HYDROLOGIC, SEDIMENTOLOGIC, AND CHEMICAL DATA DESCRIBING SURFICIAL BED SEDIMENTS AND WATER IN THE NAVIGATION POOLS OF THE UPPER MISSISSIPPI RIVER, July 1991-April 1992

Edited by John A. Moody

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OVERVIEW

Surficial bed-sediment samples were collected from 25 navigation pools on the Upper Mississippi River between July 1991 and April 1992 before the flood of 1993 on the Upper Mississippi River. The purpose was to assess the longitudinal distribution of inorganic and organic compounds in the surficial sediments. Another U.S. Geological Survey study (Open-File Report 96-580) assesses the longitudinal distribution of inorganic and organic compounds in the surficial bed sediments collected after the flood of 1993 using the same procedures. In both studies a single composite sample was collected from each pool by combining samples from 12 to 23 individual sampling sites. Subsamples were taken from this composite sample for sediment analyses and for organic chemical analyses of sterols, polynuclear aromatic hydrocarbons, linear alkylbenzene sulfonates, organochlorines, and polychlorinated biphenyls. Bed-sediment cores were also collected from the 12 to 23 individual sampling sites, composited in the laboratory, and then analyzed for major and trace elements.

In this study, the median particle diameter of the surficial bed sediments ranged from 0.002 to 0.33 millimeter and the organic carbon associated with these sediments ranged from less than 0.1 to 3.6 percent. Coprostanol concentrations ranged from 0.10 to 1.37 milligrams per kilogram (mg/kg). Seven polynuclear aromatic hydrocarbons were detected in the sediments at concentrations ranging from 0.0 to 16.87 mg/kg, and linear alkylbenzene sulfonates were detected in all sediments at concentrations ranging from 0.01 to 20.19 mg/kg. Maximum concentration of total chlordane was 36 nanograms per gram (ng/g) in Pool 1, *p,p'*-DDT was 0.7 ng/g in Pool 3, and polychlorinated biphenyls was 410 ng/g in Pool 4 (Lake Pepin). Lead (45 micrograms per gram) and mercury (0.295 micrograms per gram) concentrations were also greatest in Pool 4 (Lake Pepin). However, the maximum concentration of dieldrin was in Pool 25 (0.8 ng/g) at the downstream end of the Upper Mississippi River near St. Louis, Missouri.

ACKNOWLEDGMENTS

The sampling strategy for this complex riverine environment was an outgrowth of several discussions with people in the Upper Mississippi River Conservation Committee, especially John Sullivan with the Wisconsin Division of Natural Resources and Dan Helwig with the Minnesota Pollution Control Agency. Specialized sampling equipment for collecting bed sediments was developed by Harold Wiegner at the Minnesota Pollution Control Agency, Mike Theriot, of Theriot Machine Chauvin, Louisiana. Theodore Young, Sandwich, Massachusetts. Being able to locate each bed-sediment sample required the research vessel *Acadiana* (owned and operated by the Louisiana University Marine Consortium) to be anchored in some shallow and precarious locations, and Wayne Simoneaux and Craig LeBoeuf (captains of the vessel) showed enormous care, skill, and patience in many frustrating situations.

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	*By*	*To obtain*
	Length	
angstrom (Å)	3.937×10^{-9}	inch
centimeters (cm)	0.3937	inch
micrometer (μm)	0.00003937	inch
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile
	Area	
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile
	Volume	
microliter (μL)	0.00003382	ounces, fluid
milliliter (mL)	0.03382	ounces, fluid
liter (L)	0.2642	gallon
cubic meter (m^3)	35.31	cubic foot
	Flow	
centimeter per second (cm/s)	0.03281	foot per second
meter per second (m/s)	3.281	foot per second
cubic meter per second (m^3/s)	35.31	cubic foot per second
cubic meter per year (m^3/yr)	35.31	cubic foot per year
kilometer per hour (km/h)	0.6214	mile per hour
	Mass	
milligram (mg)	0.00003527	ounce, avoirdupois
gram (g)	0.002205	pound, avoirdupois
metric ton	2,205	pound, avoirdupois

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 1.8\ (°C) + 32$$

The following terms and abbreviations also were used in these chapters:

atomic mass unit (amu)
electronic unit (eu)
electron volts (eV)
gram per milliliter (g/mL)
megohms per centimeter (Mohm/cm)
microgram (μg)
microgram per liter (μg/L)
microgram per gram (μg/g)
microsiemens per centimeter (μS/cm)
milligrams per liter (mg/L)
milligrams per kilogram (mg/kg)
nanograms per liter (ng/L)
nanograms per gram (ng/g)
nanograms per microliter (ng/μL)
microangstrom (μÅ)normal (N)
microliter (μL)
picogram (pg)
revolutions per minute (rpm)
torr

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)-a geodetic datum derived from a general adjustment of the first-order level nets of both the Unied States and Canada, formerly called Sea Level Datum of 1929.

CHAPTER 1 - Sampling Strategy, Hydrology, and Sediment Characteristics

By John A. Moody and Carol J. Anderson

ABSTRACT

Twenty-nine navigation pools are present along the reach of the Mississippi River from Minneapolis, Minnesota, to St. Louis, Missouri. A representative composite surficial bed-sediment sample was collected from the downstream one-third of 25 of the 29 navigation pools during three research cruises spanning a period of almost 1 year to assess the distribution of sewage-derived contaminants, selected organic contaminants, and major and trace elements. The particle-size distribution of a subsample of surficial bed sediment from each pool was determined by sieve, visual-accumulation tube, and SediGraph methods. Bulk chemistry (percent nitrogen, carbonate carbon, total carbon, and total organic carbon) was determined for a second subsample of the surficial bed sediment.

The hydraulic conditions present at the time the surficial bed-sediment samples were collected were measured, and about 35 percent of the water discharge was measured outside the navigation channel in backwater areas ranging from 0.3 to 3.0 meters deep. The water velocities in the backwater areas were about 50 percent of the velocities in the navigation channel. Flushing rates varied from 0.3 hour per kilometer to about 14 hours per kilometer. The median particle diameter of the surficial bed sediments ranged from 0.002 to 0.33 millimeter and the organic carbon associated with these sediments ranged from less than 0.1 to 3.5 percent.

INTRODUCTION

The major hydraulic characteristic of the Upper Mississippi River is the series of locks and dams that create pools along its reach. Because the navigation pools are known to trap and store sediments with their associated pollutants, the U.S. Geological Survey has undertaken studies of the Upper Mississippi River as part of a larger assessment of the environmental status of the entire Mississippi River.

Twenty-nine locks and dams form 29 navigation pools on the Mississippi River between Minneapolis and St. Louis, Mo. The first navigation pool (Pool 19, table 1.1 and fig. 1.1) was formed behind a lock and dam built across the Mississippi River at Keokuk, Iowa, for electrical power generation in 1913 (Tweet, 1984; Whitacre, 1992). The second and third pools were formed by the construction of Lock and Dam 1 in 1917 at Minneapolis and by Lock and Dam 2 in 1930 at Hastings, Minn., which provided 4.5- and 6-ft navigation channels (U.S. Army Corps of Engineers, 1988a).

Twenty-three additional pools (there is no Pool 23, but there is a Pool 5A) were formed by construction of locks and dams for the 9-ft channel project between Minneapolis and St. Louis in the 1930's. The 9-ft channel was extended upstream in Minneapolis, and two small pools (1.0 and 19 km long) were formed when the Lower and Upper St. Anthony Falls Lock and Dams were finished in 1963, making navigation possible around the 23-m-high St. Anthony Falls. The last lock and dam downstream, near St. Louis (Lock and Dam 27), was completed in 1964 just downstream from the confluence of the Mississippi and Missouri Rivers. Lock and Dam 26, downstream from the confluence of the Mississippi and Illinois Rivers, was demolished and replaced in 1990 by the larger Melvin Price Lock and Dam, completing the series of 29 pools (Whitacre, 1992).

The system of navigation pools covers 36 percent of the length of the Mississippi River from Minneapolis to the Gulf of Mexico. The mean annual water discharge increases twentyfold from Minneapolis (230 m^3/s), at the beginning of the pool reach, to St. Louis (5,100 m^3/s), at the end of the pool reach.

The average length of the navigation pools is about 40 km, and approximately 8 percent of the surface area of the pools is maintained as a 9-ft navigation channel, leaving about 92 percent of the pool area as backwater areas with typical depths between 0.5 and 1.5 m. The average width-to-length ratio of the upper pools (Pools 1–15) is about twice the ratio of the lower pools (Pools 16–26), reflecting the general narrowing of the Mississippi River Valley in the downstream direction.

Figure 1.1--Location of navigation pools upstream from dams on the Upper Mississippi River. Cities are shown as solid circles and lock and dams as solid triangles.

A navigation pool can be divided into three morphologically distinct regions (fig. 1.2). The first region (riverine) is immediately downstream from the preceding dam, where the flow is confined in a relatively narrow channel. The second region (deltaic) is characterized by several channels or sloughs that branch off from the navigation channel and return to the channel farther downstream. This deltaic region consists of numerous islands, which often bifurcate in the downstream direction, sheltering quiescent bays that face downstream out of the main current velocity. The third region (lacustrine) is characterized by the broad open water just upstream from the dam. These three types of regions produce a complex, heterogeneous benthic environment within each pool in contrast to the homogeneous (mostly medium to fine sand) benthic environment of the free-flowing Lower Mississippi River downstream from St. Louis. These regions also may have different retention times for contaminants associated with the water.

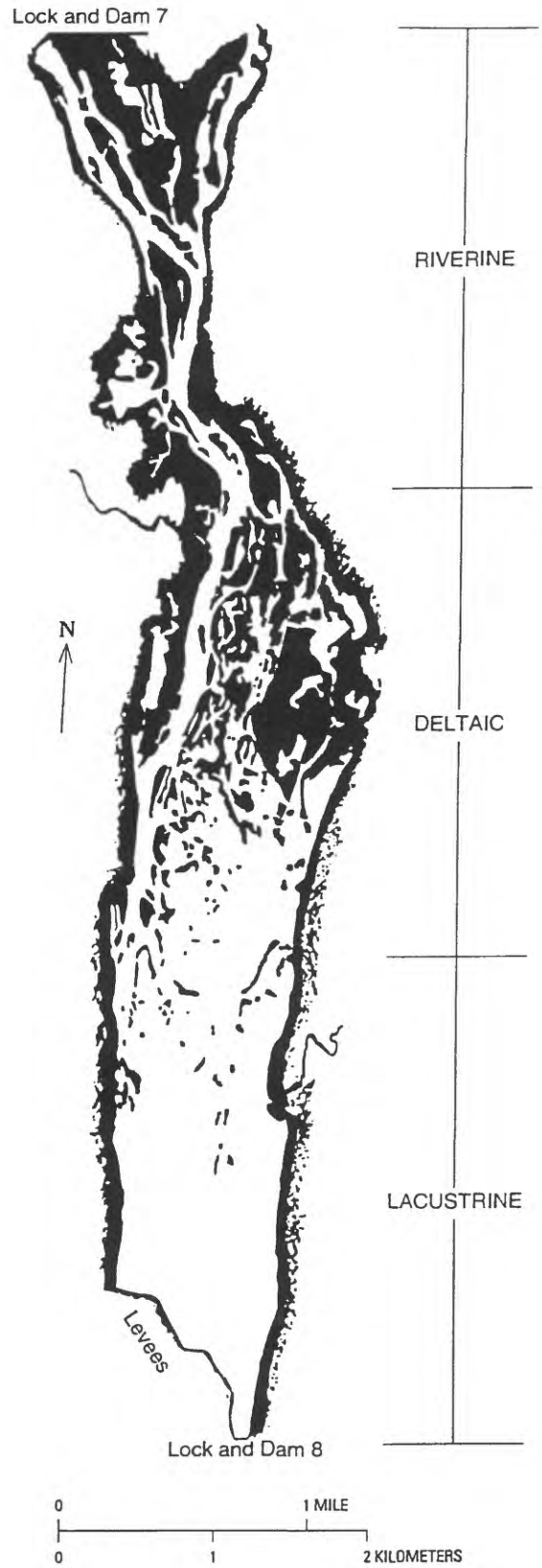

Figure 1.2--Typical navigation pool divided into three regions.

These pools do not have sufficient storage capacity to be operated as flood-control structures; they are maintained at a nearly constant elevation (table 1.1) creating an environment conducive to the storage of sediment. In Pools 1-10, the St. Paul District of the U.S. Army Corps of Engineers uses a primary control point that is approximately at midpool and maintains the pool elevation within a range of about 0.1 m (U.S. Army Corps of Engineers, 1988b). In Pools 11-22, the Rock Island District uses a primary control point at the dam, and the range of the pool elevation fluctuates between 0.03 m above to 0.12 m below project pool elevation (Bryan Goodrum, U.S. Army Corps of Engineers, Rock Island District, oral commun., 1992). In Pools 24-26, the St. Louis District uses a primary control point located about one-third of the distance upstream to the next dam and maintains pool elevations within a range of 0.2 to 0.6 m. During times when the water discharge is high, all the gates in the dams are opened (referred to as "open river" on table 1.1), and the increased water velocity in the pools inhibits the settling of suspended sediment. As the water discharge decreases, the gates are partially closed to maintain the 9-ft channel for navigation; this decreases the water velocities and decreases the flushing rate of water in the pools, creating conditions favorable for the deposition of sediment.

Between 1987 and 1990, the U.S. Geological Survey investigated the transport of contaminants by suspended sediment in the free-flowing Mississippi River between St. Louis and New Orleans (Leenheer and others, 1989, 1995; Meade and Stevens, 1990; Pereira and others, 1990, 1992, 1995; Taylor and others, 1990; Moody and Meade 1992, 1993). In 1991, the investigations were expanded to include a study of the transport of contaminants by suspended sediment and a study of the storage of contaminants in the surficial bed sediments in the navigation-pool reach of the Upper Mississippi River.

The objectives of this study were:

1. To obtain a representative composite sample of surficial bed sediments from the downstream one-third of each pool for physical and chemical analyses,

2. To locate the individual sampling sites (from which samples were collected to form a composite sample) so that the sampling could be repeated in the future,

3. To assess the longitudinal distribution of sterols, polynuclear aromatic hydrocarbons (PAH), linear alkylbenzene sulfonates (LAS), organochlorine compounds (aldrin; technical chlordane; cis-chlordane, dacthal; *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT; *p,p'*dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; hexachlorobenzene lindane; *p,p'*-methoxychlor; mirex; pentachloroanisole; pentachlorobenzene; perthane; polychlorinated biphenyls (PCB); polychlorinated naphthalenes (PCN); toxaphene; trans-chlordane; trans-nonachlor; and trifluralin), and major and trace elements in the surficial bed sediments, and

4. To collect samples of surface water overlying the bed sediments for dissolved major element, trace element, and nutrient analyses.

Table 1.1--Physical and hydrologic characteristics of navigation pools in the Upper Mississippi River

[km, kilometers; m; meters; %, percent; m^3/s, cubic meters per second; T, tributaries that contribute less than 2 percent of the discharge of the Mississippi River are not listed; there is no Pool 23; NA, data not available; <, less than; and --, not measured]

Pool	Length (km)	Project pool elevation above sea level	Surface area[1] (km^2)	Navigation channel area[2] (%)	Storage volume[3] ($10^6 m^3$)	Mean depth (m)	Mean annual discharge[4] (m^3/s)	Percentage of time at open river[5]	Tributary	
									Name	Percentage of discharge of Mississippi River downstream from mouth of tributary[4]
1	10	221.0	2	50	NA	NA	230	NA		
2	53	209.5	48	11	85	1.8	340	1	Minnesota	34
3	29	205.7	[6]36	4	35	0.5	480	14	St. Croix	25
4	71	203.3	157	5	515	3.3	710	4	Chippewa	28
5	24	201.2	51	5	73	1.4	800	1	T	--
5A	14	198.4	28	5	35	1.3	800	13	T	--
6	24	196.7	36	7	51	1.4	850	7	T	--
7	19	194.8	54	4	92	1.7	850	5	Black	5
8	39	192.3	84	5	134	1.6	1,020	4	T	--
9	50	189.0	118	4	226	1.9	1,020	15	T	--
10	53	186.2	69	8	145	2.1	1,300	18	Wisconsin	18
11	51	183.8	[7]75	7	191	2.5	1,300	3	Turkey	2
12	42	180.4	[7]47	11	46	1.0	1,300	4	T	--
13	55	177.7	120	5	NA	NA	1,400	4	Maquoketa	2
14	48	174.3	42	11	NA	NA	1,400	<1	Wapsipinicon	3
15	16	171.0	15	11	NA	NA	NA	1	T	--
16	42	166.1	51	8	131	2.6	1,530	12	Rock	11
17	32	163.4	32	10	86	2.7	1,530	22	T	--
18	42	160.9	55	8	NA	NA	1,560	7	Iowa	11
19	76	157.9	125	6	360	2.9	1,800	0	Skunk	3
20	34	146.3	31	11	108	3.5	2,000	21	Des Moines	8
21	29	143.3	26	11	86	3.3	2,000	15	T	--
22	39	140.1	36	11	105	2.9	2,000	12	T	--
24	45	136.9	[7]51	9	NA	NA	2,040	NA	Salt	2
25	51	132.2	[7]69	7	192	2.8	2,040	NA	T	
26	61	127.7	121	8	424	3.5	2,600	NA	Illinois	24
27	17	NA	NA	50	NA	NA	5,100	NA	Missouri	43

[1]References for surface area are: Pools 2–10, U.S. Army Corps of Engineers, St. Paul District, Gordon Heitzman, oral commun., 1991; Pools 11–22, U.S. Army Corps of Engineers, Rock Island District, Harry Bottorff, oral commun., 1991; Nakato, 1980; Bhowmik and others, 1987; and Pools 24–26, U.S. Army Corps of Engineers, St. Louis District, Ray Kopsky, oral commun., 1991, Bhowmik and others, 1987.

[2]Navigation channel area was computed by assuming a 100-meter-wide channel in all pools. The values in the table are about 3–4 percent lower than some given by Gilbertson and Kelly (1981).

[3]References for storage volume are: Pools 2–10, U.S. Army Corps of Engineers, St. Paul District reservoir regulation manuals; Pools 11, 16, 17, 20, 21, 22, 25, and 26, Nord, 1966; Pool 19; Union Electric Co., oral commun., Keokuk, Iowa, 1991.

[4]Discharges were taken from USGS Water Resources Data published annually for each State.

[5]References for percentage of time at open river are: Pools 2–10, U.S. Army Corps of Engineers, St. Paul District, Gordon Heitzman oral commun., 1991; Pools 11–22, U.S. Army Corps of Engineers, Rock Island District, Harry Bottorff, oral commun., 1991; and Pools 24–26, U.S. Army Corps of Engineers, St. Louis District, Don Coleman, oral commun., 1991.

[6]Lake St. Croix is not included so that the original value of 73 km^2 (which includes Lake St. Croix) was reduced (Gordon Heitzman, U.S. Army Corps of Engineers, St. Louis District, oral commun., 1991).

[7]Where two or three different values were obtained, the average value is reported in this table.

PURPOSE AND SCOPE

The purpose of this chapter is to provide a general introduction to this study of 25 pools in the Upper Mississippi River and to discuss sampling strategy and collecting methods. Approximately 8 to 11 different pools were sampled during each of three cruises in July-August 1991, October-November 1991, and April-May 1992 (Moody and Meade, 1995). Some hydraulic characteristics related to flushing rates are discussed and listed in tables. The particle-size characteristics and bulk chemical characteristics of the surficial bed sediments necessary for normalizing chemical data in succeeding chapters are listed in this chapter.

Sterols, polynuclear aromatic hydrocarbons (PAH), and linear alkylbenzene sulfonates (LAS) are discussed in Chapter 2, organochlorines in Chapter 3, and major and trace elements and nutrients in Chapter 4. The location of each sample (collected to produce the composite sample) and ancillary data at each sampling site in each pool are listed and shown on maps in Chapter 5.

SAMPLING STRATEGY

The navigation-pool reach of the Upper Mississippi River is a complex aquatic system. Wilcox (1991) lists at least 26 different aquatic habitats associated with the navigation channel and backwater areas of a pool. This diversity makes it difficult to obtain a bed-sediment sample that is representative of a pool. The number of habitats is reduced significantly if only the lacustrine region, which usually occupies the downstream one-third of a pool just upstream from the lock and dam structure, is considered. This region is generally shallow, has weak currents, and is morphologically simpler; thus, the bed sediment may be more homogeneous. The rate of deposition of fine particulate matter in this region is probably more rapid than in the higher energy environment downstream from the dams or in the deltaic regions. The association of nonionic, nonpolar contaminants with fine particulate matter has been addressed by several researchers (Leenheer, 1991). The clay-size sediments were shown by Bailey and Rada (1984) to be correlated with trace-metal concentrations in Upper Mississippi River pools. For these reasons, the bed-sediment sampling focused on the downstream one-third of each pool.

To obtain a representative sample within this region of the pool, one to five transects consisting of 2–13 sampling sites along each transect were sampled across the pool, approximately perpendicular to the flow direction, so that a variety of different shallow benthic habitats were sampled. These gave 12-23 individual samples that were combined to form one composite representative sample. The number of individual samples was based on a study of standard error as a function of number of individual samples in a composite sample for polychlorinated biphenyl data collected from Pool 7 (Sullivan, 1988). The results showed that the relative standard error decreased about 37 percent from 5 to 20 samples but only 3 percent from 20 to 30 samples.

The pools upstream from the Lower and Upper St. Anthony Locks and Dams and the last pool (Pool 27) were not sampled because they were predominantly riverine and were assumed to have little stored sediment. Most of the surface area and volume of Pool 4 is Lake Pepin—a lake formed by a natural dam consisting of sediment transported across the Mississippi River by the Chippewa River. Depths in Lake Pepin are generally 5 to 10 times greater than in the other pools; consequently, water velocities are less than 10 cm/s (Randy Burkhardt, U.S. Fish and Wildlife Service, oral commun., 1991) allowing sediment to be deposited. Since Lake Pepin is essentially a long sediment trap, the lower (Upper Mississippi River Mile 765–773) and upper (Upper Mississippi River Mile 773–785) parts of Lake Pepin were sampled separately.

It was assumed that the composition and concentration of contaminants associated with the surficial bed sediment would not change appreciably during a year so that the 25 navigation pools were divided into three groups. The pools in each group were uniformly distributed over the navigation-pool reach between Minneapolis and St. Louis, and one group was sampled on each of three sampling cruises in July-August 1991, October-November 1991, and April-May 1992 (table 1.2). To verify the assumption above, Pool 2 and Pool 8 were sampled on each cruise in order to measure any seasonal changes.

In summary, 12-23 individual bed-sediment samples were collected along transects in the downstream one-third of each pool and combined into one representative composite sample. About one-third of the 25 pools were sampled on each of three cruises and two pools were sampled on every cruise to determine any seasonal changes.

Table 1.2--Location of pool transects in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri

[X, site was sampled]

Pool	Transect number	Location, river miles upstream from mouth of Ohio River	Maximum number of samples along transect	Cruise		
				July-August 1991	October-November 1991	April-May 1992
1	1	848.0	4	X		
	2	848.5	4	X		
	3	849.2	4	X		
2	1	816.1	7	X	X	X
	2	818.1	7	X	X	X
	3	821.1	4	X	X	X
3	[1]1	798.1	8		X	
	[1]2	798.1	6		X	
	3	797.3	2		X	
[2]4	4	774.0	6		X	
	5	776.0	5		X	
	6	778.0	4		X	
[3]4	1	772.0	7		X	
	2	770.0	7		X	
	3	768.0	7		X	
5	1	744.7	9	X		
	2	741.0	6	X		
	3	739.8	3	X		
5A	[1]1	729.8	7	X		
	[1]2	729.8	7	X		
6	1	721.1	7			X
	[1]2	714.9	7			X
	[1]3	714.9	6			X
7	[1]1	702.7	13	X		
	[1]2	702.7	7	X		
8	1	684.7	7	X	Only two samples	X
	2	683.3	7	X	X	X
	3	682.1	6	X	X	X
9	1	648.0	7		X	
	[1]2	655.0	8		X	
	[1]3	655.0	3		X	
10	[1]1	615.0	3	X		
	[1]2	615.0	6	X		
	3	616.1	6	X		
	4	617.2	5	X		
11	1	591.9	7		X	
	2	587.4	8		X	
	3	585.1	5		X	

Table 1.2--Location of pool transects in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri--Continued

[X, site was sampled]

Pool	Transect number	Location, river miles upstream from mouth of Ohio River	Maximum number of samples along transect	Cruise		
				July-August 1991	October-November 1991	April-May 1992
12	[1]1	558.2	8			X
	[1]2	558.2	7			X
	3	560.7	5			X
13	1	526.0	10		X	
	2	523.7	10		X	
14	[1]1	499.8	3	X		
	[1]2	499.8	3	X		
	[1]3	494.8	7	X		
	[1]4	494.8	3	X		
15	1	484.0	2		X	
	2	485.8	10		X	
	3	487.8	6		X	
16	[1]1	458.7	8		X	
	[1]2	458.7	6		X	
	3	457.0	5		X	
18	1	414.5	9			X
	2	411.8	9			X
19	1	371.6	4		X	
	2	370.2	5		X	
	3	368.9	5		X	
	4	367.5	5		X	
	5	366.3	4		X	
20	1	346.6	6	X		
	2	344.2	6	X		
21	1	331.4	7			X
	[1]2	326.6	9			X
	[1]3	326.6	3			X
22	1	306.0	7	X		
	[1]2	303.0	7	X		
	[1]3	303.0	7	X		
24	1	273.4	4		X	
	2	274.4	7		X	
	3	275.3	7		X	
25	[1]1	243.1	8			X
	[1]2	243.1	7			X
	3	241.5	4			X
26	1	206.1	13		X	

[1]Transects were in different directions.
[2]Upper Lake Pepin.
[3]Lower Lake Pepin.

SAMPLING PROCEDURE

The backwater regions of the pools generally are less than 2-m deep, allowing all the bed samples to be collected from a small, 4.3-m boat, except in Lake Pepin (Pool 4) and in Pool 19, where depths were great enough to permit sampling from the research vessel *Acadiana*. Therefore, separate procedures were developed for shallow and deep water.

Shallow-Water Sampling

The research vessel *Acadiana* was anchored off the navigation channel or moored to a dock at a location where visibility from shore to shore across open water or over low islands. The position of the *Acadiana* was fixed by measuring the distance between the research vessel and several prominent landmarks (bridges, culverts, docks, and so forth) at the shoreline, which also were shown on U.S. Geological Survey 7.5-minute quadrangle maps (see Chapter 5 for detailed descriptions of landmarks and distance used to locate the research vessel and the transects in each pool). The distance was measured by mounting a microwave transmitter/receiver (Del Norte Model 217 Transponder) atop a davit in a small boat (fig.1.3) and positioning the small boat at the shoreline landmark. A corresponding master transmitter/receiver and the distance measuring unit were aboard the research vessel to determine the distance. The position of the research vessel was usually on the transect, and the small boat started at the opposite end of the transect (at some prominent shoreline landmark) and worked back toward the research vessel, stopping at 2–13 equally spaced sampling sites in the backwater regions of the pool. The main navigation channel was not sampled except in Pool 1, Lake Pepin, and Pool 19. Location in a direction perpendicular to the transect was maintained by visually lining up two landmarks (one was usually the research vessel if it was on the transect). This method was probably accurate to about ±10 m at 1,000 m and ±30 m at 3,000 m from the research vessel. Location along the transect was determined by the microwave unit and was accurate to ±1 m if the research vessel was moored to a fixed object but was accurate to ±20 m if the research vessel was anchored in a strong wind that caused it to swing around the anchor. When Pools 2 and 8 were resampled on the October-November 1991 and April-May 1992 cruises, the research vessel was reanchored within 80 m of the original anchor location of the June-August 1991 cruise. The individual samples were collected within ±20 m of the original sample locations in the direction along the transect and less than ±80 m in the direction perpendicular to the transect.

