately be compared with other data and studies on the river. While there is more information on the water quality of the river than was used in this report, much of this information is only applicable to a single pool, backwater, or state. To examine the water quality of the river on a systemwide approach, it was necessary to select information on the river that could be used consistently throughout the river. Even with this selection criteria, however, numerous problems were still encountered.

Final Summary

The states have designated uses for the Mississippi River and have set water quality standards so that the river supports these uses. If the uses are supported, the standards have achieved the desired results and the water quality is acceptable. If, on the other hand, the uses are not supported, then the standards may need to be revised, permitted discharge levels may need to be lowered, or more effort must be made to eliminate or regulate uncontrolled sources of pollution. Illinois and Minnesota are presently reviewing changes to their standards and Wisconsin just recently revised its standards.

If water quality is examined by only looking at exceedances of the standards, then water quality determinations may be inaccurate. Since contaminants in the river can adsorb to and concentrate in the sediment over time, acceptable levels of substances in the water can concentrate to toxic levels in the sediment. Since fish and other aquatic life can acquire contaminants from the sediment, acceptable levels of substances in the water may ultimately contribute to the nonsupport of the fish and aquatic life use. When this occurs, the water quality of the river is unacceptable for aquatic life use even though the water quality standards have not been exceeded.

Based on the conventional inorganic standards, the levels of most parameters in the river water are within the limits set by the standards. Yet there are high levels of metals and organics in the sediment and high levels of organics in the fish necessitating fish advisories for 61 percent of the river. The contamination of the sediment and the fish may be due to a combination of past discharges of pollutants over the standards or at a time when standards were not as strict, existing discharges of substances that are ubiquitous in the environment or unregulated, or nonpoint source pollution.

A collective analysis of the various types of water quality indicators reveals that the best water quality is in the 265 mile midriver segment of the river, far enough downstream so as not to be affected by the Minneapolis-St. Paul metro area and the confluence of the Minnesota River, and upstream of the confluences of the Illinois and Missouri Rivers and the St. Louis metro area. This midriver section has no fish advisories and few identified problems with sediment contamination or nonsupport of uses. It is possible though, that the water quality of this section of the river has not been thoroughly examined and may have presently undetected problems that are the same as those on the rest of the river.

Table 19. Problems in Describing Water Quality of the Upper Mississippi River

Water Quality Standards

- the Mississippi River's designated uses vary by state thus standards vary
- regulated parameters vary by state
- standards for the same parameters have different limits

Exceedance of Standards

- not all states produce or use exceedance reports
- standards change over time
- different parameters are used to evaluate water quality in different studies making comparisons difficult

Support of Uses

- the designated uses and thus designated use support varies by state
- parameters used to determine use support vary by state
- criteria used to determine degree of use support vary by state
- interpretations of EPA guidelines vary by state
- level of monitoring varies among the states
- reporting of use support data varies by state

Quality of Fishery Resource

- advisories issued by neighboring states sometimes vary on same stretch of river (fish type, fish size, advisory group)
- no recent statistical data from the National Contaminant Biomonitoring Program

Sediment Quality

- no formal sediment quality standards uniquely designed for river sediment
- lack of sediment monitoring thus lack of sediment quality data

Trend Analysis

- differences between monitoring programs and changes in the programs over time
- changes in monitoring frequency or type of analyses for specific parameters over time
- different techniques for trend analysis

Over the last decade, the water quality of the river has stayed the same or slightly improved. Exceedances of the inorganic water quality standards are continuous over time and high fecal coliform levels, low dissolved oxygen levels, high and low pH values, and high levels of toxic metals continue to occur on the river. Levels of contaminants in fish have decreased or remained the same. While there are few improvements in water quality, there is no indication that the water quality of the river is degrading.

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APPENDICES

Appendix A. Wisconsin's Water Quality Standards

Inorganic Parameters

Parameter		Warm Water Sportfish Communities Use: Acute Toxicity A*	Acute Toxicity B*	Chronic Toxicity A*	Chronic Toxicity B*	Recreation Use	Wildlife & Domestic Animals Use	Public Health and Welfare Use: Human Threshold	Human Cancer
Ammonia, Unionized	ug/l	0.04 (irrespective of effect levels)							
Antimony	ug/l							7,800	
Arsenic	ug/l	363.8		153					50
Beryllium	ug/l								0.2
Cadmium	ug/l		49.54		0.81			82	
Chlorine, Total Residual	ug/l	18.4		7.06					
Chromium	ug/l	14.2 (hexa-valent)	2,729 (tri-valent)	9.74 (hexa-valent)	79.06 (tri-valent)			9,500,000 (trivalent) 9,000 (hexavalent)	
Copper	ug/l		25.74		17.88				
Cyanide	ug/l	46.2		4.96				40,000	
Dissolved Oxygen	mg/l	5 (irrespective of effect levels)							
Fecal Coliform	#/100 ml					200			
Lead	ug/l		312.8		18.66			50	
Mercury	ug/l	1.53					0.002	880	
Nickel	ug/l		1,593.4		97.79			460	
pH	standard units	6.0-9.0 (irrespective of effect levels)							
Phenols	ug/l							160,000	
Selenium	ug/l	58		7.07				170	
Silver	ug/l		3.48		3.48			430	
Temperature	°F	5° above normal, not >89° (irrespective of effect levels)							
Thallium	ug/l							11	
Zinc	ug/l		152.8		73.37				

A* Standards are not based on the pH or hardness of the water.
B* Standards are based on a water hardness of 160 ppm. These standards will vary with different hardness of water.

Appendix A. (Continued)
Wisconsin's Water Quality Standards

Organic Parameters
(All units are in ug/l except Dioxin which is measured in ng/l)

Parameter	Warm Water Sportfish Communities Use: Acute Toxicity A*	Acute Toxicity B*	Chronic Toxicity A*	Chronic Toxicity B*	Recreation Use	Wildlife & Domestic Animals Use	Public Health and Welfare Use: Human Threshold	Human Cancer
Acrolein							470	
Acrylonitrile								4.7
Aldrin	2.16							0.00057
Benzene								140
Benzidene								0.0038
Benzo(a)pyrene								0.1
BHC, *alpha*								0.15
BHC, *beta*								0.27
BHC, technical grade								0.2
Bis (2-chloroethyl) ether								8.8
Bis (2-chloroisopropyl) ether							1,100	
Bis (chloromethyl) ether								0.0034
Carbon Tetrachloride								31
Chlordane	1.06		0.188					0.0044
Chlorobenzene							14,000	
Chloroform (trichloromethane)								87
DDT	0.43					0.00015		0.00014
Di-*n*-butyl phthalate							65,000	
1,2 - Dichlorobenzene							10,000	
1,3 - Dichlorobenzene							13,000	
1,4 - Dichlorobenzene								100
3,3'- Dichlorobenzidene								0.16
1,1 - Dichloroethane								48
1,2 - Dichloroethane							15,000	370
cis - 1,2 - Dichloroethene							15,000	
trans - 1,2 - Dichloroethene							15,000	
Dichloromethane (methylene chloride)								3,600
2,4 - Dichlorophenol							10,000	
Dichloropropene(s)							3,200	
Dieldrin	2.10							0.00057
Di-2-ethylhexyl phthalate							30,000	
Diethyl phthalate							1,100,000	
Dimethyl phthalate							1,700,000	
4,6 - Dinitro-o-cresol							220	
Dinitrophenols							3,000	
2,4 - Dinitrotoluene								260
Dioxin - 2,3,7,8 - TCDD								0.0001
1,2 - Diphenylhydrazine								2.4
Endosulfan	0.471		0.321				94	
Endrin	0.158						0.069	
Ethylbenzene							10,000	
Fluoroanthene							32	
Halomethanes								87
Heptachlor	0.396							0.0014
Hexachlorobenzene								0.0055
Hexachlorobutodiene								160
Hexachlorocyclopentadiene							7,100	
Hexachloroethane								65
Isophorone							170,000	
Lindane - Gamma BHC	3.80		0.877					0.3
Nitrobenzene							540,000	
N-Nitrosodi-*n*-butylamine								1.9
N-Nitrosodiethylamine								1.1
N-Nitrosodimethylamine								1.8
N-Nitrosodiphenylamine								120
N- Nitrosopyrrolidine								29
Parathion	0.08		0.0141					
Pentachlorobenzene							51	
Pentachlorophenol		(varies with pH and temp.)		(varies with pH and temp.)			17,000	
Polychlorinated Biphenyls - PCBs						0.003		0.00049
Polynuclear Aromatic Hydrocarbons								0.1
1,2,4,5 - Tetrachlorobenzene							28,000	
1,1,2,2 - Tetrachloroethane								64
Tetrachloroethene								49
Toluene							110,000	
Toxaphene	0.61		0.01					0.0057
1,1,1 - Trichloroethane							33,000	
1,1,2 - Trichloroethane								140
Trichloroethene								360
2,4,6 - Trichlorophenol								18
Vinyl Chloride								10
2,4,5 - TP							3,700	

A* Standards are not based on the pH or hardness of the water.
B* Standards are based on a water hardness of 160 ppm. These standards will vary with different hardness of water.

Appendix B. Summary of Minnesota Draft Water Quality Standards and Criteria, October 1987.

Pollutant	Standard/Criteria (2B, 2C Waters) (ug/l)
Ammonia, Un-ionized	40.00
Arsenic	76.00
Boron	500.00
Cadmium	2.1*
Chlorides	None
Chlorine	5.00
Chromium, Total	50.00
Chromium, Hexavalent	11.00
Chromium, Trivalent	394.8*
Cobalt	10.00 (Hardness > 49 mg/l)
Color	None
Copper	16*
Cyanide, Total	50.00
Cyanide, Free	5.20
Lead	24.6*
Mercury	0.20
Nickel	213*
Oil	500.00
Oxygen, Dissolved	5.00 mg/l (Daily Minimum)
pH	6.5 - 9.0
Phenols, Total	10.00
Selenium	18.50
Silver	2.60
Turbidity	25.00 NTU
Zinc	206.8*
a-BHC	0.016
g-BHC	0.27
Chlordane	0.001
Dieldrin	0.0002
Endosulfan I	0.15 (Toxicity Based)
Endosulfan II	---
Endrin	0.0023
Endrin Aldehyde	---
Heptachlor	0.0006
PCB-1016	0.00017 (Additive Total of Aroclors)
Benzene	93.00
Acrylonitrile	1.50
Diethylphthalate	434.00
1,1,1-Tri Chloroethane	207.00
Naphthalene	30.70
Toluene	100.00
Carbon Tetrachloride	9.60
Tetrachloroethene	15.00
Methylene Chloride	1608.00
Bis (2-Ethylhexyl) Phthalate	1.00
Di-N-Butyl Phthalate	<3.00 (Gold Book LC50 Comparison)

* Based on a water hardness of 220 mg/l.

Source: Metropolitan Waste Control Commission, 1988.

Appendix C. Frequency of Pollutant Occurrence in Mississippi River Water Near St. Louis, Missouri

Compound	Upstream West (out of 3 samples)	Downstream West (out of 3 samples)	Upstream East/Center (out of 6 samples)	Downstream East/Center (out of 5 samples)
Cyanide	2	2	5	5
Phenols (4AAP)	3	3	6	5
Volatiles				
Benzene	3	2	6	5
Chloroform				1
Dichlorodifluoromethane				2
Methylene Chloride	3	3	6	5
Toluene	2	2	5	4
1,1,1 - Trichloroethane	2	2	6	5
Trichlorofluoromethane				1
Acid				
Phenol	1	1	1	2
Base/Neutrals				
Bis (2 ethylhexyl) phthalate	1	3	4	5
2 - Chloronaphthalene		1	2	2
Diethyl phthlate	1	2	2	1
Di-n-butyl phthlate	1	2		
1,2,4 - Trichlorobenzene		1	3	
Metals				
Antimony	1	1	2	1
Arsenic	3	3	6	5
Beryllium	3	3	6	5
Cadmium	3	3	6	5
Chromium	3	3	6	5
Copper	3	3	6	5
Lead	3	3	6	5
Mercury	2	2	4	4
Nickel	3	3	6	5
Selenium	2	3	6	5
Silver	3	3	6	5
Thallium		1	2	1
Zinc	3	3	6	5
Pesticides				
alpha BHC		1	2	2
gamma BHC			2	2
Heptachlor			1	

Source: Toxic Materials Impact Upon The Mississippi River, Black and Veatch, St. Louis, Missouri for the Metropolitan St. Louis Sewer District, November 1982.