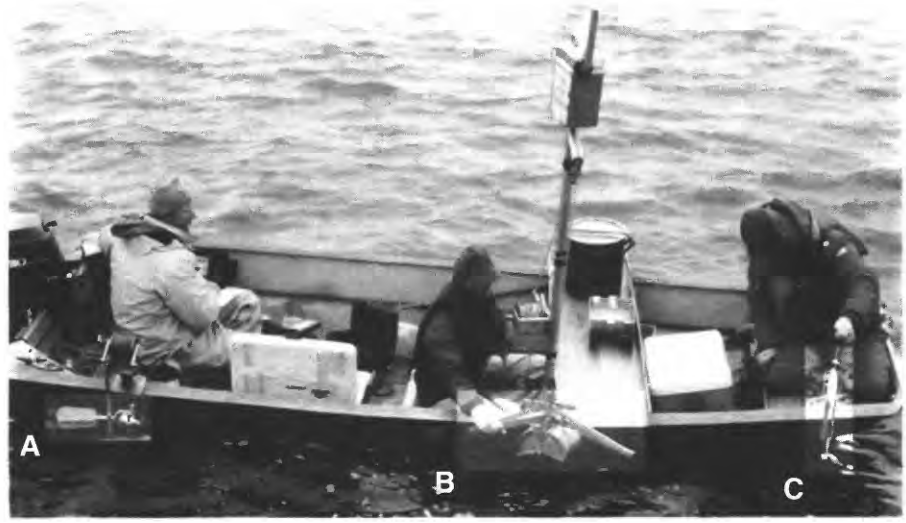

Figure 1.3--Shallow-water sampling equipment. At the bow of the 4.3-m-long boat, the small gravity corer (C) is being held over the side on a handline. Forward of the middle of the small boat, the modified van Veen grab sampler (B) is hanging from a davit and boom assembly in the open position. On top of the davit is a microwave receiver/transmitter. Hanging over the side, just forward of the stern of the small boat, is a Price AA current meter (A). Photograph by R. H. Meade.

At each sampling site, the small boat was anchored on a short anchor line to prevent swinging, and three people measured surface temperature, specific conductance, water depth, and water velocity and collected two bed-sediment samples and a surface-water sample. The surface temperature and specific conductance (listed in the Chapter 5) were measured with a LabComp model SCT-100 meter in a bucket after allowing about 30 seconds for the sensors to come to equilibrium. The accuracy of the unit was listed by the manufacturer as ±10 µS/cm for the 0–2,000 µS/cm range, with resolutions of 1 µS/cm and 0.1°C. This was checked eight times during the three cruises, and the specific conductance was within ±5 µS/cm of a laboratory standard. The LabComp specific-conductance meter broke in the middle of transect 2 in Pool 9, and an AmberScience conductivity meter (model 604) was used to measure conductivity and a Beckman pH meter (model ϕ12) was used to measure temperature in Pools 9, 11,13, 16, 24, and 26. The resolution of these meters was ±1 µS/cm and ±0.1°C. The depth was measured with a Lowrance Model X-16 analog recorder, and depths were recorded to the nearest 0.1 m. For depths less than about 1.3 m, a pole marked in 0.1-m intervals was used to measure the depth. The mean velocity was measured at 0.6 of the depth by using a standard Price AA current meter (Rantz and others, 1982), and the direction was determined by noting the direction, relative to a compass in the aluminum boat, of the current meter and sounding weight after each was quickly raised a short distance (usually 1–3 m) to the surface. The depth, temperature, specific conductance, mean velocity, and direction are listed in Chapter 5.

The two bed-sediment samples were collected by using a modified van Veen grab sampler and a gravity corer. These samplers were designed to satisfy the requirements for sample volume and eliminating contamination. The modified van Veen grab sampler (fig. 1.4, Theodore B. Young, Sandwich, Mass., oral commun., 1990) was operated from a small davit (fig. 1.3) with a hand winch. The sampler collects a 20-cm by 20-cm sample of the bed sediments (0.04 m^2), which had a maximum thickness of 10 cm. The sampler consistently collected a full sample if the bed was mud without debris. In fine and medium sand, the sampler was usually 50 to 80 percent full. The only problem was clam shells or cobbles, which got caught between the jaws and allowed the remainder of the sample to wash out. From the small boat, samples were collected in water velocities as great as 90 cm/s and water depths as great as 6 m.

After the sampler was brought aboard, two subsamples were taken. One subsample was for sterols, PAH, and LAS, and one subsample was for organochlorines. The subsamples were collected by using cores of various diameter made from Teflon cylinders fitted with a Teflon-covered syringe plunger. The individual samples were added to glass jars as they were collected, then refrigerated and shipped to the laboratory for analysis. A third subsample was collected for particle-size determination by inserting a piece of channel brass (0.4 cm wide, 0.2 cm deep, and 10 cm long) straight down into the sample, rotating the bottom of the channel brass sampler up, scraping off any excess protruding above the sides of the sampler with a spatula, then washing the sample into a plastic bottle.

The second sampler was a gravity corer (core tube was designed and built by Harold Wiegner, Minnesota Pollution Control Agency, St. Paul). The core tube, made of plexiglass (methyl methacrylate polymer), and other parts were coated with plastic (fig. 1.4). The gravity corer was designed to collect a maximum 30-cm-long, 1.9-cm-diameter core for major and trace-element analysis (see Chapter 4). The plastic core barrel was removed, the ends capped with a plastic cap, and each individual core sample was put in a plastic bag, sealed, and frozen. After being shipped to the laboratory, the cores were subsampled and combined to form a composite sample. It was difficult to obtain a gravity core if the water velocities were greater than about 40 cm/s or if the bed sediment was sand. Some samples for major and trace elements were collected from the modified van Veen grab sampler if the gravity corer failed to get a sample after three to six attempts.

A surface-water sample was collected with a Teflon, 1-L beaker at each coring site and combined with other samples in a Teflon-lined churn splitter. Aliquots of the surface-water composite were subsampled later aboard the research vessel.

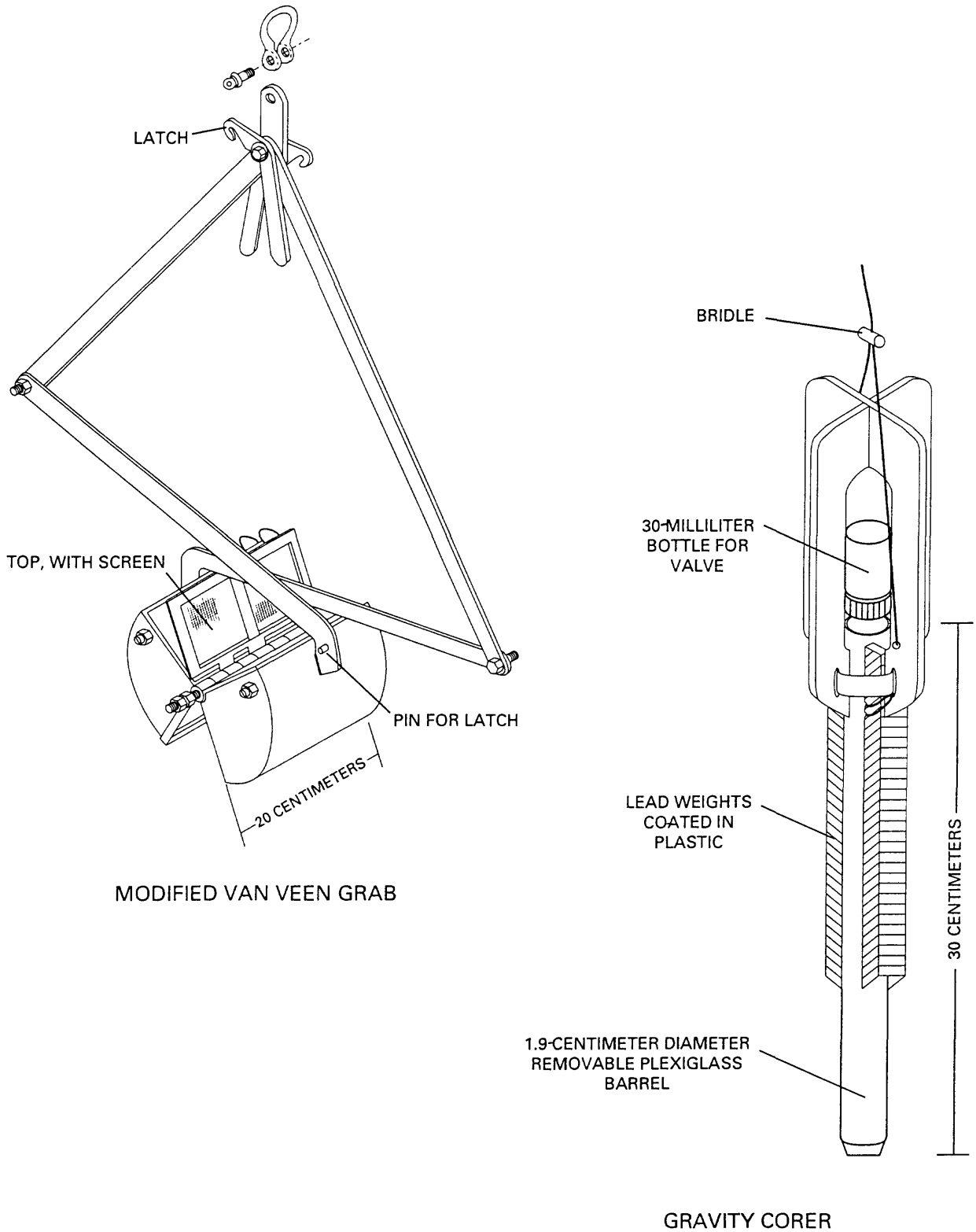

Figure 1.4--Details of the modified van Veen grab and gravity corer samplers.

Deep-Water Sampling

This sampling procedure was similar to the shallow-water procedure because the bed-sediment samples were collected with the same equipment from the *Acadiana*. The depth was determined with the same depth recorder mounted on the research vessel, the surface temperature and specific conductance were measured in the same manner, but no velocity measurements were made because the research vessel was no longer anchored or moored to a dock. Since the research vessel was the sampling platform, it had to be positioned at the sampling site. This was done by setting up two microwave transmitter/receivers at landmarks on the shoreline, plotting the desired sampling sites on a map showing the location of the microwave units, and scaling the distance between each microwave unit and the desired sampling site. The vessel's operator positioned the vessel at the sampling site by maneuvering until the distance between the research vessel and the microwave unit (displayed on a TV monitor) agreed with the distances scaled from the map. The distances listed in Chapter 5 are the distances recorded when the samplers hit bottom (denoted by a "c" for gravity corer and a "g" for modified van Veen grab).

HYDROLOGY

Cross-sectional profiles of rivers are frequently plotted with a vertical exaggeration to make variations in depth look more pronounced. It should be kept in mind that the Mississippi River is a very thin, ribbonlike layer of water. The width-to-depth ratio in the riverine reach of the pools just downstream from dams averages about 100:1 (see table 1.3). This ratio is about one-tenth that in the lacustrine reach (table 1.4) of the pools where the dams cause water to back up over wide, flat valleys. If the Upper Mississippi River were as wide as this page, its maximum depth (about 8 m in the navigation channel) would be represented by a line less than 2 mm thick, and a line representing the depths of the shallow off-channel, backwater areas would be less than 0.5 mm thick.

Discharge

The water discharge was computed from velocity measurements made at 0.6 of the depth at each sample location along the sampling transect and at additional three to six locations across the navigation and secondary channels. The standard error in the water discharge for triplicate measurements was 8 and 6 percent in Pools 8 and 11, respectively, and averaged 8 percent for all duplicate and triplicate measurements. The measured discharges in the pools were compared to the discharges reported by the U.S. Army Corps of Engineers for the dam closest to the sampling transect unless a major tributary was between the sampling transect and the dam. The measured discharges ranged from 25 percent less to 11 percent greater (and averaged about 6 percent less) than the Corps of Engineers measurements.

The percentage of the water discharge in the navigation channel was 100 percent in the riverine region and averaged about 65 percent in the lacustrine regions of the pools (tables 1.3 and 1.4). In the regions of the pool occupied by the navigation or secondary channels, the direction of the water flow was the same as in the navigation channels. In areas outside the channels, the current direction was variable and was affected by wind direction and topography, but generally was downriver (Chapter 5 has current magnitudes and directions). The mean velocity in the off-channel areas was 56 percent of the velocity in the navigation channel (table 1.4).

Table 1.3--Measured hydraulic parameters for the riverine reaches of some navigation pools in the Upper Mississippi River between Minneapolis, Minnesota and St. Louis, Missouri, July 1991-April 1992

Pool number	Location in river miles upstream from mouth of Ohio River	Date	Cross section			Mean velocity (cm/s)	Water discharge	
			Mean depth (m)	Width-to-depth ratio	Area (m^2)		Measured (m^3/s)	Ratio of discharge to mean annual discharge[1]
2	844.0	04-07-92	4.9	30	710	51	357	1.6
3	812.2	07-08-91	5.4	40	1,300	76	983	2.9
		04-10-92	5.0	60	1,140	50	567	1.7
		10-10-91	4.4	50	940	37	350	1.1
7	713.8	07-12-91	4.5	100	1,960	74	1,440	1.7
		04-14-92	4.7	90	2,010	66	1,330	1.6
		10-15-91	4.0	110	1,730	38	660	0.8
10	639.7	07-15-91	4.8	90	2,150	74	1,590	1.6
		04-17-92	5.0	90	2,260	70	1,590	1.6
		10-18-91	3.9	110	1,710	40	690	0.6
14	520.3	04-19-92	6.8	70	3,250	71	2,320	1.7
		07-18-91	6.1	80	2,930	63	1,850	1.3
		10-22-91	5.6	80	2,540	37	940	0.7
20	363.1	04-23-92	5.1	160	4,035	105	4,220	2.3
		07-21-91	3.7	210	2,860	71	2,050	1.1
		10-27-91	3.0	240	2,200	64	1,410	0.8
26	239.2	04-26-92	7.9	70	4,560	111	5,070	2.5
		07-24-91	6.0	100	3,420	100	2,730	1.3
		10-30-91	4.7	120	2,630	47	1,230	0.6

[1]Ratio of discharge is the measured discharge divided by the discharge listed in table 1.1 for the dam closest to the sampling transect unless a major tributary was between the sampling transect and the dam.

Table 1.4--Measured hydraulic parameters for the lacustrine reaches of some navigation pools in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[m, meter; m^3/s, cubic meter per second; cm/s, centimeter per second; --, not applicable]

Pool and transect number	Location in river miles upstream from mouth of Ohio River	Date	Cross section			Water discharge			Mean velocities		
			Mean depth (m)	Width-to-depth ratio	Area (m^2)	Measured (m^3/s)	Ratio of discharge to mean annual discharge	Percentage of total discharge in channels	In channel (cm/s)	Off channel (cm/s)	Cross section (cm/s)
1-3	849.2	07-04-91	3.4	90	1,040	448	1.9	100	43	--	43
1-2	848.5		2.7	120	900	447	1.9	100	49	--	49
2-2	818.1	07-07-91	1.7	770	2,220	832	2.5	58	40	37	38
		04-09-92	2.1	620	2,760	562	1.7	47	21	19	20
		10-09-91	2.2	600	2,900	415	1.2	34	12	16	14
2-1	816.1	07-07-91	1.9	730	2,630	1,028	3.0	78	54	21	39
		04-09-92	2.0	700	2,790	582	1.7	62	24	17	21
[1]4-6	778.0	10-14-91	5.6	320	10,140	[2]510	1.1	100	5	--	5
[1]4-5	776.0		6.0	360	13,020	[2]510	1.1	100	4	--	4
[1]4-4	774.0		6.1	440	16,460	[2]510	1.1	100	3	--	3
[3]4-1	772.0	10-12-91	6.4	590	24,260	[2]510	1.1	100	2	--	2
[3]4-2	770.0		6.9	520	24,970	[2]510	1.1	100	2	--	2
[3]4-3	768.0		6.4	500	20,680	[2]510	1.1	100	2	--	2
5-2	741.0	07-11-91	1.7	1,500	4,440	1,350	1.7	57	46	21	30
5-3	739.8		3.1	380	3,660	1,320	1.7	68	40	30	36
6-1	721.0	04-13-92	3.0	520	4,710	1,450	1.7	64	53	18	30
6-2	715.0		2.4	590	3,420	1,480	1.7	83	53	23	43
8-1	684.7	07-14-91	1.2	3,200	4,600	1,520	1.5	35	49	28	33
		04-16-92	1.5	2,500	5,720	1,560	1.5	45	36	23	27
8-2	683.3	07-14-91	1.5	2,500	5,730	1,480	1.5	33	40	22	26
		04-16-92	1.4	2,900	5,600	1,310	1.3	33	30	21	23
		10-17-91	1.7	2,300	6,520	585	0.6	88	23	2	9
8-3	682.1	07-14-91	1.7	1,900	5,440	1,310	1.3	41	35	20	24
		10-17-91	1.8	1,700	5,600	511	0.5	34	12	8	9
9-2	655.0	10-19-91	1.8	1,900	6,070	563	0.5	73	18	4	9

Table 1.4--Measured hydraulic parameters for the lacustrine reaches of some navigation pools in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992--Continued

[m, meter; m^3/s), cubic meter per second; cm/s, centimeter per second; --, not applicable]

Pool and transect number	Location in river miles up-stream from mouth of Ohio River	Date	Cross section			Water discharge			Mean velocities		
			Mean depth (m)	Width-to-depth ratio	Area (m^2)	Meas-ured (m^3/s)	Ratio of discharge to mean annual discharge	Percent-age of total dis-charge in channels	In chan-nel (cm/s)	Off chan-nel (cm/s)	Cross sec-tion (cm/s)
11-1	591.9	10-20-91	2.0	1,300	5,170	944	0.7	87	26	6	18
11-2	587.4		2.1	1,400	6,230	1,030	0.8	52	35	10	17
11-3	585.1		2.8	760	5,930	1,070	0.8	88	22	8	18
13-1	526.0	10-21-91	1.4	3,500	6,840	1,210	0.9	56	31	11	18
13-2	523.7		1.7	2,700	7,930	861	0.6	65	22	6	11
14-1	499.8	07-19-91	4.2	200	3,370	1,860	1.3	77	57	48	55
15-3	487.8	04-20-92	3.4	300	3,400	2,510	1.7	100	74	--	74
16-1,2	458.7	10-24-91	2.0	2,000	7,934	1,200	0.8	45	15	15	15
18-1	414.5	04-22-92	2.1	900	3,960	3,360	2.1	[4]82	96	55	85
19-1	371.6	10-26-91	4.0	390	6,290	1,410	0.8	100	22	--	22
19-2	370.2		4.3	320	6,050	1,410	0.8	100	23	--	23
19-3	368.9		3.9	420	6,350	1,410	0.8	100	22	--	22
19-4	367.5		4.2	350	6,190	1,410	0.8	100	23	--	23
19-5	366.3		4.1	390	6,700	1,410	0.8	100	21	--	21
20-1	346.6	07-22-91	2.6	600	4,030	2,490	1.2	[4]94	65	37	62
20-2	344.2		4.3	230	4,290	2,270	1.1	85	59	32	53
21-1	331.4	04-24-92	4.1	280	4,790	4,190	2.1	[4]57	100	75	87
22-1	306.0	07-23-91	3.8	280	4,060	2,360	1.2	40	74	50	58
22-2	303.0		3.6	310	4,070	2,520	1.3	78	72	41	62
24-3	275.3	10-29-91	3.7	520	7,100	1,300	0.6	55	29	13	18
24-2	274.4		3.1	650	6,200	1,500	0.7	72	27	18	24
25-2	243.1	04-25-92	2.3	1,100	5,780	5,230	2.6	98	98	20	90

[1]Upper Lake Pepin.
[2]Discharge measured at outlet of Lake Pepin on October 13, 1991.
[3]Lower Lake Pepin.
[4]Includes flow in secondary channels.
[5]Discharged measured below Lock and Dam 19 on October 27, 1991.

Mixing

Lateral gradients of specific conductance greater than 10 μS/cm (twice the precision of the conductivity meter) were measured in 12 pools (table 1.5). The change in the difference between the ends of the cross-pool sampling transects (an indicator of mixing) with downstream distance ranged from positive 9 μS/cm per kilometer (an increasing lateral gradient) to negative 9 μS/cm per kilometer (a decreasing lateral gradient).

Flushing Rates

Governing officials of cities and towns along a river are concerned about pollution and the length of time that contaminated water may remain in their area (Ketchum, 1951; Ketchum and Keen, 1953; and Rutherford and others, 1980). The Upper Mississippi River presents a difficult problem because the navigation pools are not water-storage reservoirs, nor are they like a free-flowing river, so standard methods for estimating retention times may not be applicable. The simplest standard method of computing an average retention time is to divide the volume of the pool (at project pool elevation) by the mean annual discharge. Using data in table 1.1, this method gives a retention time for each pool that is a function of the length and changing cross-sectional area of the pool (table 1.6). This simple method is based on a conceptual model in which the water velocities are the same throughout the length of the pool, and the retention time is the time it takes for the water to flow from the upstream end to the downstream end of the pool. For a given discharge, the changing cross-sectional area of the pools in the riverine, deltaic, and lacustrine regions (table 1.3 and 1.4) will affect the water velocities in the longitudinal direction, and changes in depth and the presence or absence of islands will affect the water velocities in the lateral direction. Thus, the flushing rate, in hours per kilometer (h/km) of river, is perhaps a more applicable measure to use in constructing models which include downstream variations of the flushing rate. Different rates can be applied to the appropriate regions in the pool. By multiplying the flushing rate by the length of each appropriate region and summing over the length of the pool, an improved estimate for the retention time can be obtained which includes the effects of the downstream variation due to changes in morphology of the pool. The flushing rate is the reciprocal of the mean cross-sectional velocity for a specific cross section. The estimated flushing rates, equivalent to the retention times in table 1.6, were calculated by dividing the retention time by the length of the pool for comparison to the measured flushing rates.

Flushing rates were estimated at 46 sites on the Upper Mississippi River at three different times over the period of 1 year. The discharges ranged from one-half to three times the mean annual discharge, and the flushing-rate measurements have been grouped into three discharge ranges (see table 1.7). The measured flushing rates (table 1.7) were greater than or equal to the estimated flushing rates (table 1.6) based on the simple method of computing an average retention time.

Table 1.5--Magnitude of specific-conductance difference between the ends of cross-pool sampling transects in some navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[Only differences greater than 10 µS/cm across the pool are listed; µS/cm microsiemens per centimeter at 25 degrees Celsius]

Pool	Transect number	Specific-conductance difference (µS/cm)
[1]2	1	17
[3]2	2	13
4	5	16
5	2	80
	3	90
6	1	50
	2	56
[1]8	1	12
	2	32
	3	16
[2]8	2	20
	3	17
[3]8	1	99
	2	78
11	1	20
	2	19
	3	12
14	3	16
	4	18
15	1	27
	2	32
16	1,2	141
18	1	83
20	1	52
	2	59
22	1	50
	2	37

[1]July-August 1991 cruise.
[2]October-November 1991 cruise.
[3]April-May 1992 cruise.

Table 1.6--Estimated retention time and flushing rates in some navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri

[NA, data not available; h, hour; km, kilometer]

Pool	Estimated retention time[1] (h)	Estimated flushing rate (h/km)
1	NA	NA
2	69	1.3
3	20	0.7
4	200	2.8
5	25	1.0
5A	12	0.9
6	17	0.7
7	30	1.6
8	36	0.9
9	62	1.2
10	31	0.6
11	41	0.8
12	10	0.2
13	NA	NA
14	NA	NA
15	NA	NA
16	24	0.6
17	16	0.5
18	NA	NA
19	56	0.7
20	15	0.4
21	12	0.4
22	15	0.4
24	NA	NA
25	26	0.5
26	45	0.7

[1]Used estimates of storage volumes and mean annual discharges from table 1.1.

Table 1.7--Measured flushing rates in some navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[Q, measured discharge in the pool divided by the mean annual discharge in table 1.1; <, less than; ≤, less than or equal to; h, hour; km, kilometer; --, no measurements were made]

Pool and transect number	Normalized distance[1]	Flushing rate (h/km)		
		Q≤0.6	0.6<Q≤1.4	1.4<Q≤3.0
2	[2]0.88	--		0.5
2-2	0.09	--	2.0	[3]1.1
2-1	0.03	--	--	[3]1.0
3	[2]0.84	--	0.7	[2]0.5
4-6	0.57	--	5.6	--
4-5	0.52	--	6.9	--
4-4	0.48	--	9.3	--
4-1	0.43	--	13.5	--
4-2	0.39	--	13.5	--
4-3	0.34	--	13.5	--
4	[2]0.26	--	0.9	[3]0.5
5-2	0.20	--	--	0.9
5-3	0.12	--	--	0.8
6-1	0.46	--	--	0.9
6-2	0.07	--	--	0.6
7	[2]0.98	--	0.7	[3]0.4
8-1	0.24	--	--	[3]0.7
8-2	0.18	3.1	1.2	1.1
8-3	0.13	3.1	[2]1.2	--
9-2	0.22	3.1	--	--
10	[2]0.75	0.7	--	[3]0.4
11-1	0.28	--	1.5	--
11-2	0.14	--	1.6	--
11-3	0.07	--	1.5	--
13-1	0.09	--	1.5	--
13-2	0.02	2.5	--	--

Table 1.7--Measured flushing rates in some navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992--Continued

[Q, measured discharge in the pool divided by the mean annual discharge in table 1.1; <, less than; ≤, less than or equal to; h, hour; km, kilometer; --, no measurements were made]

Pool and transect number	Normalized distance[1]	Flushing rate (h/km)		
		Q≤0.6	0.6<Q≤1.4	1.4<Q≤3.0
14	[2]0.91	--	[3]0.6	0.4
14-1	0.23	--	0.5	--
15-1	0.48	--	--	0.4
16-1,2	0.07	--	1.9	--
18-1	0.13	--	--	0.3
19-1	0.16	--	1.3	--
19-2	0.13	--	1.2	--
19-3	0.10	--	1.3	--
19-4	0.07	--	1.2	--
19-5	0.05	--	1.3	--
20	[2]0.96	--	[3]0.4	0.3
20-1	0.17	--	0.4	--
20-2	0.05	--	0.5	--
21-1	0.36	--	--	0.3
22-1	0.21	--	0.5	--
22-2	0.08	--	0.4	--
24-3	0.08	1.5	--	--
24-2	0.05	1.2	--	--
25-2	0.06	--	--	0.3
26	[2]0.96	0.6	0.3	0.3

[1]Normalized distance is the distance upstream from the dam divided by the length of the pool.
[2]These sites were not transects for sampling bed sediments (see table 1.3).
[3]Average of two values.

SEDIMENT CHARACTERISTICS

The surficial bed sediment was subsampled and analyzed for physical (particle-size) and bulk chemical (nitrogen, carbonate carbon, total carbon, and total organic carbon) characteristics. The bulk chemical characteristics were determined for a subsample of the subsample collected for organochlorine analysis.

Particle Size

The composite samples for particle-size analysis were between 40 and 150 g and were sent to the U.S. Geological Survey Sediment Laboratory in Iowa City, Iowa. Each composite sample was first sieved to separate the fine fraction (less than 63 μm) from the coarse fraction (greater than 63 μm). The size distribution of the coarse fraction was determined by the sieve method for particle diameters greater than 1 mm and by the visual-accumulation tube method for particle diameters greater than 63 μm but less than 1 mm (Guy, 1969). Particle size of the fine fraction less than 63 μm was determined by the SediGraph method described by Lara and Matthes (1986). About 1 in 10 samples was reanalyzed, and if the results did not agree within 5 percent for all size classes, the analysis was repeated (Matthes and others, 1992).

The median diameter (table 1.8) was computed by linearly interpolating between particle diameters that bracket the value of "50 percent finer than." Surficial bed sediments in Lake Pepin in Pool 4, in Pool 19 behind the large hydroelectric dam at Keokuk, Iowa, and in Pool 26 were predominantly clay sized and had the smallest median diameters, ranging from 0.002 to 0.012 mm. Downstream from Lake Pepin and the Chippewa River, the median diameter increased to 0.22 mm in Pool 5. Other pools with relatively large median particle diameter are Pools 1, 6, 15, 20, 21, 22, and 24. Some pools have relatively large tributaries such as the Wisconsin River (Pool 10) and the Des Moines River (Pool 20). Some pools (Pools 1, 2, 10, 14, and 19) are relatively narrow, with a width-to-length ratio (Surface area/Length^2 in table 1.1) less than or equal to 0.03. Some (for example, Pool 10) have essentially no lacustrine region and sampling transects had to be nearly parallel to the flow (to maintain visual and microwave communication between the small boat and the research vessel), reducing the heterogeneity of the samples and biasing the samples toward sand. Contaminants are commonly associated with clay-sized particles. The spatial distribution of average clay-sized particles (fig. 1.5) shows four pools (4, 12, 19, and 26) that have clay content greater than 25 percent.