Appendix D. Support of Uses on the Upper Mississippi River

	River* Reach	River Miles	Monitored Data (River Miles)	Fishable/ Swimmable?	All State Designated and Assessed Uses Supported?	Pollutants and/or Cause of Nonsupport	Nature of Problem
MINNESOTA	1	3.8	?	Y/__	FS	PR, MTL	
	2	8.8	8.8	Y/N	NS	PR, MTL, FCL, OTH	MUN
	3	4.9	0	Y/__	FS	PR, MTL, CLR	MUN
	4	14.8	14.8	Y/N	NS	PR, MTL, NUT, FCL, OTH	MUN, IND
	5	3.7	?	Y/__	FS	PR, MTL	
	6	3.2	3.2	Y/__	FS	PR, MTL, CLR	MUN
	7	11.4	?	Y/__	FS	PR, MTL	
	8	5.6	1.1	Y/__	FS	PR	
	9	11.8	0	Y/__	FS	PR, CLR	MUN
	10	19.4	16.1	Y/__	FS	PR	
	11	10.4	10.4	Y/__	FS	PR, CLR	MUN
	12	2.2	?	Y/__	FS	PR	
	13	9.7	7.1	__/__	FS	PR, MTL	
	14	5.8	5.8	Y/Y	PS	PR, MTL, FCL	
	15	3.2	?	__/__	FS	PR	
	16	1.9	1.9	Y/Y	PS	PR, FCL, pH	
	17	4.9	?	__/__	FS	PR	
	18	6.3	0	__/__	FS	PR, CLR	MUN
	19	4.2	4.2	Y/Y	PS	PR, FCL, pH	
	20	8.2	8.2	Y/Y	PS	PR, MTL, NUT, FCL, pH, OTH	
	21	7.0	?	__/__	FS	PR, MTL	
	22	4.3	0	__/__	FS	PR, MTL, CLR	MUN
	23	0.8	0.8	Y/Y	PS	PR, MTL, FCL, pH	
	24	4.3	4.3	Y/Y	PS	PR, MTL, NUT, FCL, pH, ORG, OTH	
	25	8.9	8.9	Y/Y	PS	PR, MTL, FCL, pH	
	26	4.0	?	__/__	FS	PR, MTL	
	27	5.0		No Data	No Data		
IOWA	28	61.1	0	Y/Y	PS	PR(h), NUT(m), ORG(m), PST(s), SLT(h)	MUN(s), IND(h), AGR(h), URB(s), NAV(m), NAT(m)
	29	10.0	0	Y/Y	PS	PR(h), MTL(s), NUT(m), ORG(m), PST(n), SLT(h)	MUN(s), IND(h), AGR(h), URB(h), NAV(m), NAT(h)
	30	88.3	0	Y/Y	PS	MTL(s), NUT(m), ORG(s), PST(s), SLT(h)	AGR(h), URB(s), NAV(m), NAT(s)
	31	10.7	10.7	N/Y	NS	MTL(h), NUT(s), ORG(s), PST(s), SLT(m), OIN(m)	MUN(h), IND(h), AGR(m), URB(s), NAV(s), NAT(s)
	32	3.0	0	Y/Y	PS	NUT(m), ORG(m), PST(s), SLT(h)	AGR(h), URB(s), NAV(m), NAT(s)
	33	12.0	12.0	Y/Y	PS	PR(h), MTL(h), NUT(m), ORG(m), PST(h), SLT(h), PTH(h)	MUN(m), IND(h), AGR(h), URB(h), NAV(m), NAT(s)
	34	4.0	0	N/Y	NS	PR(h), MTL(m), NUT(s), ORG(m), PST(m), SLT(m), PTH(m)	MUN(m), IND(h), AGR(h), URB(h), NAV(m), NAT(s)
	35	19.2	19.2	Y/Y	PS	PR(h), MTL(h), NUT(m), ORG(m), PST(h), SLT(h), PTH(h)	MUN(h), IND(h), AGR(h), URB(h), NAV(m), NAT(s)
	36	34.3	34.3	Y/Y	PS	MTL(h), NUT(m), URG(m), PST(s), SLT(h), PTH(h)	MUN(h), IND(h), AGR(h), URB(h), NAV(m), NAT(s)
	37	38.0	0	Y/Y	PS	NUT(m), ORG(s), PST(s), SLT(h)	AGR(h), URB(s), NAV(m)
	38	13.6	0	Y/Y	PS	MTL(m), NUT(m), ORG(s), PST(s), SLT(h), PTH(m)	AGR(h), URB(s), NAV(m), NAT(s), LND(s)
	39	21.4	21.4	Y/Y	PS	MTL(h), NUT(m), ORG(s), PST(s), SLT(h), PTH(h)	MUN(h), AGR(h), URB(s), NAV(m), NAT(s), LND(s)
MISSOURI	40	165	0	Y/Y	FS	FCL; ORG; chlordane in sturgeon	
	41	195	0	N/__	PS	ORG; 28 priority pollutants above St. Louis and 30 below; phenols, chlordane, dieldrin, and PCBs in fish	

Appendix D. (Continued)

	River* Reach	River Miles	Monitored Data (River Miles)	Fishable/ Swimmable?	All State Designated and Assessed Uses Supported?	Pollutants and/or Cause of Nonsupport	Nature of Problem
WISCONSIN	A	231	?	Y/Y	PS		Crop production, Animal waste, Habitat modification related to agricultural activities
ILLINOIS	B	60.6	60.6	Y/__	FS/T	NUT(s), SLT(s), FLA(s)	MUN(s), IND(s), AGR(s), HAB(s-channelization), FLW(s)
	C	4.4	4.4	Y/Y	FS/T	NUT(s), SLT(s), FLA(s)	MUN(s), IND(s), AGR(s), HAB(s-channelization), FLW(s)
	D	42.9	42.9	Y/__	FS/T	NUT(s), SLT(s), FLA(s)	MUN(s), IND(s), AGR(s), HAB(s-channelization), FLW(s)
	E	14.3	14.3	Y/__	PS/MIN	NUT(s), SLT(s), FLA(s), OHA(s)	MUN(s), IND(s), AGR(s), HAB(s)
	F	96.9	96.9	Y/__	PS/MIN	NUT(s), SLT(s), FLA(s), OHA(s)	AGR(s), HAB(s)
	G	20.1	20.1	Y/Y	PS/MIN	NUT(s), SLT(s), FLA(s), OHA(s)	MUN(s), IND(s), AGR(s), HAB(s)
	H	29.4	29.4	Y/__	PS/MIN	NUT(s), SLT(s), FLA(s), OHA(s)	AGR(s), HAB(s)
	I	12.3	12.3	Y/__	PS/MIN	NUT(s), SLT(s), FLA(s), OHA(s)	MUN(s), AGR(s), HAB(s)
	J	107.5	107.5	N/__	PS/MIN	NUT(s), SLT(s), FLA(s), OHA(s)	AGR(s), HAB(s)
	K	11.3	0	N/__	PS/MIN	PR(m), NUT(s), SLT(m), SS(m), OHA(m)	MUN(s), AGR(m-nonirrigated crop production), HAB(m)
	L	11.5	11.5	N/Y	PS/MIN	PR(m), NUT(s), SLT(m), SS(m), OHA(m)	MUN(s), AGR(m-nonirrigated crop production), HAB(m)
	M	4.2	0	N/__	PS/MOD	PR(m), MTL(s), NUT(s), SLT(m), SS(m), OHA(m)	MUN(s), IND(s), AGR(m-nonirrigated crop production), URB(s), HAB(m)
	N	9.7	9.7	N/__	PS/MIN	PR(m), MTL(m), NUT(s), SLT(m), SS(m), OHA(m)	MUN(s), IND(s), AGR(m-nonirrigated crop production), HAB(m)
	O	25.5	0	N/__	NS	PR(m), MTL(m), NUT(m), SLT(m), SS(m), OHA(m)	MUN(h), IND(m), AGR(m-nonirrigated crop production), URB(s), HAB(m), CSO(m)
	P	44.7	22.2	N/__	PS/MOD	PR(m), MTL(m), NUT(s), SLT(m), SS(m), OHA(m)	MUN(m), IND(m), AGR(m-nonirrigated crop production), URB(s), HAB(m), CSO(s)
	Q	71.8	13.2	N/__	PS/MOD	PR(h), MTL(m), NUT(s), SLT(m), OHA(m)	MUN(m), IND(m), AGRI(m-nonirrigated crop production), URB(s), HAB(m), CSO(s)
	R	2.7	2.7	N/N	PS/MOD	PR(h), MTL(m), NUT(s), SLT(m), OHA(m)	MUN(m), IND(m), AGR(m-nonirrigated crop production), URB(s), HAB(m), CSO(s)
	S	46.4	13.8	N/__	PS/MOD	PR(h), MTL(m), NUT(s), SLT(m), OHA(m)	MUN(m), IND(m), AGR(m-nonirrigated crop production), URB(s), HAB(m), CSO(s)