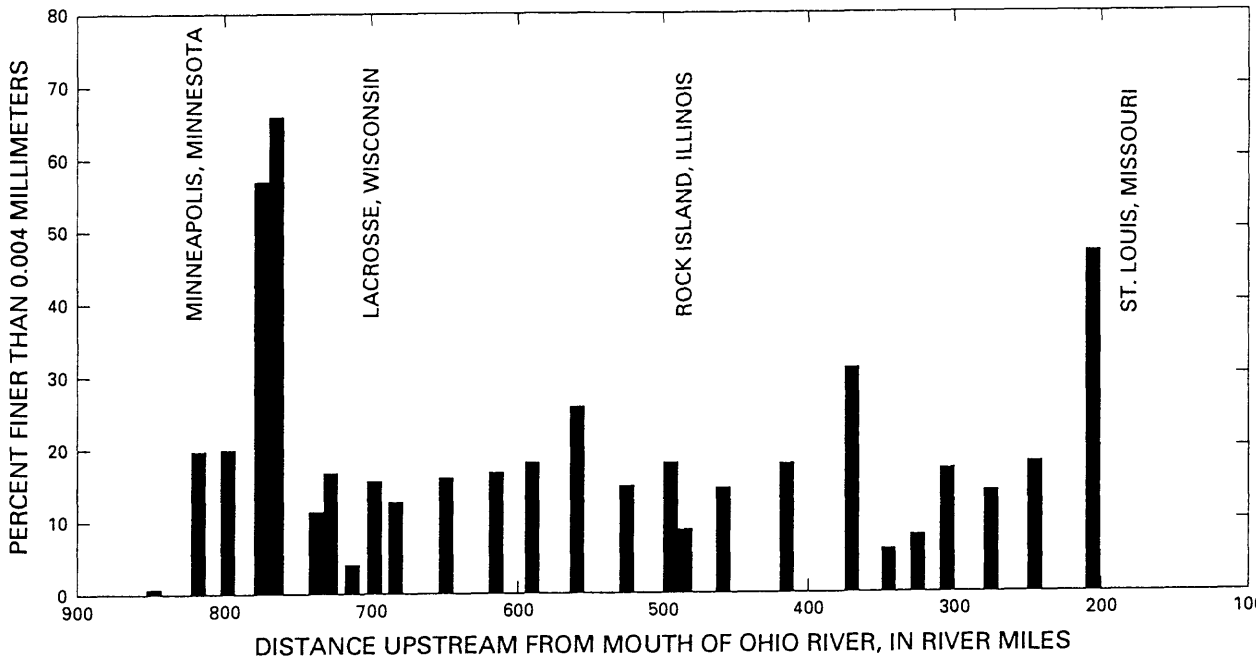

Figure 1.5--Percentage of surficial bed sediments finer than 0.004 millimeter collected from the downstream one-third of each navigation pool of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992. See table 1.2 for location of pools.

Table 1.8--Particle size of surficial bed sediments collected from the downstream one-third of each navigation pool of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[Analyses by U.S. Geological Survey Sediment Laboratory in Iowa City, Iowa; no samples were collected in the main navigation channel]

Pool	Date	Number of samples in composite	Percentage finer than indicated size, in millimeters													Median diameter[1] (mm)
			SediGraph							Visual accumulation			Sieve			
			Clay			Silt				Sand				Gravel		
			0.001	0.002	0.004	0.008	0.016	0.032	0.063	0.125	0.250	0.500	1.0	2.0	4.0	8.0
1	07-04-91	12	0.7	0.9	1.1	1.5	1.8	2.5	3.2	14.5	46.6	90.5	97.6	99.8	100.0		0.27
2	07-07-91	18	17.2	18.3	21.3	25.7	32.2	43.8	59.2	81.7	93.4	98.1	100.0				0.043
	10-09-91	18	11.5	14.9	19.1	26.0	37.2	55.6	69.4	85.3	97.1	99.7	100.0				0.026
	04-09-92	18	9.0	14.7	20.4	28.5	40.4	61.6	81.6	94.4	98.8	99.9	100.0				0.023
3	10-11-91	16	10.0	14.3	20.1	29.7	42.8	63.7	77.2	88.3	93.3	96.4	97.6	98.9	100.0		0.021
[2]4	10-14-91	15	34.6	44.3	57.2	71.5	78.8	82.1	83.0	83.5	86.9	93.5	98.7	100.0			0.003
[3]4	10-12-91	21	44.2	54.7	66.4	75.6	81.4	82.6	83.5	83.6	88.2	99.1	100.0				0.002
5	07-11-91	18	7.4	9.4	11.4	14.2	18.7	22.7	28.8	36.2	54.9	88.4	97.1	99.5	100.0		0.22
5A	07-11-91	14	12.0	14.4	17.4	21.1	27.1	43.6	60.2	83.7	95.2	99.0	100.0				0.043
6	04-13-92	20	2.3	3.1	3.7	4.4	5.4	7.9	9.9	16.9	42.1	80.8	96.1	98.7	100.0		0.30
[4]7	07-13-91	20	11.4	13.7	15.9	18.9	25.2	37.3	45.5	68.3	86.7	98.4	99.7	100.0			0.074
8	07-14-91	20	12.0	14.5	17.3	20.8	27.6	40.9	50.1	71.3	88.7	97.0	99.3	100.0			0.062
	10-17-91	15	5.6	8.4	11.2	15.8	24.9	49.7	70.0	91.4	97.8	100.0					0.032
	04-16-92	20	5.2	7.6	9.8	12.1	16.4	26.5	35.5	56.2	85.8	94.8	98.7	100.0			0.11
9	10-19-91	18	6.1	9.5	15.6	22.1	36.0	65.5	86.7	95.6	98.5	100.0					0.024
10	07-16-91	20	6.2	13.3	16.6	20.8	32.0	38.2	41.6	55.7	74.3	94.2	97.0	98.3	100.0		0.099
11	10-20-91	20	11.4	14.3	18.0	22.4	31.9	53.9	73.4	83.6	92.1	98.5	100.0				0.029
12	04-18-92	20	13.2	19.9	25.5	34.5	51.1	79.9	94.5	97.6	99.7	100.0					0.015

Table 1.8--Particle size of surficial bed sediments collected from the downstream one-third of each navigation pool of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992--Continued

[Analyses by U.S. Geological Survey Sediment Laboratory in Iowa City, Iowa; no samples were collected in the main navigation channel]

Pool	Date	Number of samples in composite	Percentage finer than indicated size, in millimeters														Median diameter[1] (mm)
			SediGraph							Visual accumulation			Sieve				
			Clay			Silt				Sand					Gravel		
			0.001	0.002	0.004	0.008	0.016	0.032	0.063	0.125	0.250	0.500	1.0	2.0	4.0	8.0	
13	10-21-91	20	8.3	11.5	15.0	20.2	28.9	55.8	79.1	88.0	95.8	99.9	100.0				0.029
14	07-19-91	16	11.4	14.5	18.0	23.7	31.4	41.3	43.9	45.6	67.7	95.8	99.1	99.7	100.0		0.15
15	04-20-92	18	3.8	6.2	8.7	11.5	16.8	27.2	34.3	37.2	44.3	72.2	93.5	99.4	100.0		0.30
16	10-24-91	19	8.5	11.7	14.7	19.7	27.2	41.7	49.9	55.2	73.4	95.7	100.0				0.063
17	Not sampled due to ship repairs																
18	04-22-92	18	9.9	13.9	18.5	24.8	34.4	53.8	66.1	72.9	80.4	91.2	98.6	99.7	100.0		0.029
19	10-26-91	23	15.4	22.2	31.2	42.7	57.7	69.2	71.7	73.6	77.3	92.5	98.4	99.7	100.0	0	0.012
20	07-22-91	12	4.2	5.2	6.5	8.0	10.6	17.8	23.5	28.8	42.9	65.6	82.3	86.3	98.4	100.0	0.33
21	04-24-92	19	4.8	6.2	7.7	10.0	13.7	21.2	25.4	32.3	47.4	83.1	97.8	99.8	100.0		0.27
22	07-23-91	21	11.1	13.8	16.8	21.2	27.5	30.1	33.6	38.7	51.8	88.5	97.5	99.3	100.0		0.23
[5]24	10-24-91	18	7.1	10.1	13.8	19.3	25.3	32.2	33.5	34.2	43.5	80.7	99.3	100.0			0.29
25	04-25-92	19	5.0	10.7	17.6	27.3	38.6	51.8	55.1	58.3	63.9	78.2	93.8	98.8	100.0		0.030
26	11-01-91	13	21.7	28.0	35.8	46.1	61.1	75.6	78.8	84.9	93.7	97.2	98.7	99.3	100.0		0.010

[1]Median diameter determined by straight-line interpolation.
[2]Upper Lake Pepin which is part of Pool 4.
[3]Lower Lake Pepin which is part of Pool 4.
[4]Lake Onalaska.
[5]Original subsample for size was lost and a second subsample was taken from the large subsample for sterols, PAH, and LAS analaysis.

Bulk Chemistry

Subsamples were taken from each subsample of surficial bed sediment collected for organochlorine analysis. This subsample was analyzed for the bulk chemical composition: percent nitrogen, percent carbonate carbon, and percent total and organic carbon (table 1.9). Percentage values are based on dry weight. All samples were dried at a temperature of 105°C until a constant weight was obtained. Nitrogen was determined by high temperature combustion on a Carlo Erba nitrogen detector. Total carbon was determined by combustion and coulometric detection, and carbonate carbon was determined by acidification and coulometric detection. Organic carbon was determined by difference between the percentages of carbonate carbon and total carbon, and all values were rounded to the nearest tenth of a percent. Pools with multiple analyses were averaged and plotted in figure 1.6 along with the pools with single values. Huffman Laboratories, Inc., Golden, Colo. performed all the analyses. The laboratory accuracy and precision uncertainty were determined by multiple measurements of the standard homogeneous reference material of total carbon ($CaCO_3$, triphenyl methane, steric acid, and National Institute for Science and Technology Buffalo River Sediment), carbonate carbon ($CaCO_3$ and Na_2CO_3), and nitrogen (acetanilide, atropine, sulfanilamide, and nicotinic acid p-toluene sulfonate). The accuracy is the average percent difference from the "true" value and was 0.1 percent for total carbon, 0.7 percent for carbonate carbon, and 0.3 percent for nitrogen. The precision is the average of the relative standard deviations and was 0.2 percent for total carbon, 0.4 percent for carbonate carbon, and 0.7 percent for nitrogen.

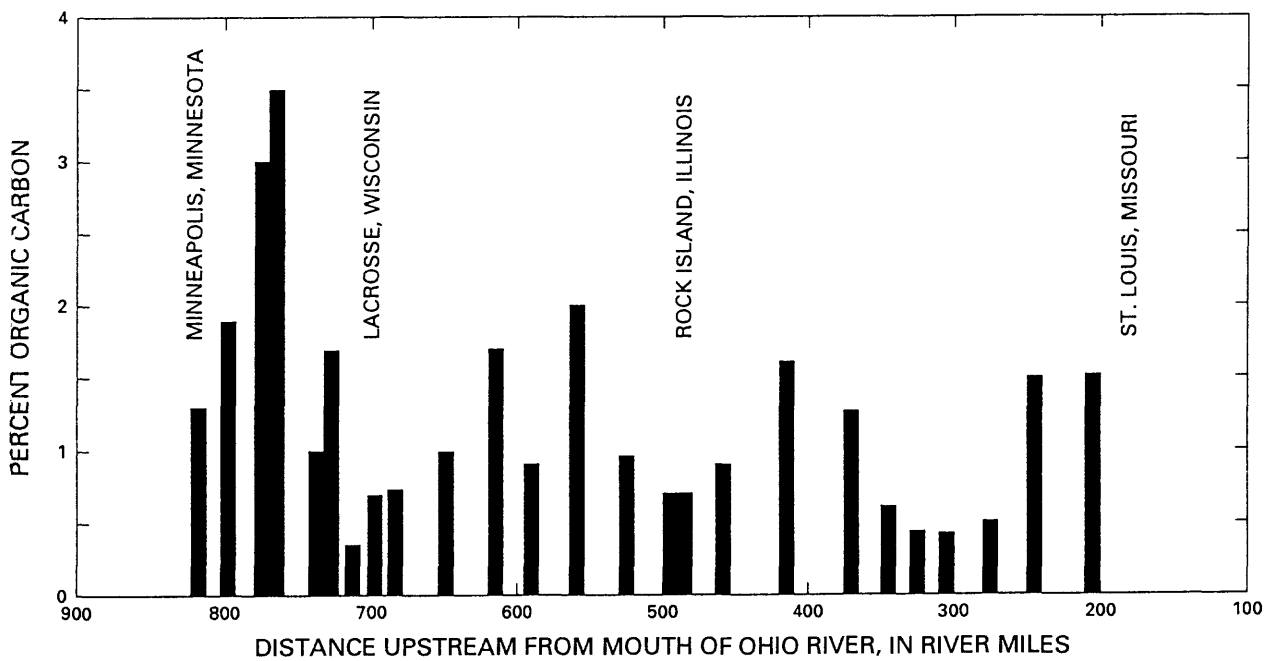

Figure 1.6--Percent organic carbon in surficial bed sediments collected from the downstream one-third of each navigation pool of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992. See table 1.2 for location of pools.

Table 1.9--Bulk chemical characteristics of surficial bed sediments collected from the downstream one-third of each navigation pool of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[Samples were analyzed by Huffman Laboratories, Inc.; <, less than; --, not reported]

Pool	Date	Number of samples in composite	Percentages based on dry weight			
			Nitrogen	Carbonate carbon	Total carbon	Organic carbon
1	07-04-91	12	0.02	0.30	0.22	<0.1
[1]2	10-08-91	1	0.2	--	--	1.1
2	07-07-91	18	0.09	1.14	2.38	1.24
	10-09-91	18	0.13	1.41	2.84	1.43
	04-09-92	18	0.14	1.46	3.02	1.56
3	10-11-91	16	0.19	1.44	3.37	1.93
[2]4	10-14-91	15	0.43	1.32	4.31	2.99
[3]4	10-12-91	21	0.42	0.69	4.29	3.60
		21	0.42	0.73	4.08	3.35
5	07-11-91	18	0.11	0.14	1.18	1.04
5A	07-11-91	14	0.12	0.26	1.92	1.66
6	04-13-92	20	0.03	0.06	0.42	0.36
		20	0.03	0.06	0.32	0.26
7	07-13-91	20	0.09	0.09	0.78	0.69
		20	0.07	0.12	0.86	0.74
8	07-14-91	20	0.07	0.38	1.17	0.79
8	04-16-92	20	0.06	0.40	1.08	0.68
9	10-19-91	18	0.14	0.36	1.38	1.02
10	07-16-91	20	0.10	0.37	2.07	1.70
		20	0.13	0.34	1.53	1.19
11	10-20-91	20	0.11	0.80	1.68	0.88
12	04-18-92	20	0.17	0.41	2.44	2.03
13	10-21-91	20	0.09	0.58	1.44	0.86
14	07-19-91	16	0.08	0.16	0.83	0.67
15	04-20-92	18	0.07	0.22	0.90	0.68
		18	0.05	0.21	0.92	0.71
16	10-24-91	19	0.10	0.30	1.18	0.83
17	---------- Not sampled due to ship repairs- ----------					
18	04-22-92	18	0.13	0.52	2.13	1.61
19	10-26-91	23	0.19	0.48	2.17	1.69
		23	0.19	0.98	1.74	0.76
20	07-22-91	12	0.04	0.09	0.69	0.60
		12	0.06	0.08	0.70	0.62
21	04-24-92	19	0.03	0.12	0.60	0.48
		19	0.04	0.08	0.49	0.41
22	07-23-91	20	0.07	0.11	0.56	0.45
		20	0.07	0.08	0.43	0.35
24	10-29-91	18	0.07	0.13	0.64	0.51
25	04-25-92	19	0.14	0.26	1.77	1.51
26	11-01-91	13	0.15	0.14	1.64	1.50

[1]Pigs Eye Slough is downstream from the discharge from the Minneapolis-St. Paul Wastewater Treatment Plant near Upper Mississippi River Mile 835.1.

[2]Upper Lake Pepin (Upper Mississippi River Mile 773.0–778.0).

[3]Lower Lake Pepin (Upper Mississippi River Mile 768.0–773.0).

SUMMARY

A representative, composite, surficial bed-sediment sample was collected from the downstream one-third of 25 navigation pools by compositing 12 to 23 individual samples from 1 to 5 transects across the pools. These individual samples were collected away from the main navigation channel in backwater regions where the water depths ranged from about 0.3 m to about 3.0 m and where the water velocities were about 50 percent of the velocity in the main navigation channel. Estimates of flushing rates varied from 0.3 h/km to about 14 h/km. The median particle diameter of the surficial bed sediments ranged from 0.002 mm in Lower Lake Pepin or Pool 4, to 0.33 mm in Pool 20. The organic carbon associated with the surficial bed sediments ranged from less than 0.1 percent in Pool 1 to an average of 3.5 percent in Lower Lake Pepin or Pool 4.

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CHAPTER 2 - Sterols, Polynuclear Aromatic Hydrocarbons, and Linear Alkylbenzene Sulfonates

By Larry B. Barber, II, Jeffrey H. Writer, Charles F. Tabor, and Jerry A. Leenheer

ABSTRACT

Fecal sterols, polynuclear aromatic hydrocarbons (PAH), and linear alkylbenzene sulfonates (LAS) were measured in bed sediments collected from 25 of the navigation pools of the Upper Mississippi River during three cruises between July 1991 and April 1992. Coprostanol is a nonionic biorefractory molecule that accumulates in bed sediments and provides an indication of long-term sewage contamination. Coprostanol concentrations in the bed sediments from the pools ranged from 0.10 to 1.37 mg/kg. A maximum concentration of 7.53 mg/kg was detected in a grab sample collected from Pigs Eye Slough, just downstream from the outfall from the Minneapolis-St. Paul Sewage treatment plant. Concentrations above 0.1 mg/kg are indicative of sewage contamination. The highest coprostanol concentrations were found in Pool 2, which receives the sewage effluent from Minneapolis-St. Paul, Minn., and Pool 4, which includes Lake Pepin and acts as a trap for sediment-bound contaminants from Minneapolis-St. Paul. PAH are widespread environmental contaminants that come from a variety of sources and also accumulate in bed sediments. Seven PAH were detected in the pool bed sediments, and the total PAH concentrations ranged from 0.0 to16.87 mg/kg. As was the case for coprostanol, the maximum PAH concentration (21.26 mg/kg) was detected in the sample from Pigs Eye Slough. LAS are widely used anionic surfactants that are water soluble, undergo rapid biodegradation, and are not strongly sorbed to bed sediments. However, LAS were detected in all of the pool bed-sediment samples at concentrations ranging from 0.01 to 0.95 mg/kg. A maximum concentration of 20.19 mg/kg was detected in the Pigs Eye Slough sample.

INTRODUCTION

For many years sewage was discharged into the Mississippi River with little or no treatment. Following the Clean Water Act of 1970, most municipalities along the Mississippi River built secondary sewage-treatment plants that use a combination of physical and biological processes to remove organic and inorganic contaminants from wastewater before discharge into the river. However, because of the large variety of compounds introduced into sewage-treatment plants (including heavy metals, pesticides, petroleum hydrocarbons, bacteria, and viruses), it is necessary to monitor the effects of sewage-effluent disposal on the river. In addition to municipal point sources, the Mississippi River is also affected by nonpoint sources of contamination. For example, runoff from livestock feedlots generally is untreated and can contribute to the degradation of water quality by introducing bacteria and placing oxygen demands on the river.

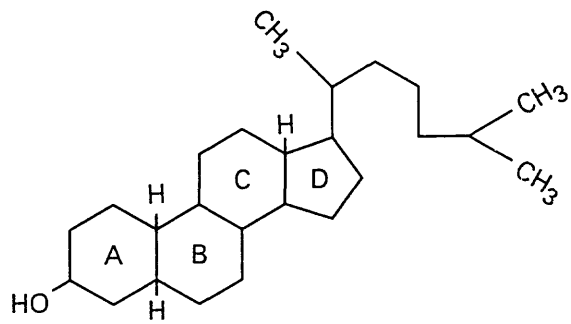

Figure 2.1--Chemical structure of the coprostanol molecule. A, B, C, and D are ring labels for the molecule; OH is the hydroxyl group; H is the point of reductive hydrogenation of the molecule; CH_3 are methyl groups.

The Upper Mississippi River between Minneapolis, Minn., and St. Louis, Mo., contains a series of 29 pools formed by navigation locks and dams (fig. 1.1). Most of the pools are active sediment traps, with accumulation rates of from 1 to 4 cm/yr (McHenry and others, 1984), and are a sink for sediment-bound organic contaminants.

Routinely monitored compounds such as nutrients, oxygen demand, and fecal coliform bacteria are fairly transient in the river environment. In contrast, nonionic-organic contaminants such as coprostanol (fig. 2.1), a sterol found in the feces of humans, livestock, and birds (Walker and others, 1982; Subbiah and others, 1972), are associated primarily with particulate matter and accumulate in the bed sediments (Brown and Wade, 1984; Hatcher and McGillvary, 1979). Because coprostanol is biodegraded slowly, it can be used as a molecular indicator of long-term sewage effects on the environment (Brown and Wade, 1984; Hatcher and McGillvary, 1979; Venkattsen and Kaplan, 1990). Tabak and others (1977) conducted a limited analysis of coprostanol in the Mississippi River around the Burlington, Iowa, wastewater-treatment plant and found that the sediments in that reach of the river had been contaminated by fecal sterols.

Polynuclear aromatic hydrocarbons (PAH) are an important class of organic contaminants that include many individual compounds (fig. 2.2). PAH come primarily from the combustion of plant material and fossil fuels such as coal and petroleum. Because of their many natural and anthropogenic sources and their widespread occurrence (Hoffman and others, 1984; Boehm and Farrington, 1984; Barrick and others, 1984), PAH are general indicators of sediment contamination. These compounds have a wide range of molecular structures and consequently have a wide range of environmental behaviors such as sorption, volatilization, and biodegradation.

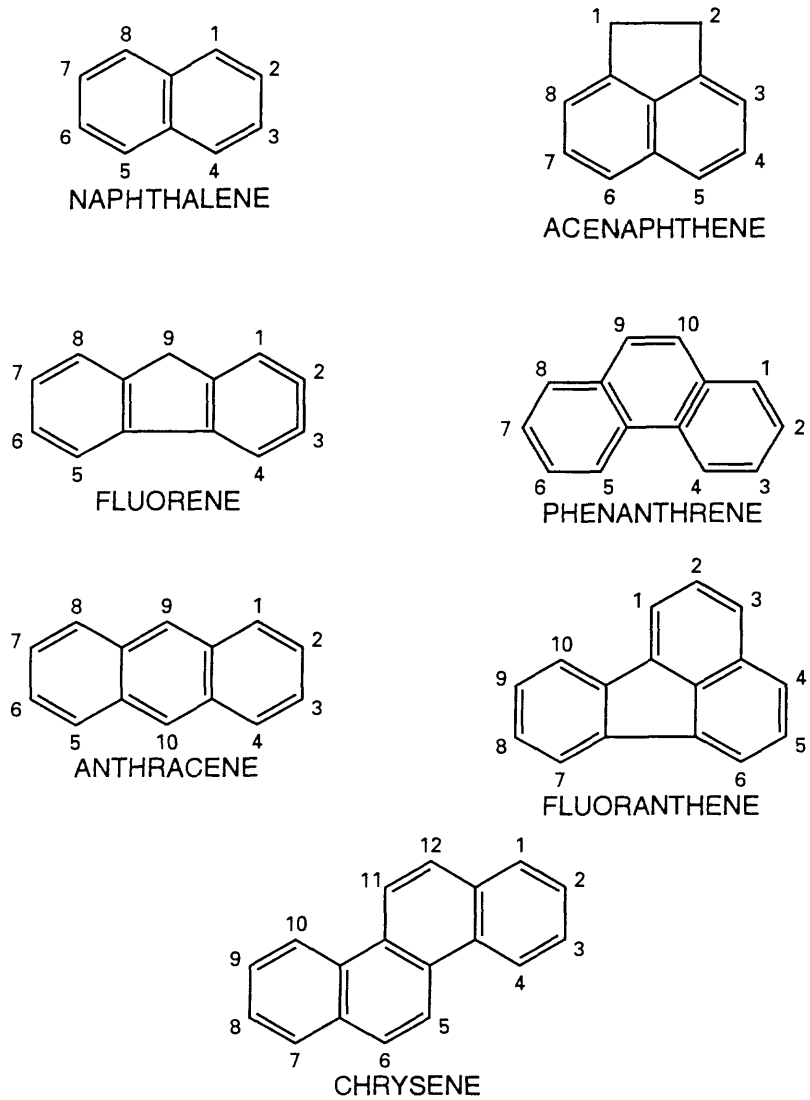

Figure 2.2--Chemical structure of some polynuclear aromatic hydrocarbons.

Linear alkylbenzene sulfonates are the most abundant anionic surfactants used in the United States for detergent formulations, and their annual consumption is about 4×10^5 metric tons (Modler and others, 1993). Most of the LAS is consumed in domestic and commercial applications and disposed of in wastewater. LAS formulations are a mixture of homologues and isomers (fig. 2.3). The alkyl-chain length varies from C_{10} to C_{14}, and the point of attachment for the alkyl chain varies from the 2-phenyl position to the 7-phenyl position. LAS is readily biodegraded under aerobic conditions, and sewage treatment is effective in removing more than 90 percent of LAS (Rapaport and Eckhoff, 1990). However, LAS slowly biodegrades under anaerobic conditions. Because of their high water solubility and anionic character, LAS are not as strongly sorbed to sediments as sterols and PAH.

The sorption of organic contaminants to sediments depends primarily on the water solubility of the compounds and the characteristics of the sediment (Chiou and others, 1983; Karickhoff, 1984; Leenheer, 1991). As the water solubility of a compound decreases, its sorption to sediments typically increases. The most important sediment variables for sorption of organic contaminants are sediment-organic matter concentrations and clay content. Smaller particles have a higher percentage of organic coatings because of the large surface area to volume ratio, and an inverse relation between particle size and percentage of organic carbon commonly exits in river bed sediments.

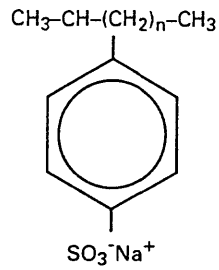

Figure 2.3--Chemical structure of linear alkylbenzene sulfonate. This example shows a 2-phenyl isomer where n ranges from 7 to 11.

PURPOSE AND SCOPE

This study was conducted as part of a comprehensive assessment of Mississippi River water and sediment quality. The particular focus of the study was to evaluate the effects of sewage-effluent disposal on the river water and bed sediments. Sediment samples were collected in the downstream one-third of each navigation pool of the Upper Mississippi River during three separate cruises between July 1991 and April 1992 (see Chapter 1). The concentrations of fecal sterols, PAH, and LAS in the Upper Mississippi River bed sediments were determined and are listed in this chapter. Graphs are presented that show the longitudinal distributions of the concentrations of these sewage-derived compounds.

METHODS

Sample Collection and Preservation

Composite samples of surficial bed sediments (approximately 800 g from the top 2 to 10 cm) were collected from 25 of the sampled navigation pools in the Upper Mississippi River (table 2.1; fig. 1.1; see Chapter 1 for more details). In addition to the composite samples, several pipe dredge samples were collected from some tributaries and selected sites along the Lower Mississippi River (table 2.2). To minimize biodegradation of organic compounds, the sediment samples were preserved by the addition of 10 mL chloroform and stored at 4°C until analysis.

Sterol Analysis

Sterols on the Mississippi River bed sediments were determined by saponification and extraction of the sediment, fractionation of the extract on a mixed bed of silica over alumina using a sequential elution process, and identification and quantification of the compounds by gas - chromatography-mass spectrometry (GC-MS). The GC-MS analysis was conducted on both the free sterol and its trimethylsilyl ether derivative. This method is a modification of the procedure developed by Brown and Wade (1984).

Extraction

The composite samples from each pool were mixed on a rotary mixer for 2 hours, and then a 50-g subsample of sediment was collected with a Teflon syringe and placed in a glass boiling flask. Another subsample was collected with the same syringe and air-dried to determine the dry weight for each sample. Exactly 50 µg of deuterated cholesterol (D_7-cholesterol) in acetone was added to the sediment sample as a surrogate standard and was allowed to equilibrate by rotating for 10 minutes and letting stand for 48 hours. The 50-g wet sediment sample was saponified by refluxing at 80°C for 2.5 hours with 100 mL of a 0.5 N solution of potassium hydroxide in methanol and 10 mL of benzene. The saponified sample then was filtered through a fritted glass funnel and collected in a separatory funnel. The reflux flask and funnel were rinsed two times with 50 mL of methylene chloride and the rinse added to the original solution. Water was removed from the extract by adding 100 mL of a 10-percent aqueous sodium chloride solution adjusted to pH 0.5 with hydrochloric acid. The upper water phase was acidified to pH 2 by adding concentrated hydrochloric acid to neutralize the potassium hydroxide. This ensured that all of the water and methanol were removed from the organic phase. The methylene chloride was drained into a collection vial, and the aqueous phase was extracted twice more with 50-mL aliquots of methylene chloride. The methylene chloride extracts were combined and dried over anhydrous sodium sulfate and then evaporated to dryness on a vacuum roto-evaporate.

Table 2.1--Particle-size and organic-carbon data for composite surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991–April 1992

[mm, millimeter; %, percent; --, no measurement; <, less than. See tables 1.8 and 1.9 for more details]

Pool	Date	Number of samples in composite	Median particle size (mm)	Sediment organic carbon (%)
1	07-04-91	12	0.27	<0.1
[1]2	10-08-91	1	--	1.1
2	07-07-91	18	0.043	1.2
	10-09-91	18	0.026	1.4
	04-09-92	18	0.023	1.6
3	10-11-91	16	0.021	1.9
[2]4	10-14-91	15	0.003	3.0
[3]4	10-12-91	21	0.002	[4]3.5
5	07-11-91	18	0.22	1.0
5A	07-11-91	14	0.043	1.7
6	04-13-92	20	0.30	[4]0.4
7	07-13-91	20	0.074	[4]0.7
8	07-14-91	20	0.062	0.8
	10-17-91	15	0.031	--
	04-16-92	20	0.11	0.7
9	10-19-91	18	0.024	1.0
10	07-16-91	20	0.099	1.7
11	10-20-91	20	0.029	0.9
12	04-18-92	20	0.015	2.0
13	10-21-91	20	0.029	[4]1.0
14	07-19-91	16	0.15	0.7
15	04-20-92	18	0.30	[4]0.7
16	10-24-91	19	0.063	0.9
18	04-22-92	18	0.029	1.6
19	10-26-91	23	0.012	[4]1.2
20	07-22-91	12	0.330	[4]0.6
21	04-24-92	19	0.270	[4]0.4
22	07-23-91	21	0.230	[4]0.4
24	10-24-91	18	0.290	0.5
25	04-25-92	19	0.030	1.5
26	11-01-91	13	0.010	1.5

[1]
[2]Pigs Eye Slough is downstream from the discharge from the Twin Cities Wastewater Treatment Plant near Upper Mississippi River Mile 835.1.
[3]Upper Lake Pepin that is part of Pool 4.
[4]Lower Lake Pepin that is part of Pool 4 average of two replicates.
Average of two replicates.

Table 2.2--Organic-carbon data for samples of surficial bed sediments collected from the Upper and Lower Mississippi River and some of its tributaries, October 1991–April 1992

[%, percent]

Sampling site	River mile	Date	Number of samples in composite	Sediment organic carbon (%)
Upper Mississippi River				
Illinois River near Hardin, Illinois	21.8	10-31-91	1	1.6
Missouri River near St. Charles, Missouri	28.4	04-29-92	1	0.6
Mississippi River at St. Louis, Missouri	[1]179.3	10-11-91	1	1.9
Mississippi River at Thebes, Illinois	[1]43.9	11-05-91	1	1.5
Lower Mississippi River				
Mississippi River near St. Francisville, Louisiana	[2]266.4	11-11-91	1	1.3
Mississippi River below Belle Chasse, Louisiana	[2]73.1	11-13-91	1	0.8

[1]
[2]Distance upstream from the mouth of the Ohio River.
Distance upstream from Head of Passes, Louisiana.

Sample Fractionation

The sediment-extract residue was redissolved in 10 mL of hexane, and copper powder was added to remove sulfur. After filtration through glass wool, the extract was evaporated to 2.0 mL under a stream of nitrogen gas. A Waters Millilab 1A Workstation was used to fractionate the sediment extract by using a Sep-Pak column containing 0.35 g neutral silica over 0.75 g neutral alumina. The silica and alumina column was used to remove fatty acids that could interfere with the analysis of coprostanol by GC-MS. The column was prepared by sequentially rinsing with separate 5-mL aliquots of methanol, methylene chloride, benzene, and hexane. The sample extract was quantitatively applied to the column followed by sequential elution with 5 mL each of hexane, benzene, and methanol. The hexane extract contained the aliphatic hydrocarbon fraction, the benzene extract contained the aromatic hydrocarbon and fatty acid fractions, and the methanol extract contained the sterol fraction. Each solvent was collected, roto-evaporated to dryness, and redissolved in 0.5 mL of hexane for analysis by GC-MS.

Gas Chromatography-Mass Spectrometry Analysis

GC-MS analysis was performed on a Hewlett-Packard 5890 gas chromatograph with a Hewlett-Packard Ultra II column (25 m x 0.2-mm inside diameter and 20-µm film thickness), a splitless injection port, ultra-high purity helium as the carrier gas (27 cm/s linear flow velocity), and a mass spectrometer interface temperature of 280°C. A Hewlett-Packard 5970 mass selective detector (MSD) was used with a source temperature of 250°C, a source pressure of 1.5×10^{-5} torr, and an ionization energy of 70 eV. Additional GC-MS operating conditions are listed in table 2.3. The sample extracts were analyzed in full-scan mode [mass-to-charge ratio (m/z) range from 45 to 550 atomic mass units/electron unit (amu/eu)] at a rate of one scan per second, and in selected-ion monitoring (SIM) mode with a dwell time of 50 milliseconds. Identification of target compounds was achieved by comparison of full-scan mass spectra and retention times with authentic standards. The SIM data provide a sensitive and selective identification of target compounds by monitoring only for the molecular ion and base peaks.

Table 2.3--Gas chromatograph operating conditions for sterol, polynuclear aromatic hydrocarbon, and linear alkylbenzene sulfonate analysis

[°C, degree Celsius; min, minute]

Condition	Sterol	Polynuclear aromatic hydrocarbon	Linear alkylbenzene sulfonate
Injection port temperature (°C)	290	290	280
Initial temperature (°C)	60	60	110
Initial time (min)	2	2	1
Ramp rate (°C/min)	10	10	8
Final temperature (°C)	300	300	300
Final time (min)	20	20	5

Sterols were determined by analyzing the methanol extract. Coprostanol is a slightly polar organic molecule with a boiling point of about 360°C (Budavari, 1989). Several parameters were critical for optimum performance on the GC-MS: (1) complete sample volatilization required a high injection port temperature, (2) elevated column temperature was required to ensure sterol elution, and (3) deactivated injection port liners and lack of active sites on the column were necessary. Due to the high boiling point of coprostanol, rapid auto-sampler injection reduced the sensitivity because of incomplete volatilization, thus making quantification below 0.5 mg/kg difficult. However, when hot-needle or cold on-column injection was used, the detection limit decreased to about 0.01 mg/kg. Chromatographic resolution and peak shape were diminished using cold on-column injection. The elution of coprostanol required high temperatures (300°C for 20 minutes), which can lead to column degradation. As column degradation proceeds, active sites on the column interfere with free sterol analysis. Repeated cold-on column injection of sediment extracts also degrades the column and reduces sensitivity.

To circumvent the problem of sensitivity to active sites in the injection port liner and column, the free sterols were derivatized to their trimethylsilyl (TMS) ethers (fig. 2.4). The extract was derivatized with N-trimethylsilylimidazole in pyridine (Tri-Sil 'Z', Pierce) at 80°C for 1 hour, blowing off the excess reagent under nitrogen gas, and redissolving the residue in 1 mL of hexane. The TMS ether is less polar and therefore not as susceptible to active sites. A free sterol concentration of 100 ng/μL could not be detected on a degraded column, whereas 10 ng/μL of the TMS ether of the sterol could be detected. Comparison of coprostanol concentrations analyzed as the free sterol and TMS ether under optimal conditions (that is, new column and injection port liner) indicated that the two methods do not provide statistically different means (t-test, $p = 0.975$, $n = 8$). However, due to better chromatographic quality of the TMS ethers and less susceptibility to active sites in the injection port liner and column, derivatization of the sterols is preferred.

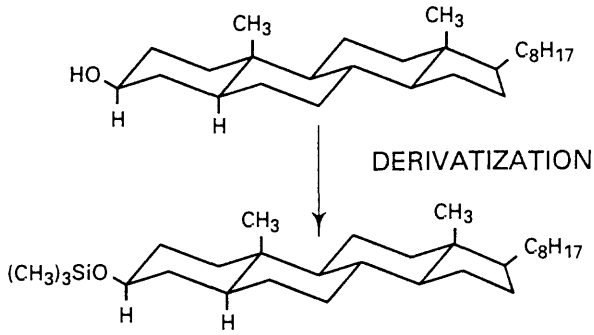

Figure 2.4--Formation of trimethylsilyl ether of coprostanol.

Four different methods were used to measure sterols by GC-MS: (1) free sterol analysis by hot needle, splitless injection and full-mass scan, (2) derivatized sterol analysis by hot needle, splitless injection and full-mass scan, (3) derivatized sterol analysis by hot needle, splitless injection and SIM, and (4) free sterol analysis by cold on-column injection of SIM. Three target sterols (cholesterol, coprostanol, and cholestanol) were identified by comparison of retention times and mass spectra with authentic standards in both the free and derivatized forms. Table 2.4 lists the molecular ions $[M]^+$ for the free sterols analyzed in the SIM mode. The TMS derivative has a $[M]^+$ that is 73 amu greater than the free sterol; however, the TMS functional group is unstable under electron-impact ionization and gives a diagnostic ion that is $[M^+-18]$ for the free sterol, indicating loss of the TMS moiety plus a water molecule.

Table 2.4--Summary of molecular ion $[M^+]$ mass-to-charge ratio for free and derivatized sterols determined by selected ion-monitoring analysis

Compound	Molecular ion mass-to-charge ratio	
	Free sterol	Derivatized sterol
D_7-Cholesterol	393	375
Cholesterol	386	368
Coprostanol	388	370
Cholestanol	388	355

Quantification of the sterols was based on the area of the extracted molecular ion profile of the surrogate standard, D_7-cholesterol. Response factors (RF) for coprostanol and other sterols were determined for standard solutions relative to D_7-cholesterol using equation 2.1:

$$RF = \frac{\text{Peak Area}_{target}}{\text{Peak Area}_{SS}} \times \frac{\text{Conc}_{SS}}{\text{Conc}_{target}} \quad (2.1)$$

where, Conc is the concentration in µg/g, Peak Area is the integrated area of the chromatographic peak, target is the target compound (coprostanol), and SS is the surrogate standard (D_7-cholesterol). Concentration of the target compound was determined by knowing the mass of the D_7-cholesterol surrogate standard and comparing peak area ratios:

$$\text{Conc}_{target}(\mu g/g) = \frac{\text{Peak Area}_{target}}{\text{Peak Area}_{SS} * RF} \times \frac{\text{Mass}_{SS}}{\text{Dry weight of sample}} \quad (2.2)$$

The dry weight was determined for a separate subsample for each pool. Triplicate analysis for the subsampling and air drying procedure had a relative standard deviation (RSD) of 1.4 percent.

Polynuclear Aromatic Hydrocarbon Analysis

Polynuclear aromatic hydrocarbons were determined by GC-MS analysis of the hexane and benzene elutants obtained from the sterol sediment extraction and fractionation process. Most of the PAH eluted in the hexane fraction, indicating the presence of trace amounts of benzene or methylene chloride in the hexane extract used to load the sample onto the adsorption column. It also is possible that the carryover is affected by deactivation of sorption sites during the cartridge preparation. Full-scan mass spectra were collected under the GC-MS conditions listed in table 2.3. SIM analysis was performed acquiring data for the molecular ions for the compounds listed in table 2.5.

Polynuclear aromatic hydrocarbons were identified by matching the mass spectrum (or molecular ion data from SIM analysis) and retention time of the compound in the sample with an authentic standard analyzed under identical conditions. Concentrations were determined by an external standard method using a single-point calibration based on a 20-µg/mL standard mix containing 16 PAH (Supelco). Concentrations were calculated using extracted ion current data for the PAH molecular ions and assuming a RF of 1 and no correction for recovery efficiency.

Table 2.5--Summary of molecular ion [M^+] mass-to-charge ratio for target polynuclear aromatic hydrocarbon compounds determined by selected ion-monitoring analysis

[Compounds listed in elution order; amu, atomic mass unit; and eu, electron unit]

Compound	Molecular ion mass-to-charge ratio (amu/eu)
Naphthalene	128
Acenaphthalene	152
Acenaphthene	153
Fluorene	166
Phenanthrene	178
Anthracene	178
Fluoranthene	202
Pyrene	202
Benzo[a]anthracene	228
Chrysene	228
Benzo[b]fluoranthene	252
Benzo[k]fluoranthene	252
Benzo[a]pyrene	252
Benzo[ghi]perylene	276
Indeno[123-cd]pyrene	276
Dibenzo[a,h]anthracene	278

Linear Alkylbenzene Sulfonate Analysis

Reagents and Standards

Chloroform was obtained from J.T. Baker. Phosphorus pentachloride and 2,2,2-trifluoroethanol were obtained from Aldrich (Milwaukee, Wis.) . Several quality-assurance and quantitation standards were used for LAS analysis. A mixture containing C_{10} to C_{14} (LAS standard #1288) was obtained from the U.S. Environmental Protection Agency. C_8-LAS (97-percent purity) and 2,2,2-trifluoroethyltoluene-sulfonic acid (C_2-LAS trifluoroethyl ester, 99-percent purity) were obtained from Aldrich . The C_9-LAS (98-percent purity) was provided by the Procter and Gamble Company. All chemicals were used as received.

The surrogate standard for LAS analysis (C_9-LAS) was added to the sediment sample prior to extraction to evaluate whole method recovery. The derivatization standard (C_8-LAS) was added to the extract just prior to derivatization, and the internal standard (C_2-LAS) was added to the final solvent extract prior to GC-MS analysis. The C_2-LAS standard was obtained as the trifluoroethyl ester and did not require derivatization. All of the standards were added to the samples at an equal mass. Quantitation of LAS was based on C_9-LAS using equations 2.1 and 2.2.

Extraction

LAS were extracted from duplicate samples of the surficial bed sediments from each pool by placing 15 to 30 g of wet sample in a centrifuge tube containing 10 mL of methanol and extracting on a rotary mixer for 12 hours at room temperature (~25°C). Each sample was centrifuged at 5,000 rpm for 20 minutes, and the supernatant liquid was transferred to a holding vial. This extraction process was performed on each sample three times. The combined extracts were evaporated to a volume of 2 mL, quantitatively transferred to a 5-mL reaction vial, and evaporated to dryness under nitrogen gas.

Derivatization

The methanol extracts were derivatized with phosphorus pentachloride and 2,2,2-trifluoroethanol to form the trifluoroethyl esters of LAS (Trehy and others, 1990). In the first step of this derivatization, the sulfonyl chlorides were formed by adding 250 mg of phosphorus pentachloride and heating for 10 minutes at 100°C. The sample was cooled and extracted with pentane. The pentane phase was transferred to a separate vial and evaporated to dryness under nitrogen gas. The pentane residue was dosed with 0.2 mL of 2,2,2-trifluoroethanol and heated for 20 minutes at 70°C. The reaction mixture was cooled and then extracted by adding 2 mL of pentane and 1.5 mL of distilled water. The pentane layer was transferred to a graduated tube, evaporated to dryness under a stream of nitrogen gas, then redissolved in 100 µL of isooctane.

Gas Chromatography-Mass Spectrometry Analysis

Analysis of the derivatized extracts was done by GC-MS in the full-scan and SIM modes. Table 2.3 lists the GC-MS conditions used in the analysis. The chromatographic conditions were optimized to provide rapid analysis while still maintaining sufficient separation of the isomers and homologues to evaluate individual components in the complex mixture. More complete chromatographic separation can be accomplished, although baseline resolution of all isomers is difficult to accomplish even with long analysis times. Table 2.6 lists the ions monitored in the SIM mode for LAS. To enhance sensitivity of the analysis, the $[M^+-99]$ ion representing loss of the trifluoroethyl ester moiety also was monitored. However, there was loss of specificity with respect to the $[M^+]$.

LAS identification was based on matching the mass spectra (or molecular ion data from SIM analysis) and retention times of the trifluoroethyl derivatives with those of the C_{10} to C_{14} LAS standard. Quantitation was based on the molecular ions of the C_{10} to C_{14} homologues and on the 253 and 267 base peak ions. The 253 ion is a stable fragment occurring when only the benzyl carbon of the alkyl chain remains attached to the benzene ring and is characteristic mainly of the 3- through 7-phenyl isomers of all homologues. The 267 ion results mainly from the 2-phenyl isomer when both the benzyl carbon and adjacent terminal methyl group remain attached to the benzene ring. The 267 ion was less useful for identification due to interferences from polysiloxanes.

LAS concentrations were calculated using a 20-µg C_9-LAS surrogate standard added to each sample prior to processing through the extraction-derivatization procedure. Each set of 12 to 18 sediment samples contained two C_{10} to C_{14}-LAS standards. The RF was determined relating the total peak area of the molecular ions of the C_{10} to C_{14}-LAS standard to the area of the molecular ion of the C_9 LAS standard (eq. 2.1), and total LAS concentrations in the surficial sediment samples were calculated from equation 2.2.

Table 2.6--Summary of molecular ion mass-to-charge [M^+] and molecular ion minus the trifluoroethyl ester moiety [M^+-99] mass-to-charge ratios for trifluoroethyl derivatives of linear alkylbenzene sulfonate

[Base peaks for 2-phenyl isomers is at a charge-to-mass ratio of 267; for isomers greater than 2-phenyl, it is at a mass-to-charge ratio of 253]

Alkyl chain length	Linear alkylbenzene sulfonate mass-to-charge ratio	
	[M^+]	[M^+-99]
2	[1]254	[1]155
8	[2]352	[2]253
9	[3]366	[3]267
10	380	281
11	394	295
12	408	309
13	422	323
1 14	436	337

[1]C_2-LAS standard.
[2]C_8-LAS standard.
[3]C_9-LAS standard.

RESULTS

Sediment Particle Size and Organic-Carbon Concentration

Results for sediment particle size and sediment organic-carbon measurements have been combined from Chapter 1 and are listed in tables 2.1 and 2.2. The median particle size of the sediments from the various pools ranged from 0.002 mm to 0.33 mm. The average sediment organic-carbon content ranged from <0.1 percent to 3.5 percent.

Sterols

Evaluation of the Analytical Procedure

The use of chloroform as a preservative raised concern about the sterols partitioning into the solvent and possible nonrepresentative subsampling resulting from phase separation of the chloroform. To evaluate the effectiveness of the subsampling procedure, an infrared spectrometry method was developed to quantitatively evaluate the distribution of chloroform in each subsample. Sediment samples were chosen from Pool 1 and Pool 2. Pool 1 is relatively sandy with a median particle diameter of 0.27 mm; Pool 2 consists of finer, silty sediments with a median particle diameter of 0.023 to 0.043 mm.

After thoroughly mixing the composite samples for 1 hour, 50 g of wet sediment from each pool was subsampled (as previously described) in triplicate. Each sample was sonic extracted with 100 mL of a 1:1 mixture of benzene and methanol and filtered through a glass-fiber filter. The filtrate was analyzed by infrared spectrometry against a reference cell containing a 1:1 mixture of benzene and methanol. The critical peak indicating chloroform occurs at 1,218 cm^{-1}. The subsampling variation in chloroform content for Pool 1 had an RSD of 7.4 percent, and Pool 2 had an RSD of 2.4 percent. These results indicate the subsampling procedure is effective in dispersing chloroform throughout the sample, and sterol partitioning into the chloroform should not disproportionately affect measured concentrations.

To evaluate the effectiveness of the silica/alumina column in fractionating the various organic compounds targeted in the sequential elution procedure, a mixture of n-octadecane, anthracene, myristic acid, coprostanol, D_7-cholesterol, and cholesterol was applied to the column. The components of the mixture were chosen to represent aliphatic hydrocarbons, aromatic hydrocarbons, fatty acids, and sterols that are common in bed sediments. The mixture was prepared at concentrations of 0.2 ng/μL, 20 ng/μL, and 100 ng/μL and was applied to the columns, sequentially eluted with hexane, benzene, and methanol, and each fraction was analyzed by GC-MS. An additional 10-mL methanol elution also was analyzed to determine if the first methanol elution was adequate for complete sterol removal.

Sterols were not observed in the hexane or benzene fractions for any of the three concentrations applied to the columns. Likewise, no sterols were observed in the second methanol elution. However, comparison of measured sterol concentrations between the mixture before and after column application indicated about 10 percent of the sterols were irreversibly bound to the column. The unrecovered sterols were sorbed onto the column in equal proportions and thus should not present problems for sediment extracts when using the surrogate standard quantitation scheme. Although this loss of mass limits the amount of sterol that can be detected, concentrations in the bed sediments were sufficiently large that the detection limit was not a problem in this study.

A critical aspect of the analytical method is addition of the D_7-cholesterol standard at the beginning of the analytical procedure. The cleanup process required to extract sterols from the sediment for quantification by GC-MS creates numerous opportunities for loss of mass. However, because the molecular structure and properties of the D_7-cholesterol are similar to the sterols in the natural environment, quantification using the D_7-cholesterol eliminates having to perform detailed recovery studies. The following conditions are necessary for quantification of sterols relative to the surrogate standard: (1) D_7-cholesterol is not present in the sediment sample, (2) D_7-cholesterol has surface-binding and solvation properties similar to those of coprostanol, (3) D_7-cholesterol has reached equilibrium with the water/sediment matrix after 48 hours, and (4) there is no loss or back-exchange of the D_7 label after saponification. To determine if the equilibration period used in this study was adequate, D_7-cholesterol was added to subsamples from Pool 14 and allowed to equilibrate for 1 hour and 48 hours. Results for the two equilibration times (table 2.7) differed by 19 percent, a value that is less than the total method analytical error of 23 percent (see Quantification of Analytical Error section). The ratio of coprostanol to cholesterol+cholestanol was the same for both equilibration times. The atom percent of the initial D_7 isotope label does not change upon saponification, indicating no loss or back-exchange is occurring during the extraction process.

Quantification of Analytical Error

Triplicate analyses were run on samples from Pools 1, 10, and 13 to quantify analytical error. Pool 1 sterols were analyzed in both the free and derivatized form, and Pool 10 and Pool 13 sterols were analyzed in the derivatized form (table 2.8). An average RSD of 23 percent for coprostanol was calculated on the basis of all analyses.

Table 2.7--Results of a deuterated cholesterol equilibration study for a subsample from Pool 14

[µg/g, microgram per gram]

Equilibration time (hour)	Coprostanol (µg/g)	Coprostanol / Cholesterol + cholestanol
1	0.30	0.14
48	0.37	0.14

Table 2.8--Analytical variance of coprostanol, cholesterol, and cholestanol for two gas chromatography and mass spectrometry analytical methods

[Free, method analyzes free sterols; Deriv., method analyzes sterols as the trimethylsilyl ether; µg/g, microgram per gram; %, percent]

Pool	Method	Standard deviation (µg/g)			Standard deviation (%)		
		Copro-stanol	Chole-sterol	Chole-stanol	Copro-stanol	Chole-sterol	Chole-stanol
1	Free	0.04	0.09	0.05	14	13	16
1	Deriv.	0.09	0.02	0.04	29	3	7
10	Deriv.	0.05	0.10	0.04	32	4	9
13	Deriv.	0.02	0.10	0.07	16	8	10
Mean					23	7	11

Concentrations

Coprostanol concentrations in the pool bed sediments ranged from 0.10 to 1.37 mg/kg (tables 2.9 and 2.10, fig. 2.5). The maximum concentration (7.53 mg/kg) was detected in Pigs Eye Slough, the sewage outfall for Minneapolis-St. Paul. Concentrations above 0.1 mg/kg in sediments indicate areas affected by fecal contamination, either from municipal or livestock sources (Hatcher and McGillvary, 1979; Brown and Wade, 1984). A positive correlation was observed by Writer and others (1995) between percentage of organic carbon and coprostanol concentrations (fig. 2.6). To eliminate this bias and provide a better value to compare coprostanol concentrations between different pools, a ratio between coprostanol (sewage sources) and cholesterol + cholestanol (sewage and nonsewage sources) was used (Writer, 1992). Most pools have a sterol ratio of less than 0.10 except for Pools 1, 2, 14, 20, and 21 (table 2.9, fig. 2.7). Pools 1 and 2 are near Minneapolis-St. Paul, Pool 14 is near Clinton, Iowa, and Pools 20 and 21 receive the discharge of the Des Moines River.

There is significant transport of sewage to the Mississippi River based on the fairly uniform coprostanol concentrations in excess of 0.1 mg/kg in many of the pools of the Upper Mississippi River. Pools that are settling basins, such as Pools 4 and 19, and contain predominantly fine-grained sediments have larger concentrations of coprostanol (Pool 4 had 0.60 and 0.68 mg/kg, and Pool 19 had 0.33 mg/kg). It has been reported that Lake Pepin (Pool 4) acts as a sink for PCB and trace metals (Bailey and Rada, 1984). However, the increased concentrations also are influenced by contaminant association with the relatively high organic-carbon content of the sediments from Pool 4 (table 2.1).

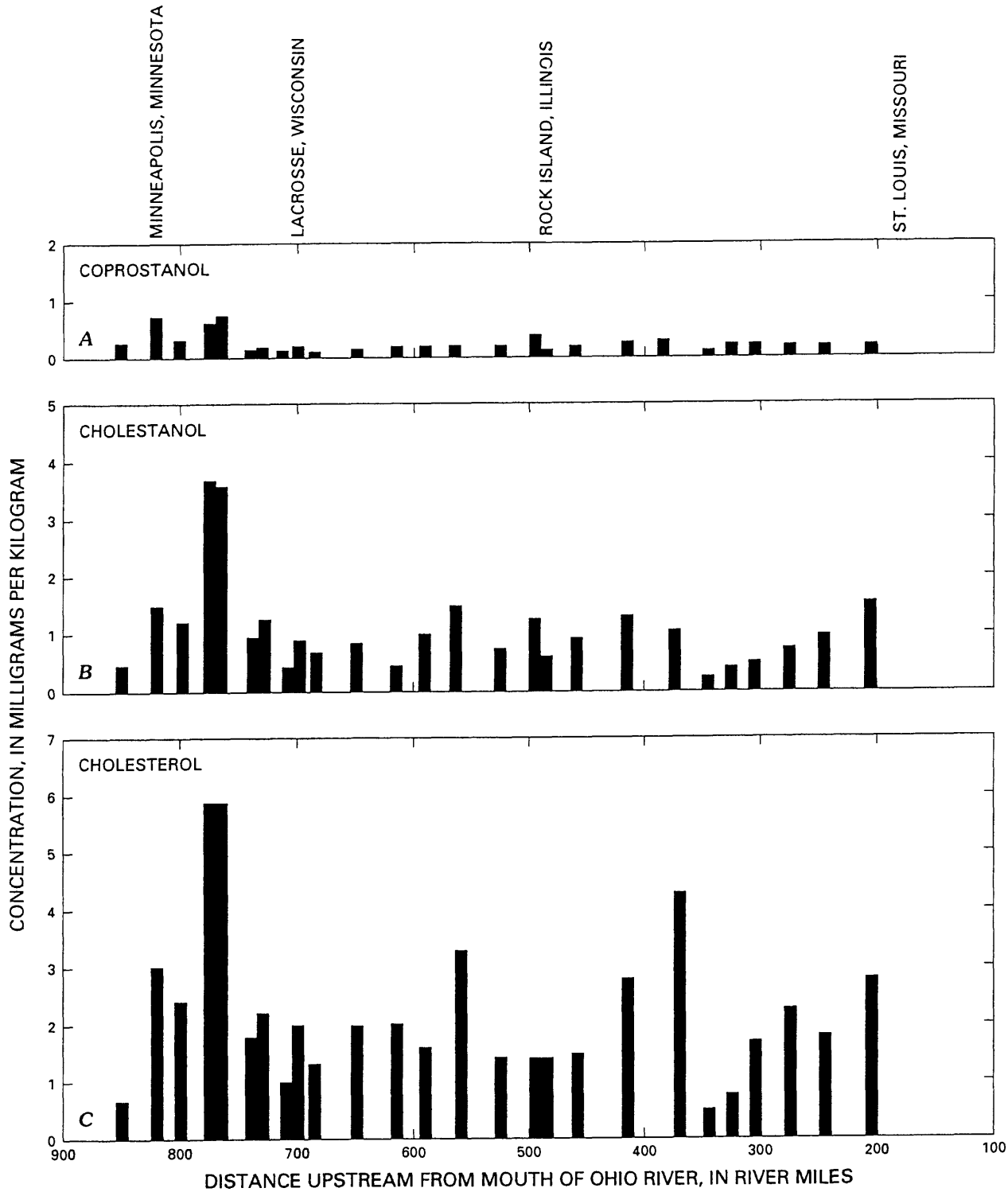

Figure 2.5--Sterol concentrations in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for location of pools.