Source: State 305(b) reports, 1988
Wisconsin Nonpoint Source Assessment Report, 1988

* River reaches are shown on the accompanying map. The river reaches for this appendix were determined by examining the use support designation for the states' designated river reaches (e.g. Illinois has 79 reaches and Minnesota has 35 reaches -- see Table 6) and combining reaches that had identical designated use support and cause of nonsupport. Thus Minnesota's 35 river reaches have been combined into 27 reaches with identical designated use support and cause of nonsupport.

Appendix D. KEY

Fishable/ Swimmable?

- Y - Yes
- N - No

All Designated/ Assessed Uses Supported?

- FS - Full Support
- FS/T - Full Support (Threatened)
- PS - Partial Support
- PS/MIN - Partial Support (Minor Impairment)
- PS/MOD - Partial Support (Moderate Impairment)
- NS - No Support

Pollutants and/or Cause of Nonsupport

- PR - priority organics/toxics
- MTL - metals
- NUT - nutrients
- FCL - fecal coliform
- pH - pH violations
- ORG - organic enrichment/DO
- PST - pesticides
- SLT - siltation
- SS - suspended solids
- CLR - chlorine
- PTH - pathogens
- FLA - flow alterations
- OTH - other causes
- OHA - other habitat alterations
- OIN - other inorganics

Magnitude of impairment:

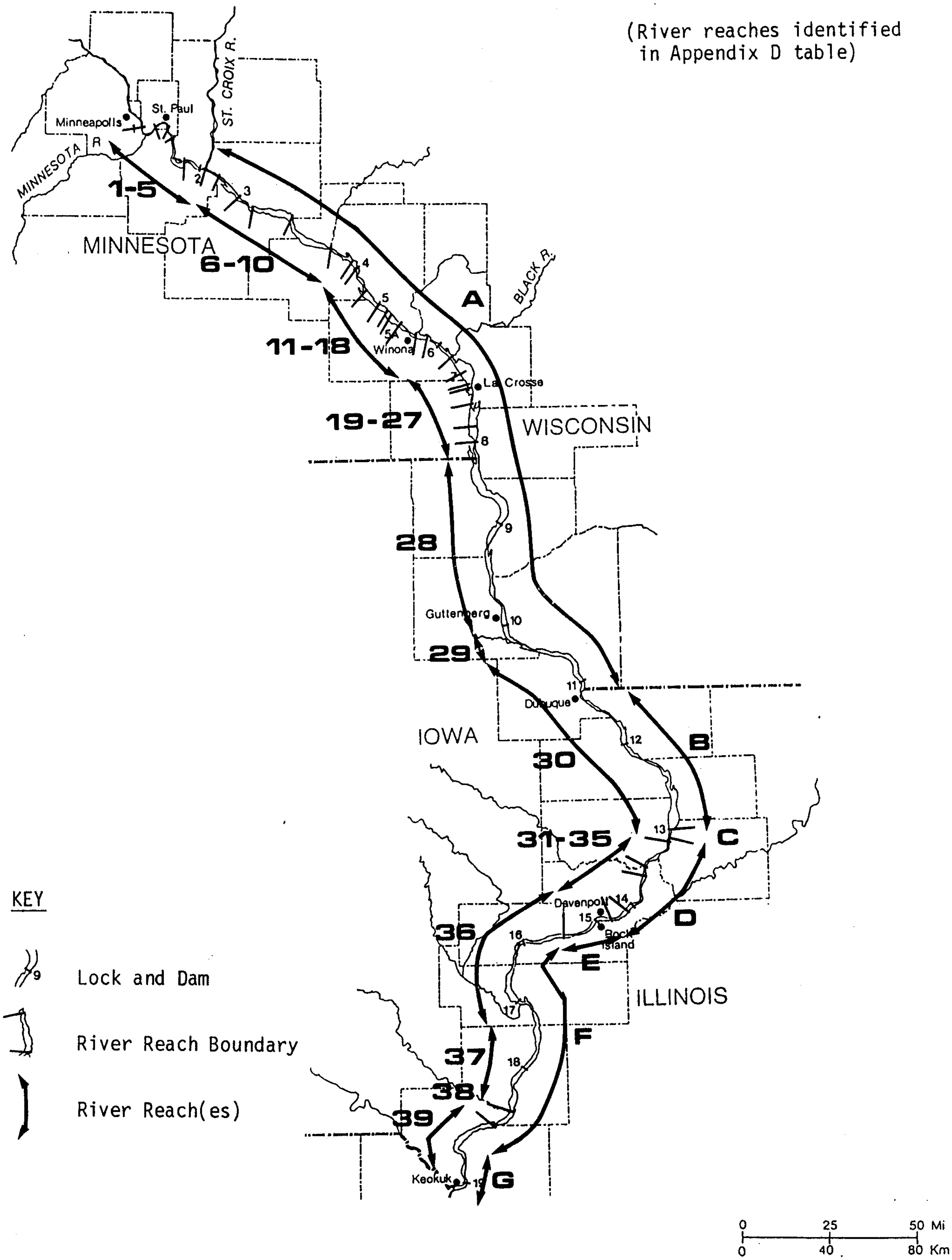
- (h) - high
- (m) - moderate
- (s) - slight