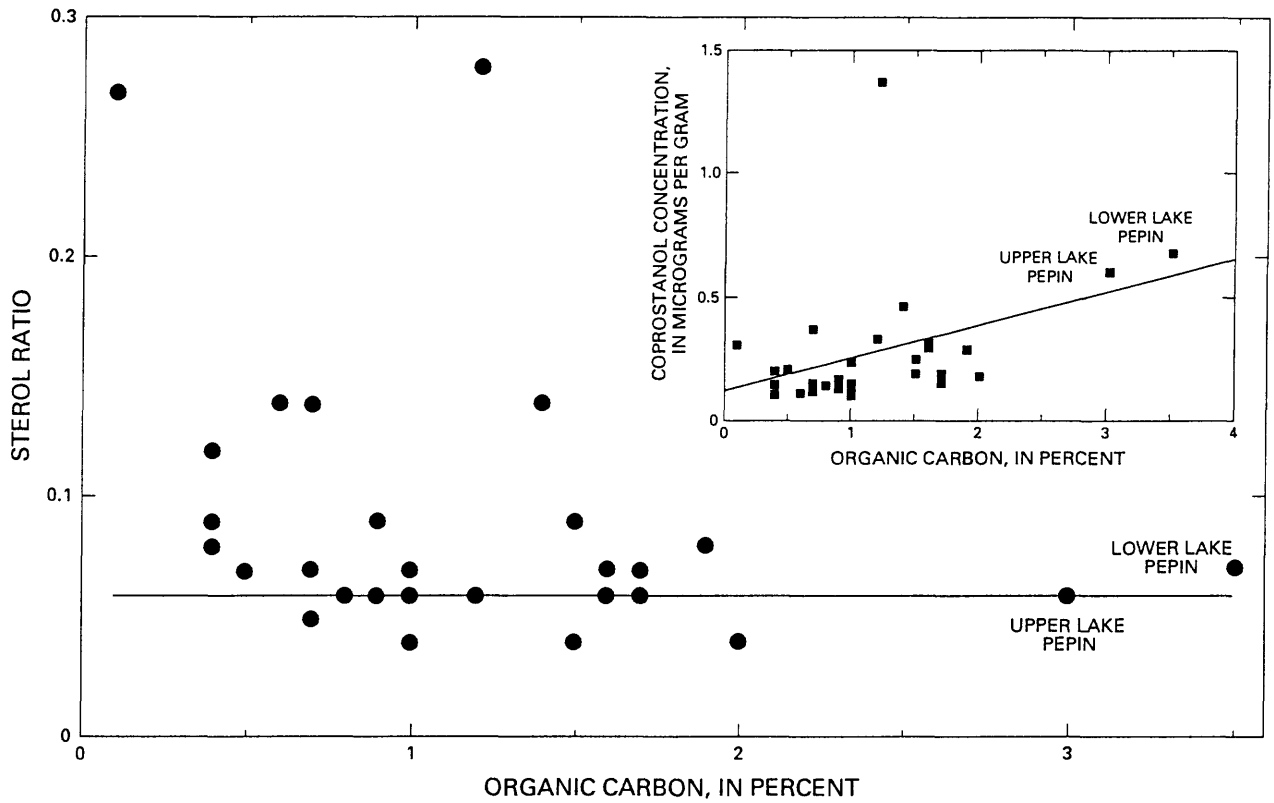

Figure 2.6--Percent organic carbon in relation to sterol ratio (coprostanol: cholesterol + cholestanol) in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River. Insert shows relation between percent organic carbon and coprostanol

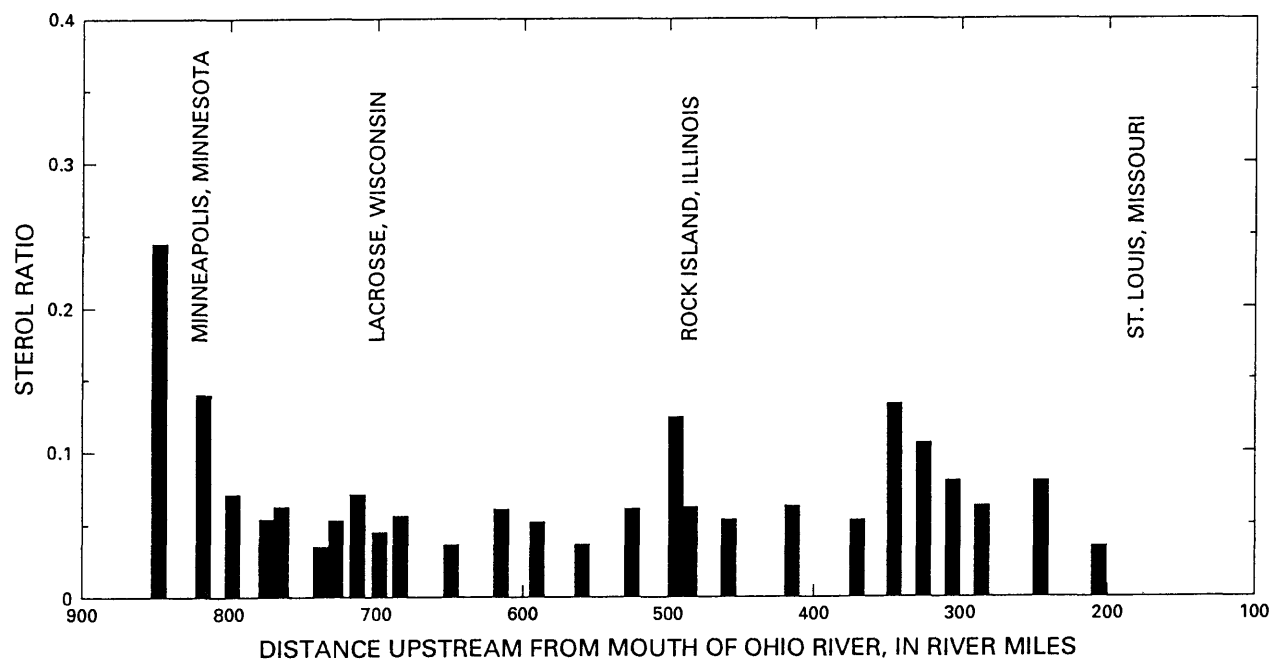

Figure 2.7--Sterol ratio (coprostanol:cholesterol+cholestanol) in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for pool locations.

Table 2.9--Sterol concentrations for composite surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[mg, milligram; kg, kilogram]

Pool	Coprostanol (mg/kg)	Cholesterol (mg/kg)	Cholestanol (mg/kg)	Sterol ratio[1]
1	0.31	0.66	0.46	0.28
[2]2	7.53	10.47	9.57	0.38
2	1.37	2.97	1.95	0.28
	0.46	2.04	1.17	0.14
	0.32	3.86	1.43	0.06
3	0.29	2.43	1.19	0.08
[3]4	0.60	5.93	3.70	0.06
[4]4	0.68	5.93	3.56	0.07
5	0.12	1.77	0.94	0.04
5A	0.19	2.21	1.15	0.06
6	0.11	1.04	0.38	0.08
7	0.15	1.98	0.90	0.05
8	0.14	1.50	0.77	0.06
	0.12	1.15	0.50	0.07
9	0.10	1.95	0.84	0.04
10	0.16	2.04	0.42	0.07
11	0.17	1.62	0.97	0.06
12	0.18	3.26	1.48	0.04
13	0.15	1.35	0.66	0.07
14	0.37	1.38	1.20	0.14
15	0.14	1.37	0.56	0.07
16	0.15	1.54	0.88	0.06
18	0.30	2.77	1.32	0.07
19	0.33	4.31	1.06	0.06
20	0.11	0.49	0.26	0.15
21	0.15	0.84	0.43	0.12
22	0.20	1.66	0.46	0.09
24	0.21	2.29	0.70	0.07
25	0.25	1.78	0.94	0.09
26	0.19	2.83	1.48	0.04

[1] Sterol ratio = concentration coprostanol/(concentration cholesterol + concentration cholestanol).

[2] Pigs Eye Slough is downstream from the discharge from the Twin Cities Wastewater Treatment Plant near Upper Mississippi River Mile 835.1.

[3] Upper Lake Pepin, which is in Pool 4.

[4] Lower Lake Pepin, which is in Pool 4.

Table 2.10--Sterol concentrations for samples of surficial bed sediments collected from the Upper and Lower Mississippi River and some of its tributaries, October 1991-April 1992

[mg, milligram; kg, kilogram; Deriv., trimethysilyl derivatized form; SIM, derivatized form and selected ion monitoring]

Sampling site	River mile	Sterol form	Coprostanol (mg/kg)	Cholesterol (mg/kg)	Cholestanol (mg/kg)	Sterol ratio[1]
Upper Mississippi River						
Missouri River near St. Charles, Missouri	[2]28.4	Deriv.	0.23	1.43	0.29	0.13
Mississippi River at St. Louis, Missouri	[3]179.3	SIM	0.26	3.29	1.34	0.06
Mississippi River at Thebes, Illinois	[3]43.9	SIM	0.78	2.78	2.09	0.16
Lower Mississippi River						
Mississippi River above Arkansas City, Arkansas	[4]566.0	Deriv.	0.24	3.00	0.67	0.06
Mississippi River near St. Francisville, Louisiana	[4]266.4	Deriv	0.13	1.06	0.39	0.09
Mississippi River below Belle Chasse, Louisiana	[3]73.1	Deriv.	0.39	1.32	0.78	0.19

1
2 Sterol ratio = concentration coprostanol/(concentration cholesterol + concentration cholestanol).
3Distance upstream from the confluence with the Mississippi River.
4Distance upstream from the mouth of the Ohio River.
Distance upstream from Head of Passes, Louisiana.

Polynuclear Aromatic Hydrocarbons

Evaluation of the Analytical Procedure

To evaluate the recovery of PAH using the sediment-extraction procedure, bed sediments were spiked with five deuterated PAH at concentrations of approximately 10 and 100 mg/kg for each PAH (table 2.11). Each sample was analyzed in duplicate. Recoveries ranged from 2 to 80 percent. The lowest recovery and poorest precision was for D_8-naphthalene, which is a volatile compound and is probably lost during the sample processing. D_{12}-chrysene, which is the most hydrophobic of the compounds tested, also had a low recovery, probably because of incomplete extraction of the sediments, sorption to the glassware used in the sample processing, or difficulty in eluting the silica-alumina during the cleanup step.

Table 2.11--Recovery of selected polynuclear aromatic hydrocarbons spiked into Pool 1 sediments at concentrations of 10 and 100 mg/kg and processed through the extraction, fractionation, and gas chromatography-mass spectrometry analytical procedure

[mg/kg, milligram per kilogram; %, percent]

Compound	Mean recovery (%)	Relative standard deviation (%)
D_8-Naphthalene	2	147
D_{10}-Phenanthrene	32	36
D_{10}-Fluoranthene	80	63
D_{12}-1,2-Benzanthracene	70	47
D_{12}-Chrysene	14	26

Concentrations

Seven PAH (fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, and chrysene) were detected in the surficial bed sediments of the Mississippi River (tables 2.12 and 2.13). Concentrations for individual compounds ranged from less than 0.1 mg/kg to 4.8 mg/kg, and concentrations of total PAH ranged from 0.0 to 16.87 mg/kg. The maximum concentrations (21.26 mg/kg total PAH) were detected in the sample from Pigs Eye Slough. As was the case for sterols, the largest concentrations occurred in Pools 1 and 2 (fig. 2.8). However, in contrast to sterols, several of the pools had no detectable PAH.

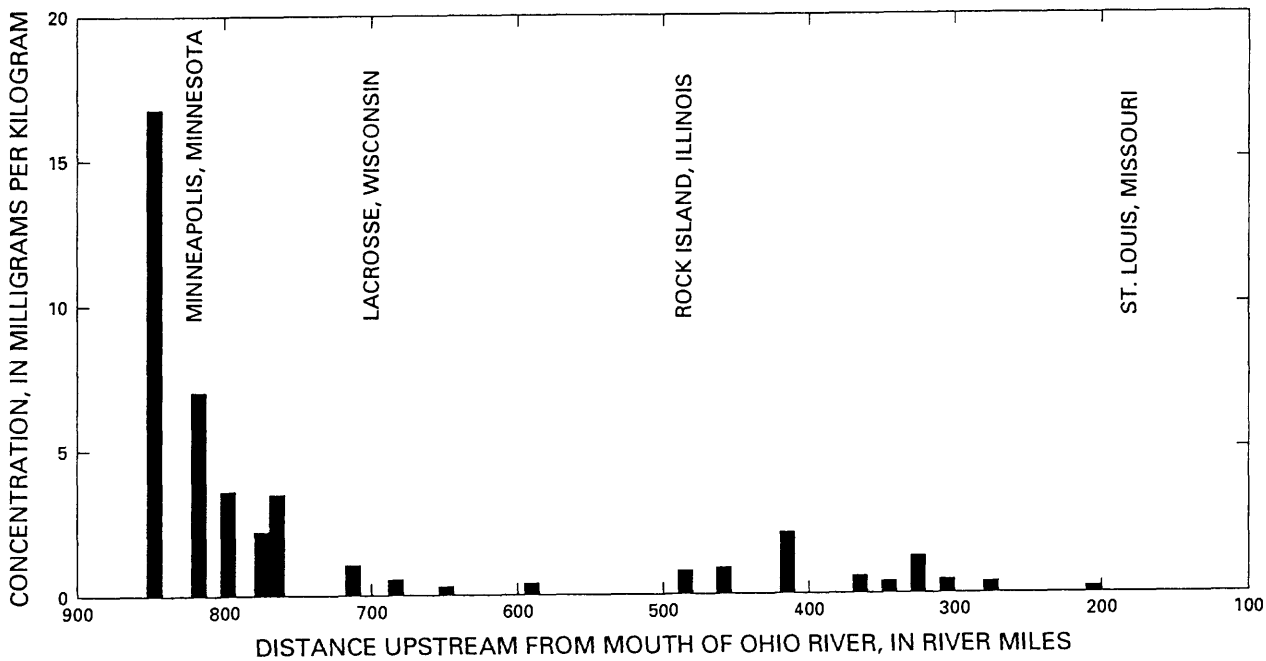

Figure 2.8--Total polynuclear aromatic hydrocarbon concentration in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for pool locations.

Table 2.12--Polynuclear aromatic hydrocarbon concentrations for composite surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992

[mg, milligram; kg, kilogram; PAH, polynuclear aromatic hydrocarbons; <, less than]

Pool	Concentration in mg/kg							
	Fluor-ocene (mg/kg)	Phenan-threne (mg/kg)	Anth-racene (mg/kg)	Fluoran-thene (mg/kg)	Pyrene (mg/kg)	Benzo [a] anthracene (mg/kg)	Chry-sene (mg/kg)	Total PAH (mg/kg)
1	0.2	2.4	0.00	4.2	4.8	2.19	3.05	16.87
2	0.00	1.7	0.00	5.8	6.64	4.03	3.05	21.26
	0.00	0.6	0.1	1.6	1.46	1.67	1.54	7.05
3	0.00	0.4	0.00	0.9	0.90	0.67	0.60	3.45
[1]4	0.00	0.00	0.00	0.8	1.40	0.00	0.00	2.18
[2]4	0.00	0.00	0.00	1.6	1.82	0.00	0.00	3.42
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.22	0.00	0.4	0.32	0.00	0.15	1.07
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.1	0.1	0.00	0.18	0.00	0.00	0.43
9	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.2	0.17	0.00	0.00	0.39
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.20	0.00	0.2	0.31	0.00	0.00	0.67
16	0.00	0.00	0.00	0.3	0.39	0.00	0.00	0.71
18	0.00	0.3	0.2	0.8	0.76	0.00	0.00	2.05
19	0.00	0.00	0.00	0.3	0.16	0.00	0.00	0.48
20	0.00	0.00	0.00	<0.1	0.07	0.00	0.00	0.11
21	0.00	0.2	0.00	0.4	0.49	0.00	0.00	1.13
22	0.00	0.00	0.00	0.2	0.18	0.00	0.00	0.37
24	0.00	0.00	0.00	0.2	0.00	0.00	0.00	0.21
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.2	0.00	0.00	0.00	0.18

[1]Upper Lake Pepin that is part of Pool 4.
[2]Lower Lake Pepin that is part of Pool 4.

Table 2.13--Polynuclear aromatic hydrocarbon concentrations in samples of surficial bed sediments collected from the Upper and Lower Mississippi River and some of its tributaries, October 1991-April 1992

[mg, milligram; kg, kilogram; PAH, polynuclear aromatic hydrocarbons]

Sampling site	River mile	Concentration in mg/kg							
		Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo [a] anthracene	Chrysene	Total PAH
Upper Mississippi River									
Missouri River near St. Charles, Missouri	[2]821	0.00	0.00	0.00	0.25	0.27	0.00	0.00	0.52
Mississippi River at St. Louis, Missouri	[3]179.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River at Thebes, Illinois[1]	[3]43.9	0.00	1.03	0.00	0.88	0.92	0.00	0.00	2.83
		0.00	0.00	0.00	0.54	0.46	0.00	0.00	0.99
Lower Mississippi River									
Mississippi River above Arkansas City, Arkansas	[4]566.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River near St. Francisville, Louisiana	[4]266.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mississippi River below Belle Chasse, Louisiana	[4]73.1	0.00	0.00	0.00	0.30	0.54	0.00	0.00	0.84

[1] Replicate samples collected on different cruise.
[2] Distance upstream from the confluence with the Mississippi River.
[3] Distance upstream from the mouth of the Ohio River.
[4] Distance upstream from Head of Passes, Louisiana

Linear Alkylbenzene Sulfonates

Evaluation of the Analytical Procedure

No spike and recovery experiments with the C_{10} to C_{14}-LAS standard were conducted. However, the average recovery for the 50 mg C_9-LAS surrogate standard spiked into all sediment samples (n=61) was 74 percent (RSD = 25 percent). Reported LAS concentrations were not corrected for recovery.

Concentrations

The spatial distribution of sorbed LAS in the bed sediments is presented in figure 2.9. Table 2.14 and 2.15 list LAS data for each sediment sample. LAS were identified in all of the sediment samples analyzed. Total LAS concentrations for the pool samples ranged from 0.01 to 0.95 mg/kg. The largest concentration (20.19 mg/kg) occurred in the sample from Pigs Eye Slough.

The C_{11} and C_{12} LAS homologues were found in all sediment samples, while C_{10} and C_{13} LAS homologues were found in 64 percent and 70 percent of the samples, respectively. The only sediment sample containing C_{14} LAS was from the canal carrying the Minneapolis-St. Paul sewage effluent. Samples collected upstream from Pool 4 show an enrichment of the C_{13} homologue and a depletion of the C_{10} and C_{11} homologues relative to the LAS standard. Samples from Lake Pepin (Pool 4) and downstream did not show this trend. The average alkyl-chain length for sorbed LAS in the pool samples ranged from 11.0 to 11.9 with a mean value of 11.6 (RSD = 2 percent). The C_{10} to C_{14} LAS isomer distributions for the sediments generally were similar to the LAS standard, with the exception of Upper Lake Pepin, which indicated loss of the internal isomers. The internal/external isomer ratio for sorbed C_{12} LAS in the pool samples ranged from 0.43 to 1.16 with an average of 0.90 (RSD = 28 percent), which is significantly less than the 1.32 value of the LAS standard.

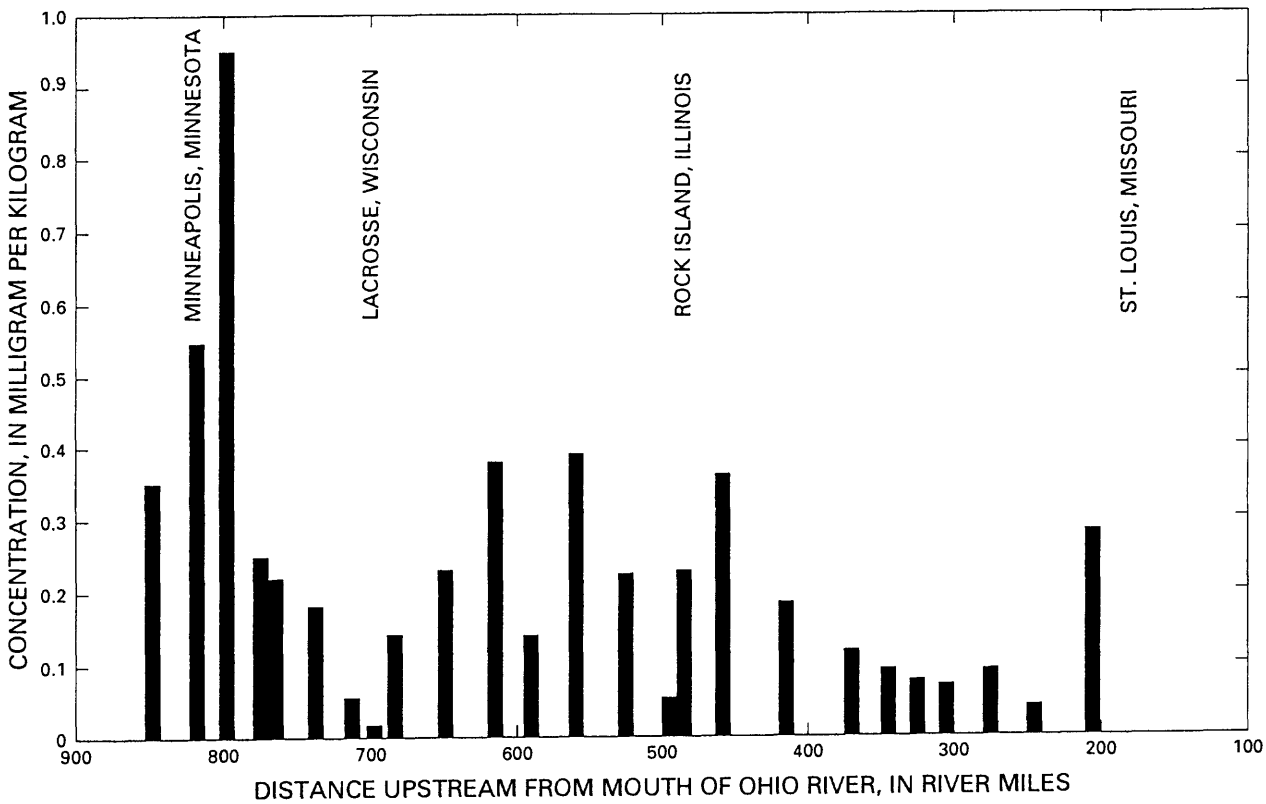

Figure 2.9--Total linear alkylbenzene sulfonate concentrations in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for pool locations.

Table 2.14--Linear alkylbenzene sulfonate analysis of composite surficial bed-sediment samples between Minneapolis, Minnesota, and St. Louis, Missouri,

[Data are the average from duplicate analyses; mg, milligram; kg, kilogram; LAS, linear alkylbenzene sulfonate;

Pool	Sampling date	LAS concentration (mg/kg)	Average chain length	I/E Ratio		Homologue (percentage of total LAS)										
				C_{11}	C_{12}	C_{10}	C_{11}	C_{12}	C_{12}	C_{14}	C_{10}-5	C_{10}-4	C_{10}-3	C_{10}-2	C_{11}-5&6	C_{11}-4
1	07-04-91	0.35	11.5	0.75	1.04	19	30	36	15	0	1	2	9	7	7	5
[1]2	07-07-91	20.19	12.5	0.74	1.10	3	12	33	34	18	1	0	1	1	3	2
2	07-07-91	0.51	11.0	1.79	0.93	40	25	26	9	0	0	0	0	5	8	6
2	10-09-91	0.60	11.6	0.67	1.07	18	26	38	18	0	0	1	7	10	6	4
2	04-09-92	0.53	11.9	0.62	1.06	5	21	53	21	0	13	11	13	3	5	5
3	10-11-91	0.95	11.3	0.65	0.95	25	32	35	8	0	1	2	6	16	7	5
[2]4	10-14-91	0.25	11.4	NI	0.43	0	60	40	0	0	0	0	0	0	0	0
[3]4	10-12-91	0.22	11.7	0.34	0.77	0	38	50	12	0	0	0	0	0	6	4
5	07-11-91	0.18	11.2	0.28	0.81	15	48	37	0	0	0	0	0	15	0	11
5A	07-11-91	-------	Not Analyzed	----		---	---	---	---	---	----	----	----	----	------	----
6	04-13-92	0.05	11.9	0.58	0.99	0	36	42	22	0	0	0	0	0	8	5
7	07-13-91	0.01	11.6	NI	NI	0	38	62	0	0	0	0	0	0	0	0
8	07-14-91	0.14	11.4	0.42	0.85	8	39	53	0	0	0	0	0	8	9	2
8	04-16-92	-------	Not Analyzed	----		---	---	---	---	---	----	----	----	----	------	----
9	10-19-91	0.23	11.5	0.46	0.77	10	40	44	6	0	0	2	0	8	9	4
10	07-16-91	0.38	11.5	0.35	1.07	6	43	42	9	0	0	0	0	6	7	4
11	10-20-91	0.14	11.8	NI	0.50	0	36	52	12	0	0	0	0	0	0	0
12	04-18-92	0.39	11.7	0.44	0.66	5	34	48	13	0	0	0	0	5	6	4
13	10-21-91	0.22	11.7	0.35	0.71	5	38	42	15	0	0	0	0	5	6	4
14	07-19-91	0.05	11.1	NI	NI	0	86	14	0	0	0	0	0	0	0	0
15	04-20-92	0.23	11.8	0.35	0.87	4	31	44	21	0	0	0	0	4	6	2
16	10-24-91	0.36	11.2	0.92	0.76	17	50	33	0	0	10	0	0	7	15	9
18	04-22-92	0.18	11.7	0.40	0.63	3	35	46	16	0	0	0	0	3	7	3
19	10-26-91	0.12	11.7	0.64	1.01	0	46	41	13	0	0	0	0	0	10	8
20	07-22-91	0.09	11.8	0.54	1.16	0	45	33	22	0	0	0	0	0	8	8
21	04-24-92	0.08	11.6	0.41	1.10	10	35	45	10	0	0	0	0	10	8	2
22	07-23-91	0.07	11.3	0.30	0.44	12	51	28	9	0	0	0	0	12	12	0
24	10-24-91	0.09	11.7	0.57	0.83	0	42	49	9	0	0	0	0	0	10	6
25	04-25-92	0.04	11.3	NI	NI	0	69	31	0	0	0	0	0	0	0	0
26	11-01-91	0.28	11.7	0.57	0.91	0	43	46	12	0	0	0	0	0	9	7
LAS Standard			11.2	1.03	1.32	25	36	37	2	0	6	5	6	8	12	7

[1]Pigs Eye Slough is downstream from the Twin Cities Wastewater Treatment Plant discharge at Upper Mississippi River Mile 835.1.
[2]Upper Lake Pepin.
[3]Lower Lake Pepin.

collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River July 1991-April 1992.

I/E, internal/external isomer ratio; c_{ii}-k, ii is the homologue and k is the phenyl group; and NI, no internal isomer]

Isomer (percentage of total LAS)																	
C_{11}-3	C_{11}-2	C_{12}-6	C_{12}-5	C_{12}-4	C_{12}-3	C_{12}-2	C_{13}-6&7	C_{13}-5	C_{13}-4	C_{13}-3	C_{13}-2	C_{14}-7	C_{14}-6	C_{14}-5	C_{14}-4	C_{14}-3	C_{14}-2
7	10	6	6	6	7	10	5	3	2	2	3	0	0	0	0	0	0
2	4	6	6	5	6	10	11	7	6	5	6	4	4	4	3	2	1
0	7	9	9	7	8	20	9	12	0	0	0	0	0	0	0	0	0
6	10	7	6	6	7	11	7	4	3	2	2	0	0	0	0	0	0
7	8	5	4	5	6	7	2	1	1	1	4	0	0	0	0	0	0
7	12	6	6	6	7	11	2	1	1	1	1	0	0	0	0	0	0
41	19	0	0	12	19	9	0	0	0	0	0	0	0	0	0	0	0
13	15	7	7	8	9	19	4	2	2	2	2	0	0	0	0	0	0
22	15	7	5	4	6	15	0	0	0	0	0	0	0	0	0	0	0
Not Analyzed																	
9	14	7	7	7	9	13	8	3	4	3	4	0	0	0	0	0	0
0	38	0	0	0	0	62	0	0	0	0	0	0	0	0	0	0	0
12	15	7	7	10	10	18	0	0	0	0	0	0	0	0	0	0	0
Not Analyzed																	
13	15	6	5	8	10	14	1	1	2	0	2	0	0	0	0	0	0
15	17	6	6	9	7	13	2	2	2	0	4	0	0	0	0	0	0
18	18	7	5	5	8	27	0	0	0	0	12	0	0	0	0	0	0
11	13	6	6	7	11	18	3	2	3	2	3	0	0	0	0	0	0
14	14	6	6	6	9	15	3	0	8	0	4	0	0	0	0	0	0
70	16	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0
10	13	7	6	8	6	18	5	3	5	2	5	0	0	0	0	0	0
12	14	8	6	0	10	9	0	0	0	0	0	0	0	0	0	0	0
11	14	6	4	7	10	18	4	3	5	2	4	0	0	0	0	0	0
12	16	6	7	8	12	9	4	3	4	0	1	0	0	0	0	0	0
14	15	6	6	6	0	15	5	3	7	4	5	0	0	0	0	0	0
13	12	8	6	10	9	12	4	2	2	0	2	0	0	0	0	0	0
24	16	5	4	0	0	19	3	3	3	0	0	0	0	0	0	0	0
11	16	7	7	8	12	15	4	0	3	0	2	0	0	0	0	0	0
43	26	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0
9	18	7	7	7	9	15	5	2	1	1	2	0	0	0	0	0	0
7	11	8	8	6	7	9	1	0	0	0	0	0	0	0	0	0	0

Table 2.15--Linear alkylbenzene sulfonate analysis of surficial bed-sediment samples tributaries, October 1991 -

[mg, milligram; kg, kilogram; LAS, linear alkylbenzene sulfonate; I/E, internal/external

Sampling site	Sampling date	LAS concentration (mg/kg)	Average chain length	I/E Ratio		Homologue (percentage of total LAS)										
				C_{11}	C_{12}	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{10}-5	C_{10}-4	C_{10}-3	C_{10}-2	C_{11}-5&6	C_{11}-4
Minnesota River at Mile 3.5, Minnesota	07-04-91	0.29	11.6	0.57	0.79	7	33	52	8	0	1	1	2	4	7	5
Illinois River near Hardin, Illinois	10-09-91	0.35	11.2	0.21	0.73	19	40	41	0	0	0	0	12	7	0	7
Missouri River near St. Charles, Missouri	04-09-92	0.19	11.7	0.73	1.14	7	37	38	18	0	0	0	0	7	9	7
Mississippi River at St. Louis, Missouri	10-11-91	0.04	10.7	0.63	1.43	54	20	25	0	0	23	0	25	6	5	3
Mississippi River at Thebes, Illinois	10-12-91	0.26	11.6	0.80	1.58	9	37	44	10	0	0	0	0	9	11	6
Mississippi River near St. Francisville, Louisiana	10-14-91	0.12	11.6	0.86	0.80	0	35	65	0	0	0	0	0	0	5	11
Mississippi River below Belle Chasse, Louisiana	07-11-91	0.42	11.5	0.56	0.89	12	34	46	8	0	2	2	0	7	8	5

collected from the Upper and Lower Mississippi River and some of its April 1992

isomer ratio; and c_{ii}-k, ii is the homologue and k is the phenyl position]

Isomer (percentage of total LAS)																	
C_{11}-3	C_{11}-2	C_{12}-6	C_{12}-5	C_{12}-4	C_{12}-3	C_{12}-2	C_{13}-6&7	C_{13}-5	C_{13}-4	C_{13}-3	C_{13}-2	C_{14}-7	C_{14}-6	C_{14}-5	C_{14}-4	C_{14}-3	C_{14}-2
6	15	8	8	8	10	19	2	1	1	2	2	0	0	0	0	0	0
11	22	9	8	0	9	15	0	0	0	0	0	0	0	0	0	0	0
10	12	6	6	8	8	10	2	2	2	1	11	0	0	0	0	0	0
4	8	6	5	4	6	5	0	0	0	0	0	0	0	0	0	0	0
10	11	11	8	8	8	9	4	2	2	1	2	0	0	0	0	0	0
4	15	10	7	11	18	18	0	0	0	0	0	0	0	0	0	0	0
10	12	7	6	9	11	13	2	2	2	0	2	0	0	0	0	0	0

SUMMARY

Coprostanol is a nonionic biorefractory molecule that accumulates in bed sediments and provides an indication of long-term sewage loads. Coprostanol concentrations in the bed sediments from the pools ranged from 0.10 to 1.37 mg/kg. Concentrations above 0.1 mg/kg indicate sewage contamination. The greatest coprostanol concentrations were found in Pool 2, which receives the sewage effluent from Minneapolis-St. Paul, Minn., and Pool 4, which includes Lake Pepin and acts as a trap for sediment-bound contaminants from Minneapolis-St. Paul. Polynuclear aromatic hydrocarbons are widespread environmental contaminants that come from a variety of sources and also accumulate in bed sediments. Seven PAH were detected in the pool bed sediments, and the total PAH concentrations ranged from 0.0 to 16.87 mg/kg. Linear alkylbenzene sulfonates are widely used anionic surfactants that are water soluble, undergo rapid biodegradation, and are not strongly sorbed to bed sediments. However, LAS was detected in all of the pool bed-sediment samples at concentrations ranging fro 0.01 to 0.95 mg/kg.

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CHAPTER 3 - Organochlorine Compounds

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ABSTRACT

Representative subsamples of surficial bed sediment were collected from 25 navigation pools on the Upper Mississippi River and analyzed for organochlorine compounds (aldrin; technical chlordane; *cis*-chlordane; dacthal; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; hexachlorobenzene; lindane; *p,p'*-methoxychlor; mirex; pentachloroanisole; pentachlorobenzene; perthane; polychlorinated biphenyls; polychlorinated naphthalenes; toxaphene; *trans*-chlordane; *trans*-nonachlor; and trifluralin), nonachlorobiphenyl congeners, and selected polychlorinated biphenyl congeners and homologues. Some samples were extracted as wet samples and some as dry samples, and three different analytical methods were used. One analytical method used surrogate internal standards, capillary gas chromatography/negative-chemical ionization/mass spectrometry; a second method used shake extraction with acetone-hexane and analysis of the extract by gas chromatography with electron-capture detection; and a third method used capillary gas chromatography and electron-capture detection.

The concentrations of most organochlorine compounds in the surficial bed sediments were between reporting levels. However, maximum concentration of some organochlorines in surficial bed sediments came from the upstream end of the navigation pool reach just downstream from Minneapolis and St. Paul, Minnesota. The maximum concentration of total chlordane was 36 nanograms per gram (ng/g) in a sample from Pool 1, and the maximum concentration of *p,p'*-DDT was 0.7 ng/g in a sample from Pool 3. The maximum concentration of total polychlorinated biphenyls (410 ng/g), *p,p'-DDD* (1.6 ng/g), and *p,p'*-DDE (2.5 ng/g) were in sample from Pool 4 (Lake Pepin). However, the maximum concentration of dieldrin was 0.8 ng/g in a sample from Pool 26 at the downstream end of the reach near St. Louis, Missouri.

INTRODUCTION

Organochlorine compounds are widespread in the environment and are derived from manufactured and natural sources. The manufacture, distribution, and use of insecticides, pesticides, and industrial chemicals [like polychlorinated biphenyls (PCB) and polychlorinated naphthalenes (PCN)] have contributed to a large array of organic contaminants and their degradation products in the environment. Anthropogenic activities such as incineration of manufactured organic compounds and combustion of fossil fuels have contributed to the production and airborne release of contaminants such as dioxins, furans, and PAH (Voldner and Li, 1995). The organic contaminants associated with surficial bed sediments determined in this study are aldrin, technical chlordane; *cis*-chlordane; dacthal; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; hexachlorobenzene; lindane; *p,p'*-methoxychlor; mirex; pentachloroanisole; pentachlorobenzene; perthane; PCB; total PCN; toxaphene; *trans*-chlordane; *trans*-nonachlor; trifluralin; nonachlorobiphenyl congeners; selected PCB congeners; and PCB homologues.

Polychlorinated biphenyls are a mixture of congeners, and the composition of diverse environmental samples are usually different from those of commercial PCB because of different environmental fates of the individual congeners (Porte and others, 1988). Different technical PCB mixtures of congeners have been marketed worldwide as Aroclor (United States), Clophen (Germany), Kanechlor (Japan), Phenoclor and Pyralene (France), and Fenoclor (Italy). Although there can be significant quantitative lot-to-lot and brand-to-brand variations, there is considerable qualitative similarity in the PCB formulations (Albro and others, 1981). However, there are considerable quantitative congener differences among the compositions of commercial PCB like Clophens and Aroclors (Duinker and Hillebrand, 1983; and Schulz and others, 1989). Congener composition also differs among environmental samples of air, water, sediment, and biotic tissue. Summing congener concentrations allows for the determination of the total PCB concentration in any type of sample, whether it contains intact Aroclors, degraded Aroclor residues or non-Aroclor PCB (Alford-Stevens and Budde, 1988). PCB congeners in this report are identified by the IUPAC (International Union of Pure and Applied Chemistry) numbers used by Albraiges (1993) and not those used previously by Ballschmiter and Zell (1980). The variability of PCB data is an indication of the complexity of the sample matrix. Sample matrix effects can cause wide variability in recoveries, especially for organic compounds (American Chemical Society, 1983).

Organochlorine compounds have been released to the air, water, and land over many years through their use and disposal. As a result of their chemical structure, organochlorine compounds are often highly persistent contaminants in both aquatic and terrestrial ecosystems. This is true even though the production and use of some of these compounds such as DDT and PCB have been eliminated or greatly restricted since 1977. Their solubility in water is generally low, and as a result, in aquatic systems they are mainly found adsorbed to suspended particulate matter and in bed sediments, especially silt-sized and clay-sized sediment (less than 63 μm) with high organic-carbon content. Thus, contaminated sediments provide a major source of present-day exposure of these chemicals to aquatic organisms (Lyman and others, 1987; and Baudo and others, 1990).

Runoff from contaminated soils or improper disposal has caused serious contamination problems in both riverine and lacustrine systems. Volatilization of organochlorine compounds to the atmosphere has resulted in their global distribution. When present at acute concentrations, these organochlorine compounds can directly affect the distribution and abundance of aquatic organisms. Furthermore, long-term exposure at low concentrations may contribute to behavioral (such as avoidance reactions) and biological (such as carcinogenicity, teratogenicity, and mutagenicity) effects. The transfer of organochlorine contaminants through the aquatic food chain contributes to contamination problems in fish, piscivorous mammals and birds, and eventually humans. In some instances, PCB and chlordane contamination in fish from the Mississippi River resulted in certain States issuing consumption advisories for commercial and sport fishing.

PURPOSE AND SCOPE

The purpose of this chapter is to (1) describe the methods to determine the concentration of organochlorine compounds in the surficial bed sediments collected from the downstream one-third of 25 navigation pools of the Upper Mississippi River between July 1991 and April 1992 and 2) list the concentrations. Three different analytical methods (U.S. Geological Survey Research method, Wisconsin State Laboratory of Hygiene method, and U.S. Geological Survey National Water Quality Laboratory method) were used because future work was anticipated that would require using methods other than the Research method. The results from the three different methods are listed separately in tables, and some results are listed in a summary table for comparison. The spatial distribution of some of the more abundant compounds in the Upper Mississippi River are shown graphically.

ANALYTICAL METHODS

The samples collected for organochlorine analysis (see Chapter 1 for collection method) were kept refrigerated at about 4°C in glass jars with Teflon-lined lids until they were analyzed by three different methods: Research method, Wisconsin State Laboratory of Hygiene method, and Schedule 1325 method. At the U.S. Geological Survey Laboratory in Arvada, Colo., the composite subsamples (see Sampling Strategy) from the three cruises (July-August 1991, October-November 1991, and April-May 1992) were mixed individually and a subsample of approximately 50 g (wet weight) was removed and analyzed by the U.S. Geological Survey Research method . The remainder of the sample from the October-November 1991 cruise [Pools 2, 3, 4 (upper Lake Pepin), 4 (Lower Lake Pepin), 8, 9, 11, 16, 19, 24, and 26] was air-dried at about 20°C and ground up to a fine powder by using a mortar and pestle. Air-drying river-sediment samples does not alter the PCB composition of even the lowest chlorinated PCB homologues (Bopp and others, 1981). Some of these dried samples from the October-November 1991 cruise [Pools 2, 3, 4 (Lower Lake Pepin), 8, 9, and 11] were split using a Teflon Jones splitter. A one-half split was analyzed by a method used by the Wisconsin State Laboratory of Hygiene in Madison, Wis. and the other one-half split was analyzed by the U.S. Geological Survey National Water Quality Laboratory Schedule 1325 method. The remaining dried samples from the October-November 1991 cruise [Pools 4 (Upper Lake Pepin), 16, 19, 24, and 26] were analyzed by the Schedule 1325 method. The remainder of the samples from the April-May 1992 cruise (Pools 2, 6, 8, 12, 15, 18, 21, and 25) were not air-dried but kept refrigerated and wet until they were analyzed by the Schedule 1325 method in November 1993.

A large volume (240 L) of surficial bed sediment was collected from Lower Lake Pepin in May 1991 and prepared as a reference sample by personnel from the U.S. Army Corps of Engineers (St. Paul and Rock Island Districts), the Minnesota Pollution Control Agency, the Wisconsin Department of Natural Resources, and the U.S. Fish and Wildlife Service. The wet sediment was mixed in three batches (approximately 80 L each), using a large Hobart blender, and then portioned into individual glass containers and frozen. Samples of the Lake Pepin reference sample were analyzed by the Research, Wisconsin State Laboratory of Hygiene, and Schedule 1325 methods, and the results are listed in the data tables as "Reference."

Research Method

The Research method uses negative chemical ionization mass spectrometry, which is capable of identifying more compounds than electron-capture detection (Wisconsin State Laboratory of Hygiene and Schedule 1325 methods); therefore, extraction procedures were designed to obtain as many organic compounds as possible. Furthermore, the use of negative chemical ionization mass spectrometry reduces instrument, analysis matrix effects relative to techniques using electron-capture detection (Porte and others, 1988). The Research method identified penta- and hexachlorobenzene, pentachloroanisole, dacthal, trifluralin, aldrin, dieldrin, endrin, nonachlorobiphenyl congeners, chlordane (*cis*- and *trans*-chlordane, *trans*-nonachlor, and total chlordane), and polychlorinated biphenyls (penta-, hexa-, hepta-, and octachlorobiphenyl).

The polychlorinated biphenyls were separated into four homologue groups (penta-, hexa-, hepta-, and octachlorobiphenyls) and one congener from each homologue group was chosen as the homologue group reference standard for quantification. The selected quantitation congener group reference standards were 2,2',3,4,5'-pentachlorobiphenyl (IUPAC number 87); 2,2',4,4',5',6-hexachlorobiphenyl (IUPAC number 154); 2,2',3,4,4',5',-heptachlorobiphenyl (IUPAC number 183); and 2,2',3,3',4,5',6,6'-octachlorobiphenyl (IUPAC number 200). These homologue group reference standards did not coelute with other known coeluting homologues (Mullin and others, 1984). Three of the four homologue group reference standards (IUPAC numbers 87, 154, 183) are listed as major components of Aroclor 1260. Because of many different technical PCB formulations, no attempt was made to match the congener composition pattern to a single technical Aroclor mixture, new or altered by the environment. Mass spectrometric response varies not only with level of chlorination but also among congeners in a given group (Alford-Stevens and Budde, 1988). Individual PCB response factors by electron-impact ionization mass spectrometry varies by a factor of 1 to 5. This variation serves as an indicator of the potential error associated with the use of one PCB congener to serve as the concentration calibration for all congeners in a group (Gebhart and others, 1985). The electron-capture relative response factors in each homologue group (Mullin and others, 1984) and for each homologue group reference standard were averaged in order to determine the possible bias caused by quantitation based on the relative response factor of the selected homologue group reference standard (table 3.1).

Table 3.1--Electron-detection relative response factors for homologue groups and for the homologue group reference standard

[IUPAC, International Union of Pure and Applied Chemistry; data from Mullin and others, 1984]

Homologue group	Number of relative response-factor values	Average electron-capture detection relative-response factors	Percent relative standard deviation	Reference standard	
				IUPAC number	Electron-capture detection relative-response factor
Pentachlorobiphenyls	46	0.72	29	87	1.02
Hexachlorobiphenyls	42	0.88	27	154	0.57
Heptachlorobiphenyls	24	1.15	31	183	0.98
Octachlorobiphenyls	12	1.07	40	200	0.37

Sample Preparation

Only ultra-high-purity distilled-in-glass (Burdick and Jackson GC[2]) solvents were used. All glassware was baked 8 hours at 340°C prior to use. The 50-g wet subsample was weighed into a 150-mL glass centrifuge bottle, spiked with surrogate internal standard (10 µL of 40 ng/µL 4,4'-dibromooctafluorobiphenyl and 128 ng/µL of terbuthylazine), and allowed to equilibrate for 1 hour, with mixing every 5 to 10 minutes.

The sample was extracted with 100 mL acetone by using a sonic probe (Tekmar) pulsed for 3 minutes at 60-percent duty cycle, 40-percent output control, centrifuged at 1,500 revolutions per minute (relative centrifugal force of 550 gravities) for 10 minutes, and the organic solvent decanted. The sample was extracted twice more with acetone and finally with 100 mL hexane. The organic extracts were combined and extracted with 900 mL of pre-extracted, aqueous, 2-percent (weight by volume) sodium sulfate solution. The organic solvent layer was retained. Residual organic compounds were reclaimed from the sodium sulfate solution by extracting it twice with 100 mL of methylene chloride. The methylene chloride extracts were combined with the organic solvent layer and dried over 5 g anhydrous sodium sulfate. This extract was concentrated in a Kuderna-Danish apparatus to a volume of less than 10 mL, followed by evaporation under a gentle stream of dry nitrogen to about 2 mL. The sample extract was fractionated on a column of neutral alumina (Bio-Rad AG-7) by sequentially eluting with 50-mL fractions of hexane (fraction A), benzene (fraction B), methylene chloride (fraction C), and 1:1 methylene chloride:methanol (fraction D). The first three fractions (A, B, and C) containing nonpolar compounds were combined and concentrated to approximately 5 mL in a Kuderna-Danish apparatus and were further concentrated to 1 mL under a gentle stream of dry nitrogen. The fraction D containing the terbuthylazine surrogate internal standard and other polar organic compounds was concentrated and stored for later analysis. The nonpolar extract was passed through a small column of activated copper to remove sulfur. After adding 100 µL benzene, the extract was further concentrated to a volume of 100 µL under a gentle stream of dry nitrogen.

Sample Analysis

The surficial bed-sediment extracts were spiked with three injection standards, decafluorobiphenyl, isodrin, and d_{-10} phenanthrene, after all sample preparation procedures were completed but before sample analysis. These injection standards compensate for variation in injected quantities and for incomplete transfer of injected material, assuming there is no bias introduced during injection, chromatography, and mass spectrometric analysis (Alford-Stevens and others, 1986). The extracts were then analyzed in duplicate or triplicate for halogenated organic compounds by gas chromatography/negative chemical ionization/mass spectrometry (GC/NCI/MS). The extracts were injected at 280°C using splitless (45-second split vent delay) injections. The extracts were separated on a 30-m by 0.25-mm inside diameter, 0.25-µm Rtx-5 Restek capillary gas chromatographic column (Restek Corporation, Bellefonte, Pennsylvania) at 50°C for 1 minute, increased to 300°C at 10°C/min, and held for 12 minutes. Electron-capture negative chemical ionization (NCI) was achieved with ultra-high-purity methane reagent gas at 0.30 torr in the ion source at 100°C, with a filament emission current of 0.25 microamperes and electron energy of 100 electron volts. The Finnigan MAT TSQ-46 mass spectrometer (San Jose, California) scanned the first quadrupole from 50 to 600 daltons in 1 second, with the electron multiplier at 1,000 electron volts and the conversion dynode at 5 kilovolts. Full-scan NCI mass spectra were acquired for all analyses.

The most intense ion in the negative molecular-ion cluster of each selected compound was used for quantitation. Quantitation was based on the surrogate internal standard 4,4'-dibromooctafluorobiphenyl, which was added to the sample (not to the extraction solvent) in the very first sample preparation step and carried through the entire extraction preparation procedure. A six-point internal response calibration curve was generated from 50 pg to 16 ng of each selected compound. Using a surrogate internal standard that was carried through the entire preparation procedure compensates for differences in individual sample extraction and concentration recoveries. DDT and its degradation products, DDE and DDD, were not quantitated using this method because of their low, nonspecific response to NCI.

With time, the instrument loses sensitivity because of contamination of the ion source. Contamination occurs from the chemical ionization process itself and from the complex matrix of the samples. The ion volume in the ion source was replaced often to compensate for this problem. Because the response is dependent upon reagent gas pressure, fluctuations in the reagent gas pressure also can cause variations in the data. Because there can be instrumental reasons for variation of the data (Arbogast and others, 1990), especially nondetected values, each sample was analyzed at least twice. The analytical detection limits for the selected anthropogenic organic compounds for a 50-g sample are given in table 3.2 and were determined as the concentration that is 4 standard deviations above instrument background. It does not account for the range of organic-carbon composition, organic-carbon content, and variety of sediments analyzed, nor the day-to-day variation in instrument performance.

Each sample analyzed was spiked with isodrin prior to injection to provide an indication of method performance in terms of precision and bias of concentration measurements for every extract analyzed (Alford-Stevens and others, 1986). The percent recovery of the 4,4'-dibromooctafluorobiphenyl, based on isodrin, averaged 73 percent for samples from the April-May 1992 cruise. The recoveries of other organochlorine compounds are listed in table 3.3.

Table 3.2--Instrumental analytical detection limit for 50-gram sample using the Research method

[Data from Rostad and others, 1995]

Compound	Nanogram per gram
Pentachlorobenzene	0.005
Hexachlorobenzene	0.005
Pentachloroanisole	0.005
DCPA (dacthal)	0.001
Trifluralin	0.005
Aldrin	0.020
Dieldrin	0.020
Endrin	0.020
Nonachlorobiphenyl congeners	0.001
trans-chlordane	0.020
cis-chlordane	0.020
trans-nonachlor	0.020
Pentachlorobiphenyl congeners	0.005
Hexachlorobiphenyl congeners	0.005
Heptachlorobiphenyl congeners	0.005
Octachlorobiphenyl congeners	0.005

Table 3.3--Recovery of selected organochlorine compounds from surficial bed sediments spiked at 8, 12, and 24 nanograms per gram using the Research method

Compound	Average recovery (percent)	Relative standard deviation (percent)
Pentachlorobenzene	77	10
Hexachlorobenzene	40	6
Pentachloroanisole	50	5
DCPA (dacthal)	31	7
Trifluralin	55	7
trans-chlordane	32	2
trans-nonachlor	111	8
Pentachlorobiphenyl congeners	65	11
Hexachlorobiphenyl congeners	26	1
Heptachlorobiphenyl congeners	67	11
Octachlorobiphenyl congeners	25	2

Wisconsin State Laboratory of Hygiene Method

The Wisconsin State Laboratory Hygiene (WSLOH) method was designed to identify 85 PCB congeners (some eluting as pairs or triplets) in surficial bed sediments by using capillary gas chromatography with an electron-capture detection (Wisconsin State Laboratory of Hygiene, 1993). The sum of the individual PCB congeners provided an estimate of the total PCB concentration. No other organochlorines were determined.

Sample Preparation

The sediment sample was air-dried for about 2 to 5 days so that it would pass through a #10 sieve. Remaining material that did not pass through the sieve was discarded. A 10- to 25-g subsample of the homogenized sample was dried at 103°C for at least 10 hours in order to determine the percent moisture. If the percent moisture was greater than 30 percent, the sample was redried. A 40- to 50-g subsample was then weighed into an acetone-washed paper Soxhlet extraction thimble and placed in an acetone-washed Soxhlet extraction apparatus. Each dry sample was spiked with a surrogate compound (consisting of three PCB congeners with IUPAC numbers 14, 65, and 166 at concentrations of 100, 75, and 25 ng/mL, respectively) at 2 to 5 times the detection level to measure analytical recoveries for establishing upper and lower warning limits (equal to 2 standard deviations either side of the average analytical recovery). The average analytical recoveries (± the standard deviation for at least 321 samples) for the three PCB congeners were 87.1±12.6, 90.5±12.2, and 102±10.9 percent, respectively, for laboratory quality-assurance information reported in August 1993.

A few glass beads or boiling chips were placed in the Soxhlet flask with 300 mL of 50:50 (volume: volume) acetone:hexane. Granular activated copper was added to minimize sulfur interferences. The apparatus was placed on a hot plate, and the sample was extracted for approximately 8 hours. The acetone-hexane was then concentrated under a gentle stream of filtered air or in a rotary evaporation apparatus to about 10 mL. Anhydrous sodium sulfate was added to aid in the removal of water.

Sample Analysis

For PCB congener analysis, a florisil and silica gel fractionation was performed prior to gas chromatographic (Hewlett-Packard 5880 Gas Chromatograph) analysis on a capillary column (60 m x 0.2-mm) inside diameter and 0.1–μm film DB-5 Column (J and W Scientific), and an electron-capture detector. The calibration standard included a mixture of Aroclors 1232, 1248, and 1262 at concentrations of 0.250, 0.180, and 0.180 mg/L, respectively. The concentration of each congener is listed by Mullin (1985). This standard also contained PCB congener numbers IUPAC 30 (12 ng/mL) and 204 (13.8 ng/mL), which were used as retention-time reference peaks and as internal standards for quantitation. These internal standards were added to all extracted samples.

Precision estimates (average absolute difference of duplicate sediment samples) and accuracy measurements (based on percent recoveries of spiked sediment samples) were conducted over a period of several years. One matrix spike sediment sample was analyzed for every 10 sediment samples. Matrix spike solutions consisted of the same PCB Aroclor mixtures used for calibration standards described previously. Average and standard deviation values for the precision and accuracy measurements are utilized to establish warning limits or upper and lower control limits for PCB congener determinations. Sample results falling outside the control limits were reanalyzed or flagged for further evaluation. The method detection limit, limit of quantification, average precision, and average percent recovery for PCB congeners analyzed using the WSLOH method are listed in table 3.4. This table represents typical laboratory performance for several years ending in August 1993. The method detection limit is defined as the minimum concentration of a substance that can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte (U.S. Environmental Protection Agency, 1991). The limit of quantification is defined as the concentration of a substance above which quantitative results may be obtained within 99-percent confidence limits; the limit of quantification is approximately 3.3 times the method detection limit (American Chemical Society, 1983).