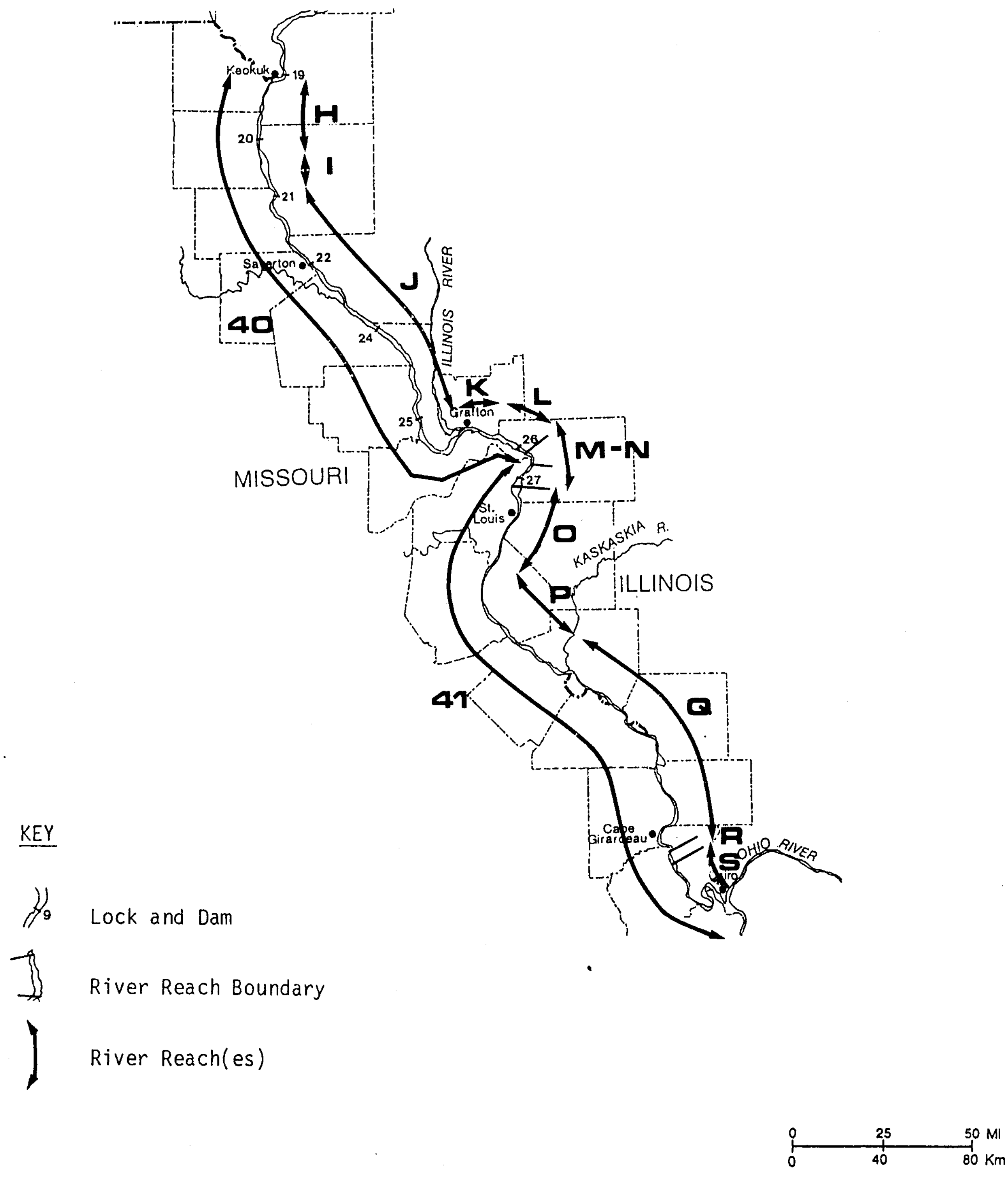
Nature of Problem

- MUN - municipal
- IND - industrial
- AGR - agricultural
- URB - urban runoff
- HAB - hydrologic/habitat modification
- NAV - navigation
- NAT - natural
- LND - land disposal
- FLW - flow regulation/ modification
- CSO - combined sewer overflows

Appendix D continued

(River reaches identified in Appendix D table)




Keokuk
19
H
20
I
21
J
ILLINOIS RIVER
Saverton
22
40
24
K
L
Grafton
25
26
M-N
MISSOURI
27
St. Louis
O
KASKASKIA R.
P
ILLINOIS
Q
41
Cape Girardeau
R
S
OHIO RIVER
Cairo
KEY
9
Lock and Dam
River Reach Boundary
River Reach(es)
0 25 50 MI
0 40 80 Km

Appendix E. Fish Advisories for the Upper Mississippi River

	Affected River Reaches	Fish Type	Group*
ILLINOIS (Chlordane)	Des Moines River - L&D 20	Carp, catfish	II
	L&D 24 - L&D 25	Catfish	II
	Illinois River - Alton	Carp, catfish	II
	Jefferson Barracks Bridge - Fort Chartres	Carp, catfish	III
	Fort Chartres - Cairo	Carp, catfish	II
(Dieldrin)	L&D 22 - Cairo	Sturgeon, Sturgeon eggs	III
IOWA	No Fish Advisories		
MINNESOTA (PCB's)	St. Anthony Falls - Iowa border	All species	
MISSOURI (Chlordane & Dieldrin)	Identical to Illinois Health Advisories		
WISCONSIN (PCB's)	Prescott - Alma	Drum, Sauger, Walleye, Buffalo ≤ 18" (Pool 3) Buffalo ≤ 20" (Pool 4) Carp ≤ 21" Channel catfish ≤ 16" (Pool 3) Channel catfish ≤ 21" (Pool 4) Flathead catfish ≤ 30" White bass ≤ 13"	I
		Channel catfish 16"-23" (Pool 3) Channel catfish 21"-23" (Pool 4)	II
		Buffalo > 18" (Pool 3) Buffalo > 20" (Pool 4) Carp > 21" Channel catfish > 23" Flathead catfish > 30" White bass > 13"	III
	Alma - L&D 6	Buffalo, Drum, Flathead catfish, Sauger, Walleye, White Bass, Carp ≤ 24" Channel catfish ≤ 21"	I
		Carp > 24" Channel catfish > 21"- 25"	II
		Channel catfish > 25"	III
	L&D 6 - L&D 9	Buffalo, Carp, Crappie, Drum, Flathead catfish, Walleye, White bass, Channel catfish ≤ 24"	I
		Channel catfish > 24"	II

* Advisory groups are defined in Table 10.