Table 3.4--Method detection limit, limit of quantification, precision, and accuracy information for polychlorinated biphenyl congener analysis at the Wisconsin State Laboratory of Hygiene, Madison, Wisconsin

[Congeners are listed in order as reported by the laboratory; IUPAC, International Union of Pure and Applied Chemistry; ng/g, nanogram per gram of dry weight; N, number of replicate analyses; and %, percent]

IUPAC number	Structure	Method detection limit (ng/g)	Limit of quantification (ng/g)	Precision[1]		Accuracy[2]	
				N	%	N	%
7	2,4	0.20	0.70	30	6.7	45	85.9
6	2,3′	0.45	1.5	36	8.5	44	89.7
5/8	2,3/2,4′	1.3	4.3	42	8.3	45	87.3
19	2,2′,6	0.30	1.0	30	10.0	42	69.0
18	2,2′5	0.35	1.2	41	5.8	45	87.3
17	2,2′,4	0.30	1.0	41	5.1	45	87.4
24/27	2,3,6/2,3′,6	0.30	1.0	36	5.9	44	85.5
16/32	2,2′,3/2,4′,6	0.40	1.5	42	7.4	44	85.9
26	2,3′,5	0.35	1.2	40	9.6	44	90.0
28/31	2,4,4′/2,4′,5	1.4	4.6	43	7.0	44	90.7
33	2′,3,4	0.45	1.5	36	8.8	45	89.8
22	2,3,4′	0.60	2.0	39	8.4	45	91.7
45	2,2′,3,6	0.30	1.0	38	7.0	45	83.0
46	2,2′,3,6′	0.35	1.2	35	6.3	45	82.7
52	2,2′,5,5′	0.30	1.0	44	4.8	45	92.3
49	2,2′,4,5′	0.30	1.0	42	5.0	45	91.1
47/48	2,2′,4,4′/2,2′,4,5	0.50	1.6	38	5.1	45	89.0
44	2,2′,3,5′	0.30	1.0	42	5.3	45	91.2
37/42	3,4,4′/2,2′,3,4′	0.40	1.3	40	7.4	45	91.1
41/64/71	2,2′,3,4/2,3,4′,6/2,3′,4′,6	0.50	1.6	39	7.4	45	88.1
40	2,2′,3,3′	0.30	1.0	37	6.1	45	87.7
74	2,4,4′,5	0.30	1.0	43	8.0	45	94.8
70/76	2,3′,4′,5/2′,3,4,5	0.45	1.5	45	7.6	45	96.4
66/95	2,3′,4,4′/2,2′,3,5′,6	0.60	2.0	43	6.1	45	93.2
91	2,2′,3,4′,6	0.40	1.3	39	5.5	45	96.1
56/60	2,3,3′,4′/2,3,4,4′	0.80	2.6	43	7.8	45	94.3
84/92	2,2′,3,3′,6/2,2′,3,5,5′	0.70	2.3	39	6.2	44	93.8
101	2,2′,4,5,5′	0.30	1.0	45	7.0	44	97.1
99	2,2′,4,4′,5	0.30	1.0	42	6.5	44	94.8
97	2,2′,3′,4,5	0.30	1.0	40	4.9	44	96.1
87	2,2′,3,4,5′	0.35	1.2	42	8.7	44	98.0
85	2,2′,3,4,4′	0.35	1.0	32	5.4	45	98.4
136	2,2′,3,3′,6,6′	0.20	0.70	21	6.1	45	94.6
77/110	3,3′,4,4′/2,3,3′,4′,6	0.40	1.3	45	7.4	44	96.1

Table 3.4--Method detection limit, limit of quantification, precision, and accuracy information for polychlorinated biphenyl congener analysis at the Wisconsin State Laboratory of Hygiene, Madison, Wisconsin--Continued

[Congeners are listed in order as reported by the laboratory; IUPAC, International Union of Pure and Applied Chemistry; ng/g, nanogram per gram of dry weight; N, number of replicate analyses; and %, percent]

IUPAC number	Structure	Method detection limit (ng/g)	Limit of quantification (ng/g)	Precision[1]		Accuracy[2]	
				N	%	N	%
82	2,2′,3,3′,4	0.30	1.0	36	7.8	44	93.8
151	2,2′,3,5,5′,6	0.30	1.0	40	9.8	45	93.4
135/144	2,2′,3,3′,5,6′/2,2′,3,4,5′,6	0.30	1.0	36	9.1	45	92.5
149	2,2′,3,4′,5′,6	0.30	1.0	41	7.0	45	93.6
118	2,3′,4,4′,5	0.45	1.5	44	8.5	44	95.6
146	2,2′,3,4′,5,5′	0.35	1.2	33	6.2	44	102.0
132/153	2,2′,3,3′,4,6′/2,2′,4,4′,5,5′	0.45	1.5	44	8.8	45	95.4
141	2,2′,3,4,5,5′	0.30	1.0	31	7.1	45	93.0
137/176	2,2′,3,4,4′,5/2,2′,3,3′,4,6,6′	0.30	1.0	45	10.0	45	95.5
138/163	2,2′,3,4,4′,5′/2,3,3′,4′,5,6	0.40	1.3	45	10.0	45	96.8
178	2,2′,3,3′,5,5′,6	0.40	1.3	22	13.0	45	94.6
182/187	2,2′,3,4,4′,5,6′/2,2′,3,4′,5,5′,6	0.40	1.3	40	9.8	45	94.3
183	2,2′,3,4,4′,5′,6	0.40	1.3	32	12.0	45	95.4
185	2,2′,3,4,5,5′,6	0.30	1.0	13	7.6	45	94.9
174	2,2′,3,3′,4,5,6′	0.30	1.0	39	8.3	45	93.7
177	2,2′,3,3′,4′,5,6	0.35	1.2	34	8.2	45	95.5
171/202	2,2′,3,3′,4,4′,6/2,2′,3,3′,5,5′,6,6′	0.30	1.0	27	11.0	45	96.2
172/197	2,2′,3,3′,4,5,5′/2,2′,3,3′,4,4′,6,6′	0.50	1.6	14	14.0	45	93.9
180	2,2′,3,4,4′,5,5′	0.35	1.2	41	8.4	45	96.0
199	2,2′,3,3′,4,5,6,6′	0.30	1.0	5	7.6	45	92.6
170/190	2,2′,3,3′,4,4′,5/2,3,3′,4,4′,5,6	0.70	2.3	32	9.0	45	95.4
201	2,2′,3,3′4,5,5′,6	0.50	1.6	39	11.0	45	95.3
196/203	2,2′,3,3′,4,4′,5,6′/2,2′,3,4,4′,5,5′,6	0.70	2.3	38	10.0	45	94.8
195/208	2,2′,3,3′,4,4′5,6/2,2′,3,3′,4,5,5′,6,6′	0.70	2.3	30	13.0	45	93.8
194	2,2′,3,3′,4,4′,5,5′	0.50	1.6	36	12.0	45	96.5
206	2,2′,3,3′,4,4′,5,5′,6	0.40	1.3	39	17.0	45	93.8
128	2,2′3,3′4,4′	0.50	1.6	----------no data----------			
167	2,3′,4,4′,5,5′	0.50	1.6	----------no data----------			

[1]Precision-average absolute difference between duplicate analyses over several years ending August 18, 1993.

[2]Accuracy-average percent recoveries of sediment samples spiked with standard solutions analyzed under similar test conditions over several years ending August 18, 1993.

Schedule 1325 Method

The Schedule 1325 method is used for the determination of organochlorine insecticides (lindane; heptachlor; aldrin; heptachlor epoxide; technical chlordane; endosulfan I; dieldrin; *p,p'*-DDE; endrin; perthane; *p,p'*-DDD; *p,p'*-DDT; *p,p'*-methoxychlor; mirex; and toxaphene), gross polychlorinated biphenyl (PCB), and gross polychlorinated naphthalene (PCN) in sediment (Wershaw and others, 1987). Because it uses the electron-capture detector, which is nonselective, fewer compounds are identified using this method than are potentially possible using the Research method. Gross PCB are the sum of Aroclors 1242, 1254, and 1260.

Sample Preparation

The sample preparation consisted of three steps: extraction, concentration, and cleanup. Organochlorine compounds were extracted from 50 g of equivalent dry sediment. The homogenized wet or dry sediment was shaken on a wrist-action shaker for 20 minutes with 20 mL of acetone, then shaken for 10 minutes with 80 mL of hexane. The solvent was decanted and the process repeated two additional times. The combined extracts were gently rolled in a separatory funnel containing 500 mL of distilled water to remove the acetone. The hexane layer was removed and concentrated to approximately 4 mL in a 500-mL Kuderna-Danish apparatus. It was then concentrated to exactly 4 mL using a gentle stream of nitrogen.

The first step in the cleanup procedure was to fractionate the sample on an 8.5-percent deactivated alumina column using 2 mL of the 4-mL Kuderna-Danish extract. The sample was eluted with 43 mL of hexane to obtain A1 fraction (18 mL) and A2 fraction (25 mL). The A3 fraction (20 mL) was collected by eluting with 25 mL of benzene. The A1 fraction was evaporated to exactly 1 mL under a gentle stream of nitrogen. Sulfur was removed by shaking the A1 fraction with elemental mercury. The A1 fraction is further fractionated on 3.0-percent deactivated silica column that was prerinsed with hexane and eluted with 19 mL of hexane to obtain the S1 fraction (20 mL). The S2 fraction (20 mL) was collected by eluting the column with 20 mL of benzene. A portion of the final extract from the A2 and A3 fractions was archived and a portion used for analysis.

Sample Analysis

Organochlorine analytes were confirmed on a dual-column capillary gas chromatograph (Hewlett-Packard 5890) with dual electron-capture detectors. Rtx-5 and Rtx-1701 columns (30-m by 0.25-mm, Restek Corporation) were preceded with an uncoated guard column connected to the injector by glass Y union and a splitless deactivated liner. The oven temperature ramp was from 60°C (held for 2 minutes) to 180° at 30°C per minute (held for 2 minutes at 180°C), to 210°C at 1°C per minute, and finally to 280°C at 4°C per minute, and held for 5 to 25 minutes. The injector port temperature was 220°C and the detector temperature was 350°C. The carrier gas was helium and the make-up gas was nitrogen.

A solution containing *p,p'*-DDT and endrin was used to evaluate the percent breakdown of these analytes in the injection port. This was followed by standards containing aldrin; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; lindane; *p,p'*-methoxychlor; mirex; and perthane at 1, 5, 10, 20, 50, and 100 pg/μL; Aroclors 1242, 1254, and 1260 at 50 and 100 pg/μL; toxaphene at 400 and 800 pg/μL; technical chlordane at 40, 80, and 160 pg/μL; and a third-party standard containing at least six of the organochlorine analytes at 20 pg/μL. Standards were measured to within 20 percent of their acceptable value. A method blank was analyzed for every 10 samples, and a reagent spike containing all of the individual organochlorine analytes was used to monitor method accuracy.

The method detection limits were determined using the procedure outlined in the Code of Federal Regulations (U.S. Environmental Protection Agency, 1991) and were rounded up to the reporting levels. The reporting levels (see table 3.5) are listed for the analytes in the order that they elute from the Rtx-5 column. Each sample was spiked with a surrogate, isodrin, at 0.200 ng/g. The accuracy data (table 3.5) are the mean percent recovery of 20 samples for each spike analyte. The precision data (table 3.5) are the mean relative percent differences for each analyte calculated from 10 sets of sample duplicates. A midrange standard (20 pg/μL) was run every 10 samples to monitor analytical performance.

A minimum 5-point calibration curve bracketing the targeted concentration range (generally 1 to 100 pg/μL) must requantitate within 20 percent of the expected values based on a linear curve regression coefficient (r^2) greater than 0.995. Continuing calibration checks (± 20 percent) and performance check standards (breakdown less than or equal to 20 percent) were run every 8 to 10 samples. A third-party check standard was run at the beginning of each batch (± 30 percent) to ensure the standards were accurate. Surrogates were added to all samples, blanks, and spikes and had to measure within three standard deviations of the mean. Two compounds, tetrachloro-m-xylene and decachlorobiphenyl, are added to all samples as retention-time markers. More details of the sample extraction and analysis procedures are described by Wershaw and others (1987) and Hrinko (1994).

Table 3.5--Reporting levels, accuracy estimates, and precision estimates of organochlorine measurements made using the Schedule 1325 method

[These values reflect the analytical laboratory uncertainty and do not include the field sampling uncertainty; accuracy is given as the mean percent recovery (%) for 20 samples; precision is given as the mean relative perfect difference (RPD) for each analyte calculated from 120 sets of sample duplicates; reporting level is given in nanogram per gram (ng/g); and na, not available]

Compounds	Reporting level [1] (ng/g)	Accuracy (%)	Precision (RPD)
Lindane	0.1	78	11
Heptachlor	0.1	73	10
Aldrin	0.1	75	1.1
Heptachlor epoxide	0.1	74	2.5
Technical chlordane	1.0	70	5.7
Endosulfan I	0.1	67	2.6
Dieldrin	0.1	79	2.2
p,p'-DDE	0.1	82	5.3
Endrin	0.1	63	na
Perthane	1.0	103	na
p,p'-DDD	0.1	91	5.8
p,p'-DDT	0.1	77	5.8
p,p'-Methoxychlor	0.1	103	na
Mirex	0.1	68	32
Toxaphene	10.0	71	na
Gross PCB	1.0	99	3.1
Gross PCN	1.0	na	na

1 Reporting level for ideal matrix; if there are interferences, the reporting level is raised.

Table 3.6--Recoveries of isodrin added to surficial bed-sediment samples and analyzed by the Schedule 1325 method

[NA, does not apply]

Pools	Type of sample	Recovery (percent)			
		Number of		Range	Average
		Samples	Duplicates		
NA	Blank	3	0	66–77	70
2,6,8,12,15,18,21,25	Wet	10	2	52–78	67
2,3,4 (Upper Lake Pepin), 4 (Lower Lake Pepin), 8,9,11,16, 19,24,26	Dry	12	1	85–100	93
4 (Lower Lake Pepin)	Reference	3	1	46–91	61

RESULTS

The concentrations of organochlorine compounds associated with surficial bed sediments are listed in a separate table for each method. The concentrations in nanograms per gram of dry weight of selected organochlorine compounds determined by the Research method are listed in table 3.7 and were not corrected for recovery because quantitation was based on an internal surrogate. The individual PCB congener concentrations for seven pools determined by the Wisconsin State Laboratory of Hygiene method are listed in table 3.8 along with the sum of congeners or total PCB concentration.

The concentrations determined by the Schedule 1325 method are listed in table 3.9. Some values are for samples that were received wet [Pools 2 (April 1992), 6, 8 (April 1992), 12, 15, 18, 21, and 25] and some values are for samples that were received dry [Pools 2 (October 1991), 3, 4 (Upper Lake Pepin), 4 (Lower Lake Pepin), 8 (October 1991), 9, 11, 16, 19, 24, and 26)].

Polychlorinated biphenyls in surficial bed-sediment samples from some pools were measured by all three methods, and these measurements are shown in figure 3.1. The average results for chlordane, dieldrin, and PCB based on the three methods are also listed in table 3.10. Figures 3.2 and 3.3 show the spatial distribution of PCB and dieldrin in the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River. Average PCB concentrations increase from Pool 1 to a maximum of 290 ng/g in Pool 4 (Lower Lake Pepin) and then decrease to concentrations of about 10-25 ng/g in pools downstream from Pool 4. Dieldrin concentrations show more spatial variability than PCB concentrations, but the maximum for the Research and Schedule 1325 methods are 0.70 ng/g in Pool 25 and 0.8 ng/g in Pool 26, respectively.

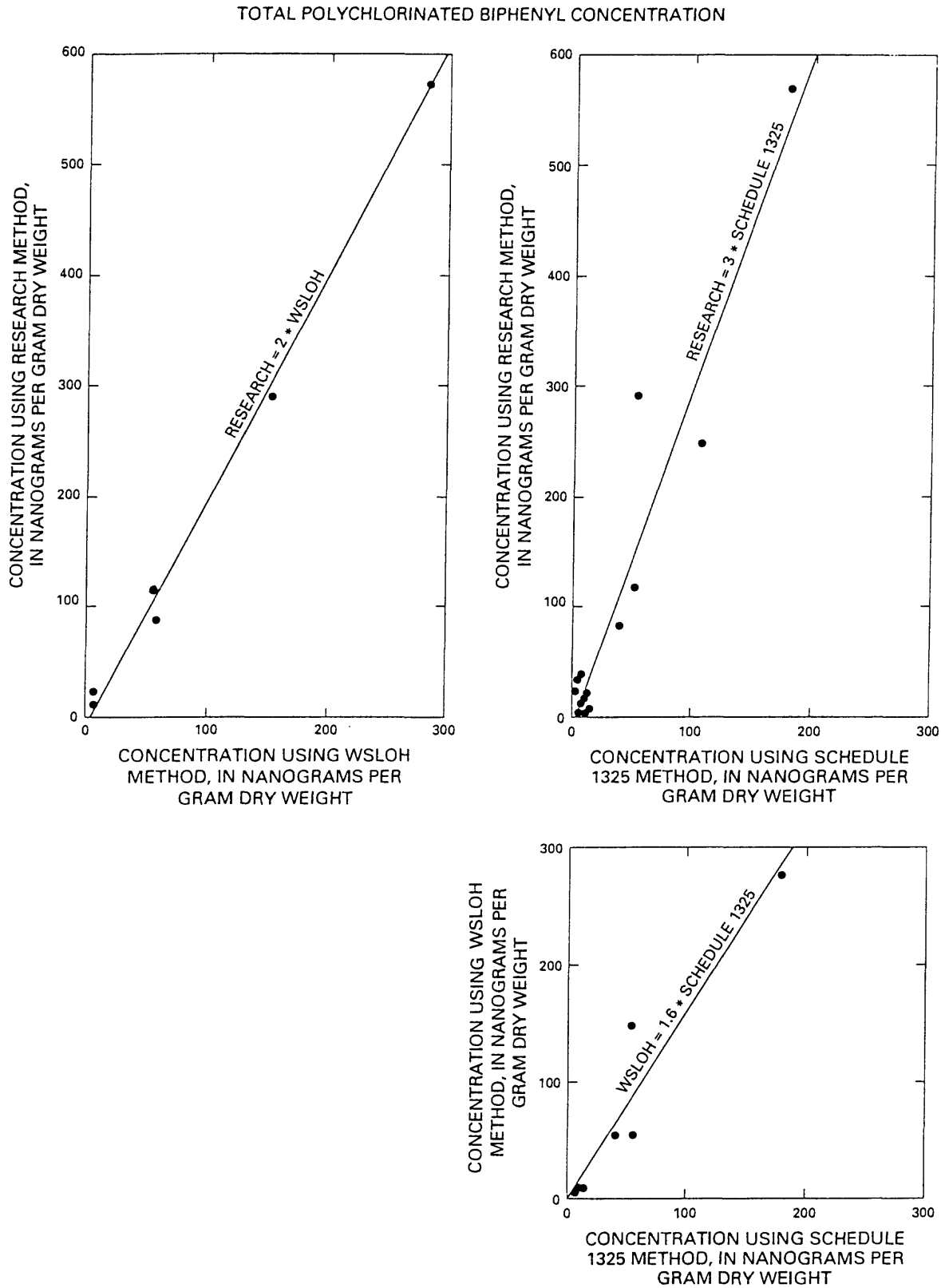

Figure 3.1--Concentration of total polychlorinated biphenyls using (A) Research and Wisconsin State Laboratory of Hygiene (WSLOH) methods, (B) Research and Schedule 1325 methods, and (C) WSLOH and Schedule 1325.

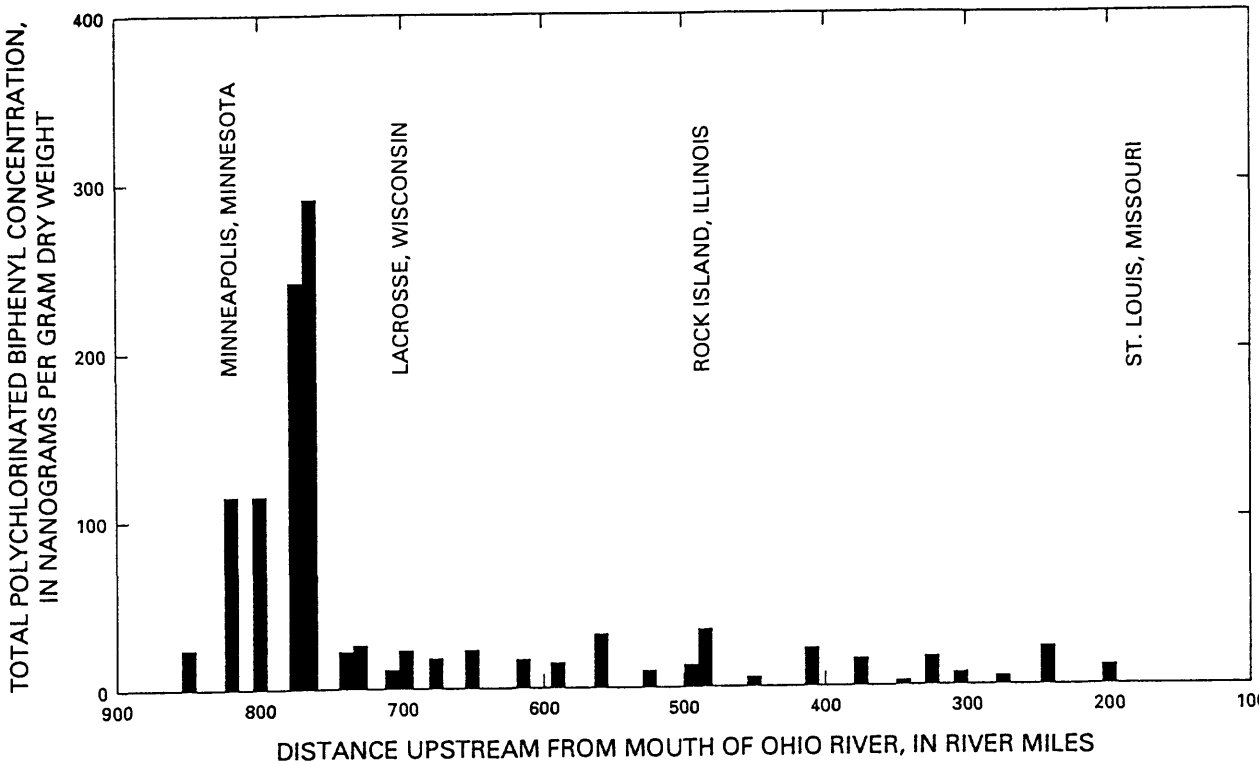

Figure 3.2.--Concentration of total polychlorinated biphenyls in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. Research data have been plotted and the three seasonal samples in pools 2 and 8 have been averaged.

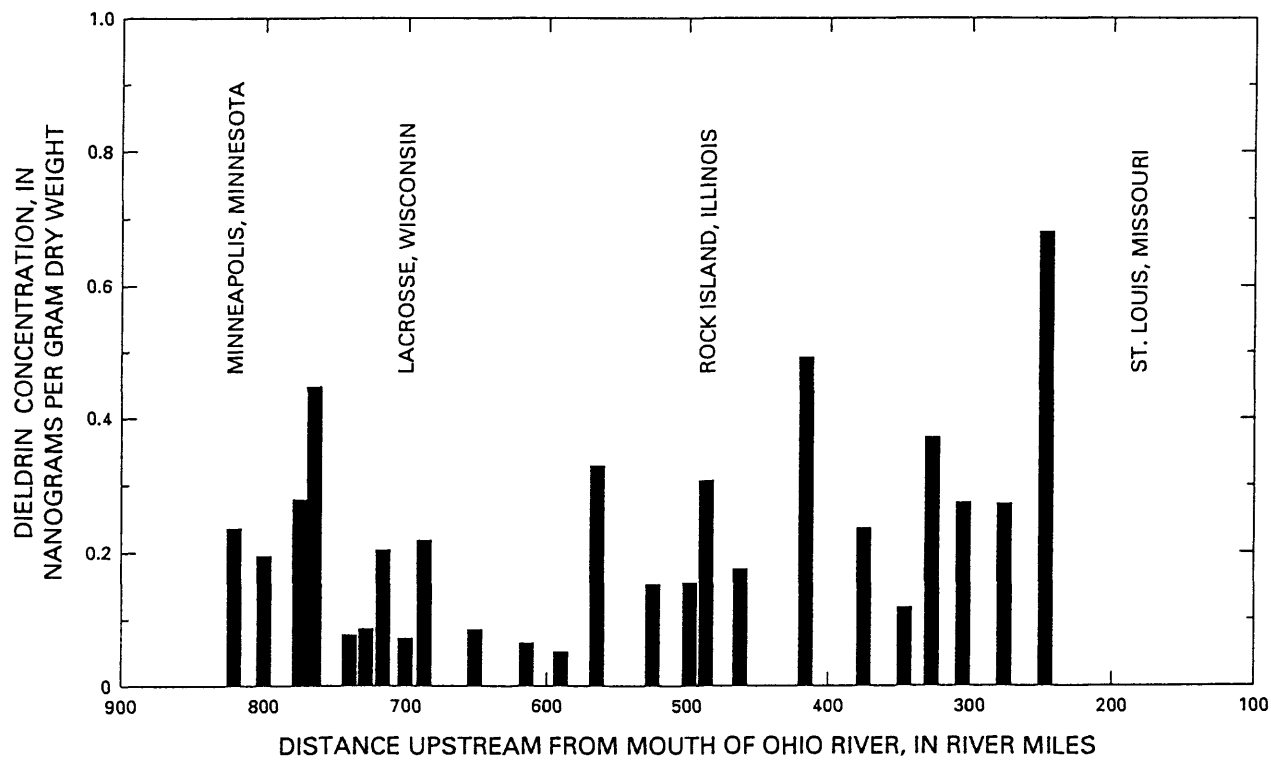

Figure 3.3--Concentration of dieldrin in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. Research data have been plotted and the three seasonal samples in pools 2 and 8 have been averaged.

Table 3.7--Concentration of organochlorine compounds in surficial bed sediments River and analyzed by the

[Analyzed by gas chromatography/negative chemical ionization/mass spectrometry; concentrations are nanogram

Pool	Date collected	Sample replicate	Penta-chloro-benzene	Hexa-chloro-benzene	Penta-chloro-anisole	DCPA (dacthal)	Trifluralin	Aldrin	Dieldrin	Endrin	Nona-chloro-biphenyl congeners
Ref.	05-15-91	1-1	---------- only polychlorinated biphenyls were measured ----------								
		1-2									
1	07-04-91	1-1	0.06	0.04	0.01	0.03	0.02	nd	nd	nd	0.01
		1-2	0.02	0.03	0.03	0.01	0.02	0.08	nd	nd	0.01
2	07-07-91	1-1	nd	nd	nd	nd	nd	nd	nd	nd	nd
	10-09-91	2-1	nd	0.03	0.04	nd	0.06	nd	0.13	nd	0.01
	10-09-91	2-2	0.07	0.05	0.10	0.01	0.06	0.13	0.20	0.08	0.01
	04-09-92	3-1	0.07	0.04	0.13	<0.01	0.06	0.07	0.24	0.18	0.01
	04-09-92	3-2	0.10	0.08	0.18	0.02	0.13	0.15	0.32	0.25	0.01
3	10-11-91	1-1-1	nd	0.03	0.07	nd	0.04	nd	nd	0.58	0.01
		1-1-2	0.05	0.05	0.20	0.01	0.04	0.09	0.19	0.02	0.01
$^{1}4$	10-14-91	1-1	nd	0.05	nd	nd	0.08	nd	nd	nd	0.01
		1-2	0.11	0.07	0.05	<0.01	nd	0.06	0.28	nd	0.01
$^{2}4$	10-12-91	1-1	nd	nd	nd	nd	nd	nd	nd	nd	0.02
		1-2	0.07	0.05	0.06	0.01	0.03	0.36	0.45	0.32	0.03
		1-3	nd	0.04	nd	nd	nd	nd	nd	1.4	0.04
		1-4	0.04	0.05	nd	nd	nd	nd	0.44	nd	nd
5	07-11-91	1-1	nd	nd	nd	nd	nd	0.14	nd	nd	nd
		1-2	<0.01	0.01	0.03	0.02	0.01	0.15	0.07	0.22	0.03
5A	07-11-91	1-1	nd	0.01	nd	<0.01	nd	0.15	nd	nd	nd
		1-2	0.02	0.01	0.01	<0.01	0.01	0.11	0.08	nd	<0.01
6	04-13-92	1-1	nd	0.01	0.03	0.01	0.01	0.16	0.06	0.15	<0.01
		1-2	nd	0.02	0.07	0.14	0.03	0.23	0.46	0.24	0.09
		1-3	nd	0.01	0.01	0.01	<0.01	0.12	0.15	0.15	nd
		1-4	0.01	0.02	0.03	0.02	0.01	0.21	0.12	0.07	<0.01
7	07-13-91	1-1	nd	0.01	nd	nd	nd	nd	nd	nd	nd
		1-2	0.02	0.01	0.01	<0.01	nd	0.16	nd	nd	<0.01
		1-3	0.01	0.01	0.03	<0.01	nd	0.05	nd	nd	<0.01
		1-4	nd	nd	nd	nd	nd	nd	nd	nd	nd
		1-5	<0.01	0.01	0.01	<0.01	<0.01	0.08	0.05	nd	nd
8	07-14-91	1-1	0.02	0.02	0.12	<0.01	0.01	0.02	nd	nd	<0.01
		1-2	nd	0.01	0.04	<0.01	0.01	0.07	nd	nd	<0.01
		1-3	nd	0.01	nd	nd	nd	nd	nd	nd	nd

collected from the downstream one-third of each navigation pool of the Upper Mississippi Research method, May 1991-April 1992

per gram of dry weight; Ref., Lake Pepin reference sample; nd, not detected; <, less than]

Pool	Chlordane				Polychlorinated biphenyls				
	Trans-	Cis-	Trans-nonachlor	Total	Penta-	Hexa-	Hepta-	Octa-	Total
for comparison with other methods- - - - - - - - - - - - - - - - -					229	309	11	2	550
					256	322	12	2	590
1	12	12	12	36	10	25	1	<1	36
	3	3	9	15	3	11	1	<1	15
2	0.18	0.26	0.48	0.92	34	67	2	<1	100
	nd	0.08	0.14	0.22	24	65	3	<1	92
	0.10	0.08	0.16	0.34	19	60	2	<1	81
	0.17	0.10	0.23	0.50	43	89	3	1	140
	0.10	0.08	0.11	0.29	47	97	3	1	150
3	nd	0.09	nd	0.09	35	90	4	1	130
	0.10	0.08	0.15	0.33	27	66	3	<1	96
1/4	0.15	nd	nd	0.15	70	204	10	2	290
	0.11	nd	nd	0.11	48	140	13	1	200
2/4	nd	nd	nd	nd	87	310	12	2	410
	0.08	0.10	0.19	0.37	48	160	6	2	220
	nd	nd	0.20	0.20	74	280	12	2	370
	nd	nd	nd	nd	39	120	7	1	170
5	nd	nd	nd	nd	7	15	<1	<1	22
	0.02	0.03	nd	0.05	3	5	<1	<1	8
5A	nd	nd	nd	nd	9	17	1	<1	27
	0.01	0.02	0.04	0.07	4	12	<1	<1	16
6	0.01	nd	nd	0.01	3	6	<1	<1	9
	0.09	0.08	0.07	0.24	2	5	<1	<1	7
	nd	nd	nd	nd	2	5	<1	<1	7
	nd	nd	nd	nd	<1	6	<1	<1	6
7	nd	nd	nd	nd	11	22	1	<1	34
	nd	0.04	nd	0.04	3	8	<1	<1	11
	0.01	nd	nd	0.01	4	10	<1	<1	14
	nd	nd	nd	nd	14	23	1	<1	38
	<0.01	0.01	nd	0.01	3	10	<1	<1	13
8	0.02	0.02	nd	0.04	1	4	<1	<1	5
	0.01	0.01	nd	0.02	2	6	<1	<1	8
	nd	nd	nd	nd	7	13	<1	<1	20