Appendix F. Dredged Sediment Disposal and Sediment Quality Classification

U.S. Environmental Protection Agency Dredged Spoil Disposal Criteria Classification Guidelines (mg/kg dry weight) for Great Lakes Harbors

Parameter	Nonpolluted	Moderately Polluted	Heavily Polluted
Volatile solids	<50,000	50,000-80,000	>80,000
COD	<40,000	40,000-80,000	>80,000
TKN	<1,000	1,000-2,000	>2,000
Oil and grease (hexane solubles)	<1,000	1,000-2,000	>2,000
Lead	<40	40-60	>60
Zinc	<90	90-200	>200
Ammonia	<75	75-200	>200
Cyanide	<0.10	0.10-0.25	>0.25
Phosphorus	<420	420-650	>650
Iron	<17,000	17,000-25,000	>25,000
Nickel	<20	20-50	>50
Manganese	<300	300-500	>500
Arsenic	<3	3-8	>8
Cadmium	*	*	>6
Chromium	<25	25-75	>75
Barium	<20	20-60	>60
Copper	<25	25-50	>50
Mercury			≥1
Total PCBs†			≥10

*Lower limits not established.
†The pollutional status of sediments with total PCB concentrations between 1 and 10 mg/kg dry weight are determined on a case-by-case basis.

Source: U.S. Environmental Protection Agency, 1977

Appendix F. (Continued)

Classification of Illinois Stream and Lake Sediment*

Parameter	Stream Sediment Elevated	Lake Sediment Elevated
Arsenic (ppm)	>11	27-41
Cadmium (ppm)	>1.0	1.8-2.6
Chromium (ppm)	>23	30-38
Copper (ppm)	>60	100-150
Lead (ppm)	>38	100-150
Mercury (ppm)	>0.17	0.25-0.40
Zinc (ppm)	>100	175-200
Chlordane (ppb)	>6	16-23
Sum DDT (ppb)	>10	6-9
Dieldrin (ppb)	>6	17-29
Heptachlor Epoxide (ppb)	>1.5	3-5
PCB's (ppb)	>50	16-20

* From Kelly and Hite (1981, 1984) -- is a statistic classification and does not indicate toxicity or human health hazard.

Source: Illinois EPA, 1988

Wisconsin's Proposed Sediment Criteria
(ug/g dry weight)

Arsenic	<10.0
Barium	<500.0
Cadmium	<1.0
Chromium	<100.0
Copper	<100.0
Lead	<50.0
Mercury	<0.1
Nickel	<100.0
Selenium	<1.0
Zinc	<100.0
PCB's	<0.5
Total 2, 3, 7, 8 TCDD	<1.0 (pg/g)
Total 2, 3, 7, 8 TCDF	<1.0 (pg/g)
Aldrin	<0.01
Dieldrin	<0.01
Chlordane	<0.01
Endrin	<0.05
Heptachlor	<0.05
Lindane	<0.05
Toxaphene	<0.05
DDT	<0.01

Source: MWCC, 1988

Appendix G. Corps Sediment Quality Data+

River Mile	Location	Habitat Type*	Arsenic	Cadmium	Chromium	Lead	Mercury	Zinc
843.4	Minnesota River Mouth	1					4.6	
813.0	Hastings Small Boat Harbor	2			40.0	40.0		90.0
760.0	Wabasha Small Boat Harbor	2				80.0		
759.0	Above Crats Island	1	3.0					
758.6	R-Bay Lower End of Island	3			25.0			
757.3	L-Bay Down of Disposal	3			34.0			98.8
752.5	R-Island 40	3	84.1					
			77.7					
			130.8					
747.8	West Newton	1			28.3			
745.3	R-Weaver Bottoms	3	13.0		26.0		2.4	
745.0	Fischer Island	1	10.9					
745.0	R-Weaver Bottoms	3	4.6	7.6				
744.8	R-Weaver Bottoms	3	8.6					
		3	13.0		34.0		1.7	
743.9	R-Weaver Bottoms	3	11.0				1.6	
743.2	Somerfield Island	1			33.0			
743.0	Somerfield Island	1			28.0			
742.4	L-Behind Is N&W Spring Lake	3			29.0			
734.5	Island 58	1			28.7			
734.0	Island 58	1			30.0			
733.4	Fountain City B. Yard	2	3.3					
722.7	L-Bay Behind Island	3			25.0			
694.6	L-Bay Cnflnc Bluff & Run	3			28.0			
688.1	Head of Raft Channel	1			106.0			
687.3	Deadman's Slough	1	3.0					
686.7	Deadman's Slough	1	3.0					
677.9	Island 126	1			30.0			
671.0	L-Blackhawk Ab. Road	3	5.0					
	L-Cold Springs South	3	9.6					120
	R-R Desc. Bnk Iowa R Channel	3						102
653.8	L-Cold Springs South	3	9.9					
646.5	Hay Point	1	3.0					
635.5	Prairie du Chien Boat	2	29.0			40.0		
633.2	McGregor	1			94.0			

* Habitat Type 1 - main channel
2 - boat harbor
3 - backwater

+ This sediment quality data is only a supplement to the sediment quality data and determinations from Minnesota and Wisconsin. Other sediment quality data is available from the Corps for river reaches that have already been determined by Minnesota and Wisconsin to contain contaminated sediment.

Appendix H. Water Quality Data for 11 Stations on the Upper Mississippi River

STORET Code	Parameter	Unit	St. Paul, MN (1973-1987) Mean	St. Paul, MN (1973-1987) Range	Nininger, MN (1977-1988) (1977-1982 metals) Mean	Nininger, MN (1977-1988) (1977-1982 metals) Range	Red Wing, MN (1977-1988) Mean	Red Wing, MN (1977-1988) Range	Winona, MN (1963-1986) Mean	Winona, MN (1963-1986) Range
00010	Temperature	°C	12.5	0 - 30	11.01	0 - 28	11.52	0 - 28.5	10.76	0 - 28
00060	Streamflow	cfs	11,500	1,020 - 66,900	14,674	1,710 - 13,300	16,458	1,020 - 72,280	48,696	9,570 - 263,000
00061	Instantaneous Discharge	cfs							46,267	5,200 - 217,000
00076	Turbidity	FTU	14.45	1.4 - 96.0	10.76	0.40 - 38.0			5.10	0.30 - 15.0
00095	Specific Conductance	us/cm	520	90 - 5,700			466	69 - 716		
00300	Dissolved Oxygen	mg/l	9.88	4.3 - 15.7	9.95	2.30 - 14.60	9.75	5.2 - 17	10.81	6.60 - 15.90
00400	pH	SU	8.05	6.70 - 12.10	8.06	7.30 - 8.90	7.96	6.90 - 8.90	7.83	6.80 - 9.30
00608	Ammonia, Dissolved	mg/l			0.55	0.02 - 1.50	0.37	0.02 - 2.20	0.15	0 - 0.62
00631	NO_2 + NO_3, Dissolved	mg/l			2.01	0.10 - 7.80	1.60	0.20 - 5.20	1.38	0.03 - 3.60
00665	Phosphorous, Total	mg/l	0.22	0.08 - 1.90	0.23	0.04 - 0.97	0.18	0.10 - 0.38	0.15	0.03 - 0.31
01002	Arsenic, Total	ug/l	2.63	1 - 8	2.49	1.00 - 6.00	<10	<10 - <10	1.86	0 - 6.00
01027	Cadmium, Total	ug/l	0.59	0.02 - 19	2.02	0 - 12.00	0.32	0.20 - 1.0	3.62	0 - 20.00
01042	Copper, Total	ug/l	8.51	2 - 66	7.79	3.00 - 60.00	15.92	3.00 - 55.00	15.57	3.00 - 40.00
01051	Lead, Total	ug/l	7.43	0.3 - 120.0	14.8	0 - 130.00	3.68	3.00 - 11.00	25.2	0 - 180.0
01092	Zinc, Total	ug/l	41.31	2 - 3,700	41.42	10.00 - 500.00	<20	<20 - <20	27.78	10.00 - 60.00
31625	Fecal Coliform	#/100 ml			594	1.0 - 3,500			2,717	1.0 - 140,000
70300	Dissolved Solids-Direct	mg/l			346.5	227.0 - 474.0			219.1	138.0 - 369.0
70301	Dissolved Solids-Sum	mg/l								
71900	Mercury, Total	ug/l	0.29	0.1 - 1.9	0.36	0.10 - 0.50	0.20	0.2 - 0.3	0.35	0.10 - 0.50
80154	Suspended Sediment	mg/l			41.87	1.00 - 139.00			20.57	2.0 - 86.0

Print Key

12.5 Mean derived directly from computer data. There are no "Less than detect" values.

2.63 "Less than detect" values are not included since they skew the mean upward excessively.

41.31 "Less than detect" values are included since they only skew the mean upward slightly.

Appendix H. (Continued)

STORET Code	Parameter	Unit	Lynxville, WI (1977-1988) (1977-1979 metals)		Clinton, IA (1974-1987)		Davenport, IA (1972-1985)		Keokuk, IA (1974-1987)	
			Mean	Range	Mean	Range	Mean	Range	Mean	Range
00010	Temperature	°C	10.89	0 - 27.5	12.70	0 - 29.0	12.61	0 - 29	13.31	0 - 30
00060	Streamflow	cfs	35,228	8,600 - 103,000						
00061	Instantaneous Discharge	cfs			52,737	-- - 162,000			75,666	12,600 - 220,000
00076	Turbidity	FTU	9.60	3.0 - 15.0	24.64	1.10 - 95.00			49.09	1.40 - 960.0
00095	Specific Conductance	us/cm	364	45 - 506	340	210 - 495	363	210 - 470	401	240 - 950
00300	Dissolved Oxygen	mg/l	10.63	2.4 - 20.0	10.08	4.70 - 19.50	10.34	5.0 - 18.5	9.97	3.50 - 18.7
00400	pH	SU	7.86	6.70 - 9.60	8.16	7.20 - 9.60	7.86	7.30 - 8.40	8.15	7.30 - 9.30
00608	Ammonia, Dissolved	mg/l	*0.13*	*0.02 - 0.61*	*0.13*	*0 - 0.57*			*0.21*	*0 - 1.6*
00631	$NO_2 + NO_3$, Dissolved	mg/l	*1.08*	*0.02 - 3.0*	1.24	0.09 - 2.80			*2.36*	*0.05 - 6.1*
00665	Phosphorous, Total	mg/l	0.16	0.05 - 0.32	0.18	0.02 - 0.76	0.23	0.04 - 0.95	0.26	0.09 - 1.4
01002	Arsenic, Total	ug/l	<10	<10 - <10	*2.22*	*1.00 - 7.00*	<10	<10 - <10	2.34	1.0 - 5.0
01027	Cadmium, Total	ug/l	*0.22*	*0.2 - 0.4*	*3.31*	*0 - 25.00*	*6.54*	*1.00 - 10.00*	*5.67*	*0 - 150.00*
01042	Copper, Total	ug/l	*6.04*	*3.00 - 21.00*	*10.89*	*3.00 - 37.00*	*9.80*	*1.00 - 10.00*	*10.64*	*0 - 50.00*
01051	Lead, Total	ug/l	*4.67*	*3.00 - 22.00*	21.19	0 - 230.00	*18.61*	*10.00 - 100.00*	22.74	0 - 200.00
01092	Zinc, Total	ug/l			43.6	10.0 - 130.0	*45.22*	*1.00 - 1100*	*35.77*	10.00 - 90.00
31625	Fecal Coliform	#/100 ml			*790*	13 - 2,400			*707*	0 - 11,000
70300	Dissolved Solids-Direct	mg/l			206.6	143.0 - 338.0			241.9	156.0 - 326.0
70301	Dissolved Solids-Sum	mg/l			193.6	118.0 - 429.0			223.3	140.0 - 323.0
71900	Mercury, Total	ug/l	*0.20*	*0.70 - 0.70*	*0.27*	*0 - 1.30*			*0.30*	*0 - 1.80*
80154	Suspended Sediment	mg/l			68.57	2.00 - 323.0			91.17	1.00 - 424.0

Print Key

12.5 Mean derived directly from computer data. There are no "Less than detect" values.

2.63 "Less than detect" values are not included since they skew the mean upward excessively.

4.31 "Less than detect" values are included since they only skew the mean upward slightly.

Appendix H. (Continued)

STORET Code	Parameter	Unit	Hannibal, MO (1967-1988) (1981-1988 metals) Mean	Hannibal Range	Alton, IL (1974-1988) Mean	Alton Range	Thebes, IL (1973-1988) Mean	Thebes Range
00010	Temperature	°C	12.42	0 - 30	14.64	0 - 33.5	14.91	0 - 31.5
00060	Streamflow	cfs			109,052	18,200 - 389,000	218,112	50,000 - 699,000
00061	Instantaneous Discharge	cfs			128,914	25,300 - 406,000	284,794	63,900 - 804,000
00076	Turbidity	FTU			44.06	1.50 - 380.0	90.84	1.00 - 500.00
00095	Specific Conductance	us/cm	441	220 - 569	463	281 - 670	521	300 - 760
00300	Dissolved Oxygen	mg/l	10.06	3.8 - 19.6	9.46	2.60 - 19.0	8.52	3.00 - 60.00
00400	pH	SU	8.09	7.10 - 8.80	8.14	7.30 - 8.90	7.97	7.40 - 8.50
00608	Ammonia, Dissolved	mg/l	0.12	0.12 - 0.12	*0.77*	*0 - 0.99*	*0.16*	*0 - 0.66*
00631	NO_2 + NO_3, Dissolved	mg/l	1.10	1.10 - 1.10	2.79	0 - 10.00	2.14	0.71 - 4.00
00665	Phosphorous, Total	mg/l	0.21	0.01 - 0.47	0.25	0.06 - 0.93	0.31	0.09 - 1.00
01002	Arsenic, Total	ug/l			3.73	1.00 - 31.00	*4.25*	*1.00 - 21.00*
01027	Cadmium, Total	ug/l	*1.92*	*1.00 - 11.00*	*4.72*	*0 - 20.00*	*35.22*	*0 - 880.00*
01042	Copper, Total	ug/l	*8.26*	*4.00 - 14.00*	*31.24*	*5.00 - 130.00*	37.7	5.0 - 5300.0
01051	Lead, Total	ug/l	*6.24*	*1.00 - 15.00*	29.5	0 - 180.00	39.5	4.0 - 290.0
01092	Zinc, Total	ug/l	*55.0*	*10.0 - 470.0*	*73.72*	*20.00 - 280.00*	*76.38*	*20.00 - 180.00*
31625	Fecal Coliform	#/100 ml	994	0 - 8,400	781	4 - 12,000	5,740	64 - 140,000
70300	Dissolved Solids-Direct	mg/l			281.2	188.0 - 419.0	315.17	164.0 - 455.0
70301	Dissolved Solids-Sum	mg/l	210	210 - 210	263.3	141.0 - 387.0	304.9	176.0 - 435.0
71900	Mercury, Total	ug/l	0.17	0.1 - 0.3	*0.28*	*0 - 2.50*	*0.48*	*0 - 3.50*
80154	Suspended Sediment	mg/l			214.0	3.0 - 1,310.0	394.6	29.0 - 1,620.0

Print Key

12.5 Mean derived directly from computer data. There are no "Less than detect" values.

2.63 "Less than detect" values are not included since they skew the mean upward excessively.

4.37 "Less than detect" values are included since they only skew the mean upward slightly.

Appendix I. Illinois Water Quality Indices Used to Determine Fishable Use Support

Index of Biotic Integrity (IBI)

The index is calculated from fish monitoring data and incorporates 12 measures (metric) of fish community structure which fall into three major categories:

Category	Metric
Species richness and composition	Total number of fish species Number and identity of darter species Number and identity of sunfish species Number and identity of sucker species Number and identity of intolerant species Proportion of individuals as green sunfish
Trophic composition	Proportion of individuals as omnivores Proportion of individuals as insectivorous cyprinids Proportion of individuals as top carnivores
Fish Abundance and condition	Number of individuals in sample Proportion of individuals as hybrids Proportion of individuals with disease, tumors, fin damage, and other anomalies

The fish community at a site is scored with each metric receiving a value of 1, 3, or 5. The sum of these 12 values is the IBI for the site. Theoretically, IBI can range from 12 (worst) to 60 (best).

Macroinvertebrate Biotic Index (MBI)

The index is a modification of the index developed by Hilsenhoff (1982) and is calculated as a measure of the severity of pollution impacts as indicated by biological information. Each macroinvertebrate taxon has been assigned a pollution tolerance value which is the level of pollution tolerable to the species. A rating of 0 is assigned to the high water quality taxa and 11 is assigned to taxa that can occur in severely polluted or disturbed streams. Intermediate ratings are assigned for taxa that occur in streams with intermediate degrees of pollution. This information is used in the following equation to determine the macroinvertebrate biotic index (MBI):

$$MBI = \frac{m_i t_i}{N}$$

m_i = number of individuals in the ith taxon
t_i = tolerance value assigned to that taxon
N = total number of individuals in that sample

Biological Stream Characterization (BSC)

BSC is a five-tiered stream classification system predicated largely on IBI values and other fish community attributes. Following is a description of the five tiers:

Stream Class	BSC Category	IBI Range	MBI Range	Stream Quality Description
A	Unique Aquatic Resource	51-60	N/A	EXCELLENT. Comparable to the best situations without human disturbance; threatened and/or endangered species may be present
B	Highly Valued Aquatic Resource	41-50	N/A	GOOD. Good fishery for important gamefish species; species richness may be somewhat below expectations for stream size or geographic region.
C	Moderate Aquatic Resource	31-40	N/A	FAIR. Fishery consists predominantly of bullhead, sunfish, and carp. Species diversity and number of intolerant fish reduced. Trophic structure skewed with increased frequency of omnivores, green sunfish and/or tolerant species.
D	Limited Aquatic Resource	21-30	7.5-10.0	POOR. Fishery predominantly for carp; fish community dominated by omnivores and tolerant forms.
E	Restricted Aquatic Resource	≤20	≥10.0	VERY POOR. Few fish of any species present; no sport fishery exists.

Water Quality Index (WQI)

This method can utilize up to 10 water quality pollutant categories to determine the index. Parameters are chosen which most accurately represent water quality in the water body being evaluated. The U.S. Environmental Protection Agency fishable/swimmable criteria is then used to assign an acceptable value to each parameter. For example, to support fish, dissolved oxygen should not drop below 5.0 mg/l. Thus, dissolved oxygen at 5.0 mg/l is assigned a WQI value of 20. Dissolved oxygen levels higher than 5.0 mg/l will receive a lower index value down to 0. Dissolved oxygen levels lower than 5.0 mg/l will recieve a WQI from 20 to 100. The index for all the parameters is summed, averages are determined, and index values are weighted. General stream condition/water quality based on the index is as follows:

Water Quality Index	Stream Condition/Water Quality
0-10	Excellent
10-30	Very Good
30-50	Fair - Good
50-70	Poor
>70	Very Poor

Source: Illinois EPA, 1988