Table 3.7--Concentration of organochlorine compounds in surficial bed sediments River and analyzed by the

[Analyzed by gas chromatography/negative chemical ionization/mass spectrometry; concentrations are nanogram

Pool	Date collected	Sample replicate	Penta-chloro-benzene	Hexa-chloro-benzene	Penta-chloro-anisole	DCPA (dacthal)	Trifluralin	Aldrin	Dieldrin	Endrin	Nona-chloro-biphenyl congeners
8	04-16-92	3-1	0.04	0.06	0.06	0.01	0.01	0.33	0.16	0.09	0.01
		3-2	0.02	0.06	0.07	0.05	0.02	0.39	0.27	0.07	<0.01
9	10-19-91	1-1	nd	nd	nd	nd	nd	nd	nd	nd	nd
		1-2	0.09	0.02	0.17	0.01	nd	0.26	0.08	0.10	<0.01
10	07-16-91	1-1	nd	0.02	nd	nd	nd	nd	nd	nd	<0.01
		1-2	<0.01	0.02	nd	<0.01	0.01	0.09	0.04	nd	<0.01
		1-3	0.01	<0.01	0.01	<0.01	nd	0.02	0.08	nd	nd
		1-4	nd	nd	nd	nd	nd	nd	nd	0.09	nd
		1-5	0.01	0.01	0.03	<0.01	nd	0.02	nd	nd	0.01
		1-6	0.01	0.01	0.03	nd	nd	nd	nd	nd	<0.01
		1-7	0.07	0.01	0.01	<0.01	nd	0.08	nd	nd	0.01
11	10-20-91	1-1	nd	0.01	nd	nd	nd	0.11	nd	nd	nd
		1-2	0.07	0.01	0.04	<0.01	nd	0.07	0.05	nd	<0.01
12	04-18-92	1-1	0.05	0.07	0.06	<0.01	0.01	0.29	0.29	0.34	0.01
		1-2	0.05	0.10	0.05	0.03	0.01	0.41	0.26	0.27	0.01
		1-3	0.07	0.09	0.08	0.06	0.02	0.39	0.39	0.09	<0.01
		1-4	0.08	0.08	0.08	0.07	0.02	0.41	0.41	0.23	0.01
13	10-21-91	1-1	nd	nd	0.02	nd	nd	nd	nd	0.86	<0.01
		1-2	0.05	0.02	0.08	0.01	nd	0.05	0.16	nd	nd
		1-3	nd	nd	nd	nd	nd	nd	nd	nd	nd
		1-4	nd	nd	0.01	nd	nd	0.04	0.15	0.10	nd
14	07-19-91	1-1	0.01	0.01	0.02	<0.01	0.01	0.10	0.15	nd	nd
15	04-20-92	1-1	0.05	0.03	0.05	0.04	0.03	0.21	0.43	0.21	0.01
		1-2	0.03	0.03	0.04	0.03	0.03	0.22	0.30	0.13	0.01
		1-3	0.07	0.04	0.04	0.02	0.02	0.21	0.28	0.07	<0.01
		1-4	0.03	0.04	0.06	0.05	0.03	0.30	0.23	0.13	0.01
16	10-24-91	1-1	0.02	0.02	0.02	<0.01	0.01	0.04	0.18	0.06	nd
18	04-22-92	1-1	0.07	0.04	0.05	0.02	0.09	0.31	0.40	nd	0.01
		1-2	0.09	0.06	0.06	0.04	0.09	0.41	0.61	0.34	0.01
19	10-26-91	1-1	nd	nd	nd	nd	0.07	nd	nd	nd	nd
		1-2	0.04	0.04	0.11	<0.01	0.02	0.10	0.29	0.24	<0.01
		1-3	nd	0.01	nd	nd	0.05	nd	nd	nd	nd
		1-4	0.03	0.04	0.04	<0.01	0.03	0.12	0.22	0.14	<0.01

collected from the downstream one-third of each navigation pool of the Upper Mississippi Research method, May 1991-April 1992--Continued

per gram of dry weight; Ref., Lake Pepin reference sample; nd, not detected; <, less than]

Pool	Chlordane				Polychlorinated biphenyls				
	Trans-	Cis-	Trans-nonachlor	Total	Penta-	Hexa-	Hepta-	Octa-	Total
8	nd	nd	nd	nd	9	16	1	<1	26
	nd	nd	nd	nd	6	15	1	<1	22
9	nd	nd	nd	nd	11	13	1	<1	25
	0.02	nd	nd	0.02	2	7	1	<1	10
10	nd	nd	nd	nd	10	13	1	<1	24
	0.01	nd	nd	0.01	2	7	<1	<1	9
	0.01	0.01	nd	0.02	2	4	<1	<1	6
	nd	nd	nd	nd	8	15	<1	<1	23
	0.02	0.03	nd	0.05	<1	4	<1	<1	4
	nd	nd	nd	nd	2	4	<1	<1	6
	0.03	nd	nd	0.03	2	6	<1	<1	8
11	nd	nd	nd	nd	6	7	<1	<1	13
	0.02	0.08	0.03	0.13	1	3	<1	<1	4
12	0.04	0.04	0.06	0.14	9	20	1	<1	30
	0.03	0.03	0.06	0.11	11	19	1	<1	31
	0.04	0.02	nd	0.06	6	18	1	<1	25
	0.04	0.04	0.07	0.15	6	24	2	<1	32
13	nd	nd	nd	nd	4	5	<1	<1	9
	0.02	nd	nd	0.02	1	4	<1	<1	5
	nd	nd	nd	nd	5	5	<1	<1	10
	nd	nd	nd	nd	1	2	<1	<1	3
14	0.02	nd	nd	0.02	1	3	<1	<1	4
15	0.03	0.08	nd	0.11	18	17	1	<1	36
	0.04	0.03	0.05	0.12	20	16	1	<1	37
	0.04	nd	nd	0.04	15	15	1	<1	31
	0.05	0.03	0.06	0.14	23	15	1	<1	39
16	0.03	nd	nd	0.03	2	3	<1	<1	5
18	0.11	0.05	0.17	0.33	7	11	1	<1	19
	0.13	0.33	0.24	0.70	7	11	1	<1	19
19	nd	nd	nd	nd	8	7	<1	<1	15
	0.08	0.06	nd	0.14	1	5	1	<1	7
	nd	nd	nd	nd	8	12	1	<1	21
	0.08	0.01	0.15	0.24	2	10	1	<1	13

Table 3.7--Concentration of organochlorine compounds in surficial bed sediments River and analyzed by the

[Analyzed by gas chromatography/negative chemical ionization/mass spectrometry; concentrations are nanogram

Pool	Date collected	Sample replicate	Penta-chloro-benzene	Hexa-chloro-benzene	Penta-chloro-anisole	DCPA (dacthal)	Trifluralin	Aldrin	Dieldrin	Endrin	Nona-chloro-biphenyl congeners
20	07-22-91	1-1-1	nd	nd	nd	nd	0.02	nd	0.10	nd	nd
		1-2	<0.01	<0.01	0.02	<0.01	0.02	0.09	nd	0.05	<0.01
		1-3	0.01	<0.01	0.01	<0.01	0.02	0.09	0.15	nd	nd
		1-4	nd	nd	nd	nd	0.02	nd	0.18	nd	nd
		1-5	<0.01	0.01	0.01	<0.01	0.02	0.14	0.10	nd	nd
		1-6	nd	nd	0.02	<0.01	0.02	0.05	0.06	0.10	<0.01
21	04-24-92	1-1	0.04	0.04	0.03	0.02	0.07	0.24	0.38	0.15	<0.01
		1-2	0.04	0.04	0.02	0.03	0.09	0.27	0.49	0.13	<0.01
		1-3	0.04	0.04	0.04	<0.01	0.06	0.15	0.36	0.06	nd
		1-4	0.04	0.04	0.04	0.02	0.09	0.20	0.28	0.11	<0.01
22	07-23-91	1-1	nd	nd	nd	nd	0.03	nd	0.43	0.05	<0.01
		1-2	<0.01	0.01	0.02	<0.01	0.02	0.10	0.22	nd	<0.01
		1-3	nd	0.01	nd	nd	nd	nd	nd	nd	<0.01
		1-4	<0.01	0.01	0.01	<0.01	0.03	0.09	0.20	nd	<0.01
24	10-29-91	1-1	nd	nd	nd	nd	0.04	nd	nd	nd	nd
		1-2	0.14	0.01	0.09	<0.01	0.02	0.14	0.28	0.10	nd
25	04-25-92	1-1	0.09	0.06	0.08	0.05	0.14	0.43	0.57	0.27	0.01
		1-2	0.04	0.06	0.07	0.06	0.15	0.48	0.83	nd	<0.01
26	11-01-91	1-1	nd	nd	nd	nd	nd	nd	nd	nd	nd

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.

collected from the downstream one-third of each navigation pool of the Upper Mississippi Research method, May 1991-April 1992--Continued

per gram of dry weight; Ref., Lake Pepin reference sample; nd, not detected; <, less than]

Pool	Chlordane				Polychlorinated biphenyls				
	Trans-	Cis-	Trans-nonachlor	Total	Penta-	Hexa-	Hepta-	Octa-	Total
20	--	--	--	--	<1	<1	<1	<1	1
	0.05	nd	0.10	0.15	1	1	<1	<1	2
	0.04	0.01	0.03	0.08	<1	1	<1	<1	1
	nd	nd	nd	nd	2	2	<1	<1	4
	0.03	0.02	0.03	0.08	<1	1	<1	<1	1
	0.04	nd	0.07	0.11	<1	1	<1	<1	1
21	0.12	0.08	0.18	0.38	6	13	1	<1	20
	0.17	0.08	0.15	0.40	6	13	1	<1	20
	0.10	0.08	0.13	0.31	3	7	1	<1	11
	0.13	0.06	0.08	0.27	4	10	1	<1	15
22	0.05	nd	nd	0.05	4	5	<1	<1	9
	0.04	0.02	0.05	0.11	1	2	<1	<1	3
	nd	nd	0.14	0.14	3	4	<1	<1	7
	0.04	0.01	0.08	0.13	1	2	<1	<1	3
24	nd	nd	nd	nd	<1	6	<1	<1	6
	0.03	nd	0.06	0.09	1	3	1	<1	5
25	0.14	0.05	0.24	0.43	6	11	1	<1	18
	0.11	0.04	0.24	0.39	6	12	1	<1	19
26	0.05	nd	nd	0.05	6	2	<1	<1	8

Table 3.8--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by Wisconsin State Laboratory of Hygiene method, May-October 1991

[IUPAC, International Union of Pure and Applied Chemistry; Reference, Lake Pepin reference sample number 1 and 3; ng/g, nanogram per gram; --, no congener detected]

Congener IUPAC	Reference [1]	Pool and date sample was collected					
		2	3	4	8	9	11
	05-15-91	10-9-91	10-11-91	10-12-91	10-17-91	10-19-91	10-20-91
5/8	1.4	2.9	3.5	2.3	--	2.7	2.6
18	0.45	0.69	0.72	--	--	--	--
17	0.61	--	--	--	--	--	--
16/32	--	2.0	1.9	0.94	1.4	1.5	3.3
26	--	--	--	0.36	--	--	--
28/31	5.5	2.2	2.4	3.1	--	--	--
33	--	--	0.57	--	--	--	--
22	0.80	--	--	0.63	--	--	--
52	4.6	1.0	1.1	2.4	--	--	--
49	3.4	0.89	0.74	1.8	--	--	--
47/48	2.8	1.0	0.65	1.4	--	--	--
44	3.2	0.72	0.86	1.7	--	--	--
37/42	2.9	0.64	0.65	1.6	--	--	--
41/64/71	2.9	--	0.63	1.3	--	--	--
40	0.52	--	--	0.95	--	--	--
74	2.3	--	0.41	--	--	--	--
70/76	8.0	1.4	1.8	3.7	--	--	--
66/95	22	3.4	4.2	11	0.78	0.89	0.62
91	3.2	0.61	0.57	1.6			
56/60	4.3	--	0.96	2.1	--	--	--
84/92	7.5	1.4	1.7	4.1	--	--	--
101	12	2.0	2.4	6.7	0.33	0.42	--
99	7.5	1.0	1.1	3.8	--	--	--
97	5.3	0.75	0.90	2.7	--	--	--
87	8.3	1.1	1.4	4.2	--	--	--
136	--	--	--	0.39	--	--	--
77/110	28	4.3	5.0	15	0.66	0.82	0.57
82	2.2	0.32	0.41	1.1	--	--	--
151	3.0	0.54	0.51	1.5	--	--	--
135/144	2.4	0.41	0.41	1.2	--	--	--
149	10	1.8	2.0	5.3	--	0.33	--

Table 3.8--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by Wisconsin State Laboratory of Hygiene method, May-October 1991--Continued

[IUPAC, International Union of Pure and Applied Chemistry; Reference, Lake Pepin reference sample number 1 and 3; ng/g, nanogram per gram; --, no congener detected]

Congener IUPAC	Reference [1]	Pool and date sample was collected					
		2	3	4	8	9	11
	05-15-91	10-9-91	10-11-91	10-12-91	10-17-91	10-19-91	10-20-91
118	18	3.3	3.6	9.5	--	0.49	--
146	4.1	0.84	0.61	2.2	--	--	--
132/153	24	5.1	4.4	13	0.66	0.75	0.53
138/163	28	5.5	5.0	15.0	0.67	0.75	0.54
178	0.81	--	--	0.43	--	--	--
182/187	2.7	0.77	--	1.6	--	--	--
183	2.5	0.53	0.41	1.3	--	--	--
185	0.6	--	--	--	--	--	--
174	2.9	0.57	0.51	1.6	--	--	--
177	2.5	0.50	--	1.2	--	--	--
171/202	1.2	--	--	0.60	--	--	--
172/197	1.1	--	--	0.63	--	--	--
180	8.0	2.0	1.4	4.3	--	--	--
170/190	9.4	2.2	1.6	5.0	--	--	--
201	2.8	0.54	--	1.5	--	--	--
196/203	3.4	--	--	1.8	--	--	--
195/208	2.2	--	--	1.2	--	--	--
194	1.8	--	--	0.94	--	--	--
206	1.6	--	--	0.83	--	--	--
128	6.2	1.0	0.94	3.3	--	--	--
167	1.2	--	--	0.70	--	--	--
Sum	280	54	56	150	4.5	8.7	8.2

[1]Values are the average of two separate samples.

Table 3.9--Concentration of organochlorine compounds in surficial bed sediments River and analyzed by

[Analyzed by gas chromatography/electron-capture detector; concentrations are nanogram per gram of dry weight; NA, not and <, less than

Pool	Date	Type of sample	Sample replicate	Lindane	Hepta-chlor	Aldrin	Hepta-chlor epoxide	Technical chlordane	Endo-sulfan I	Dieldrin	*p,p'*-DDE	Endrin
NA	10-19-93	Blank	1-1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<0.1
NA	11-03-93	Blank	1-1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<0.1
NA	11-04-93	Blank	1-1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<0.1
NA	05-15-91	Ref. 1	1-1	<0.1	<0.5	<0.5	<0.1	4.0	<0.1	0.2	3.5	<0.1
NA	05-15-91	Ref. 2	2-1	<0.1	<0.1	<0.1	<0.1	7.0	<0.1	0.6	5.3	<0.6
NA	05-15-91	Ref. 3	3-1	<0.1	<0.1	<0.1	<0.1	4.0	<0.1	0.1	3.4	<0.6
			3-2	<0.1	<0.1	<0.1	<0.1	5.0	<0.1	0.4	2.9	<0.1
2	10-09-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	4.0	<0.1	0.2	0.9	<0.2
	04-09-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	3.0	<0.1	<0.1	1.4	<0.1
3	10-11-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	3.0	<0.1	0.1	1.2	<0.1
[1]4	10-14-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	4.0	<0.1	0.3	2.5	<0.1
[2]4	10-12-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	4.0	<0.1	<0.1	0.9	<0.1
6	04-13-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	<1.0	0.1	0.1	<0.1	<1.0
8	10-17-91	Dry	1-1	<0.1	<0.1	<0.2	<0.1	1.0	<0.1	<0.1	0.2	<0.1
	04-16-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	0.2	<0.1
9	10-19-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	1.0	<0.1	0.1	0.4	<0.1
11	10-20-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	0.1	0.2	<0.1
12	04-18-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	1.0	<0.1	0.1	0.4	<0.1
15	04-20-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	1.0	<0.1	0.4	0.2	<0.2
		Wet	1-2	<0.1	<0.1	<0.1	<0.1	1.0	<0.1	0.4	0.2	<0.2
16	10-24-91	Dry	1-1	<0.1	<0.1	<0.2	<0.1	1.0	<0.1	0.2	0.4	<0.1
		Dry	1-2	<0.1	<0.1	<0.2	<0.1	1.0	<0.1	0.2	0.5	<0.1
18	04-22-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	2.0	<0.1	0.4	0.9	<0.3
		Wet	1-2	<0.1	<0.1	<0.1	<0.1	2.0	<0.1	0.7	0.5	<0.1
19	10-26-91	Dry	1-1	<0.1	<0.1	<0.1	<0.2	2.0	<0.1	0.6	0.5	<0.1

collected from the downstream one-third of each navigation pool of the Upper Mississippi the Schedule 1325 method, May 1991-April 1992

applicable; PCBs, polychlorinated biphenyls; PCNs, polychlorinated naphthalenes; Ref., Lake Pepin reference sample; reporting level]

Pool	Perthane	*p,p'*-DDD	*p,p'*-DDT	*p,p'*-meth-oxychlor	Mirex	Toxaphene	PCBs Gross	PCNs Gross	Percent isodrin recovery
Blank	<1.0	<0.1	<0.1	<0.1	<0.1	<10.0	<1.0	<1.0	66.3
Blank	<1.0	<0.1	<0.1	<0.1	<0.1	<10.0	<1.0	<1.0	66.4
Blank	<1.0	<0.1	<0.1	<0.1	<0.1	<10.0	<1.0	<1.0	77.0
Ref. 1	<1.0	2.0	0.2	<0.1	<0.1	<10.0	190	<1.0	46.4
Ref. 2	<1.0	2.9	0.2	<0.1	<0.1	<10.0	220	<1.0	90.7
Ref. 3	<1.0	1.3	0.1	<0.1	<0.1	<10.0	150	<1.0	58.2
	<1.0	2.0	0.1	<0.1	<0.1	<10.0	150	<1.0	49.6
2	<1.0	1.0	0.8	<0.1	<0.1	<10.0	40	<1.0	94.0
	<1.0	1.1	<0.1	<0.1	<0.1	<10.0	33	<1.0	52.0
3	<1.0	1.0	0.7	<0.1	<0.1	<10.0	56	<1.0	86.5
[1]4	<1.0	1.6	0.3	<0.9	<0.1	<10.0	110	<1.0	84.9
[2]4	<1.0	1.2	0.4	<0.1	<0.1	<10.0	52	<1.0	95.3
6	<1.0	0.1	<0.1	<0.1	<0.1	<10.0	<2	<1.0	78.0
8	<1.0	0.1	0.1	<0.1	<0.1	<10.0	8	<1.0	87.0
	<1.0	0.1	<0.1	<0.1	<0.1	<10.0	2	<1.0	68.0
9	<1.0	0.2	<0.1	<0.1	<0.1	<10.0	13	<1.0	92.0
11	<1.0	0.1	<0.1	<0.1	<0.1	<10.0	9	<1.0	96.0
12	<1.0	0.3	<0.1	<0.3	<0.1	<10.0	4	<1.0	63.5
15	<1.0	0.2	<0.1	<0.1	<0.1	<10.0	11	<1.0	71.5
	<1.0	0.2	<0.1	<0.2	<0.1	<10.0	10	<1.0	55.0
16	<1.0	0.3	<0.1	<0.1	<0.1	<10.0	13	<1.0	97.0
	<1.0	0.4	0.1	<0.1	<0.1	<10.0	14	<1.0	100.0
18	<1.0	0.5	<0.1	<0.2	<0.1	<10.0	4	<1.0	71.5
	<1.0	0.5	<0.1	<0.1	<0.1	<10.0	8	<1.0	67.5
19	<1.0	0.3	0.1	<0.1	<0.1	<10.0	10	<1.0	95.0

Table 3.9--Concentration of organochlorine compounds in surficial bed sediments River and analyzed by

Pool	Date	Type of sample	Sample replicate	Lindane	Hepta-chlor	Aldrin	Hepta-chlor epoxide	Technical chlordane	Endo-sulfan I	Dieldrin	*p,p'*-DDE	Endrin
21	04-24-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	2.0	<0.1	0.3	0.8	<0.2
24	10-29-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	2.0	<0.1	0.4	0.3	<0.1
25	04-25-92	Wet	1-1	<0.1	<0.1	<0.1	<0.1	2.0	<0.1	0.6	1.1	<0.3
26	11-01-91	Dry	1-1	<0.1	<0.1	<0.1	<0.1	2.0	<0.1	0.8	0.6	<0.1

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.

collected from the downstream one-third of each navigation pool of the Upper Mississippi the Schedule 1325 method, May 1991-April 1992

applicable; PCBs, polychlorinated biphenyls; PCNs, polychlorinated naphthalenes; Ref., Lake Pepin reference sample; reporting level]

Pool	Perthane	*p,p'*-DDD	*p,p'*-DDT	*p,p'*-meth-oxychlor	Mirex	Toxaphene	PCBs Gross	PCNs Gross	Percent isodrin recovery
21	<1.0	0.8	<0.1	<0.1	<0.1	<10.0	4	<1.0	65.5
24	<1.0	0.1	<0.1	<0.1	<0.1	<10.0	8	<1.0	97.0
25	<1.0	0.6	<0.1	<0.1	<0.1	<10.0	4	<1.0	71.0
26	<1.0	0.1	<0.1	<0.1	<0.1	<10.0	18	<1.0	90.0

Table 3.10--Concentrations of chlordane, dieldrin, and total polychlorinated biphenyls in surficial bed sediment collected from the downstream one-third of each navigation pool of the Upper Mississippi River and analyzed by three analytical methods, May 1991-April 1992

[Values appearing in this table are in nanograms per gram and are the average values appearing in tables 3.7, 3.8, and 3.9; Research, U.S. Geological Survey Research method; WSLOH, Wisconsin State Laboratory of Hygiene method; Schedule 1325, U.S. Geological Survey National Water Quality Laboratory method; nd, not detected; --, not measured]

Pool	Date	Chlordane[1]		Dieldrin		Polychlorinated biphenyls		
		Research	Schedule 1325	Research	Schedule 1325	Research	WSLOH	Schedule 1325
Reference	05-15-91	--	5.0	--	[2]0.3	570	280	180
1	07-04-91	26	--	nd	--	26	--	--
2	07-07-91	0.92	--	nd	--	100	--	--
2	10-09-91	[3]0.28	4.0	0.16	0.2	86	54	40
2	04-09-92	0.40	3.0	0.28	<0.1	140	--	33
3	10-11-91	[3]0.21	3.0	[2]0.19	0.1	110	56	56
4 (Upper Lake Pepin)	10-14-91	[3]0.13	4.0	[2]0.28	0.3	240	--	110
4 (Lower Lake Pepin)	10-12-91	[2]0.24	4.0	[2]0.44	<0.1	290	150	52
5	07-11-91	[2]0.05	--	[2]0.07	--	15	--	--
5A	07-11-91	[2]0.07	--	[2]0.08	--	22	--	--
6	04-13-92	[2]0.12	<1.0	0.20	0.1	7	--	<2
7	07-13-91	[2]0.02		[2]0.05	--	22	--	--
8	07-14-91	[2]0.03	--	nd	--	11	--	--
8	10-17-91	--	1.0	--	<0.1	--	4.5	8
8	04-16-92	nd	<1.0	0.22	<0.1	24	--	2
9	10-19-91	[2]0.02	1.0	[2]0.08	0.1	18	8.7	13
10	07-16-91	[2]0.03	--	[2]0.06	--	11	--	--
11	10-20-91	[2]0.13	<1.0	[2]0.05	0.1	8	8.2	9
12	04-18-92	0.12	1.0	0.34	0.1	30	--	4
13	10-21-91	[2]0.02	--	[2]0.16	--	7	--	--
14	07-19-91	0.02	--	0.15	--	4	--	--
15	04-20-92	0.10	1.0	0.31	0.4	36	--	10
16	10-24-91	0.03	1.0	0.18	0.2	5	--	14
18	04-22-92	0.52	2.0	0.50	0.6	19	--	6
19	10-26-91	[2]0.19	2.0	[2]0.26	0.6	14	--	10
20	07-22-91	[2]0.10	--	[2]0.12	--	2	--	--

Table 3.10--Concentrations of chlordane, dieldrin, and total polychlorinated biphenyls in surficial bed sediment collected from the downstream one-third of each navigation pool of the Upper Mississippi River and analyzed by three analytical methods, May 1991-April 1992--Continued

[Values appearing in this table are in nanograms per gram and are the average values appearing in tables 3.7, 3.8, and 3.9; Research, U.S. Geological Survey Research method; WSLOH, Wisconsin State Laboratory of Hygiene method; Schedule 1325, U.S. Geological Survey National Water Quality Laboratory method; nd, not detected; --, not measured]

Pool	Date	Chlordane[1]		Dieldrin		Polychlorinated biphenyls		
		Research	Schedule 1325	Research	Schedule 1325	Research	WSLOH	Schedule 1325
21	04-24-92	0.34	2.0	0.38	0.3	16	--	4
22	07-23-91	[3]0.11	--	[2]0.28	--	6	--	
24	10-29-91	[2]0.09	2.0	[2]0.28	0.4	6	-	8
25	04-25-92	0.41	2.0	0.70	0.6	18	--	4
26	11-01-91	0.05	2.0	nd	0.8	8	--	18

[1]Chlordane is total chlordane for Research method and technical chlordane for Schedule 1325 method.
[2]The average does not include "not detected" values.
[3]This represents a minimum average; it is possible that the average is larger-see table 3.7.

SUMMARY

Surficial bed-sediment samples from the navigation pools of the Upper Mississippi River were analyzed for organic compounds by using three different methods: Research method was used by the U.S. Geological Survey, WSLOH method was used by the Wisconsin State Laboratory of Hygiene, and the Schedule 1325 method was used by the U.S. Geological Survey National Water Quality Laboratory.

Maximum concentration of most organochlorines in surficial bed sediments were from the upstream end of the navigation pool reach just downstream from Minneapolis and St. Paul, Minnesota. The maximum concentration of total chlordane and *p,p'*-DDT was 36 nanograms per gram (ng/g) in a sample from Pool 1 and 0.7 ng/g in a sample from Pool 3, respectively. The maximum concentrations of total polychlorinated biphenyls (410 ng/g), *p,p'*-DDD (1.6 ng/g), and *p,p'*- DDE (2.5 ng/g) were in samples from Pool 4 (Lake Pepin). However, the maximum concentration of dieldrin was 0.8 ng/g and came from Pool 26 at the downstream end of the reach near St. Louis, Missouri.

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CHAPTER 4 - Major Elements, Trace Elements, and Nutrients

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ABSTRACT

Bed-sediment cores were collected in the backwater areas from 25 of the 29 navigation pools of the Upper Mississippi River. The number of cores taken along a transect and the number of transects varied, resulting in the collection of 12 to 23 core samples per pool. The bed-sediment cores from each pool were composited and subsampled, with the less than 2-mm sediment fraction chemically digested and analyzed for major and trace elements. A water sample also was obtained at each bed-sediment-core collection site. The water sample was collected as a surface grab sample and all samples from the same pool were composited. Onsite processing consisted of filtration and preservation of the water samples soon after collection. The concentrations of dissolved constituents were determined later in a laboratory for the major cations including silicon as silica, trace elements, major anions, nutrients, and dissolved organic carbon.

Methods of analysis for the major and trace elements were inductively coupled plasma-atomic emission spectrometry for the major and high-concentration trace elements, inductively coupled plasma-mass spectrometry for the low-concentration trace elements, cold vapor-atomic fluorescence spectrometry for trace mercury, and flame atomic absorption spectrometry for potassium. Major anions were determined by ion chromatography and alkalinities by titration. Nutrients were determined by segmented-flow colorimetric spectrophotometry, and dissolved organic carbon was determined by infrared absorption spectrometry.

Digestion methods include a three-part sequential extraction for which only the values of the sums are reported. A single-step, total digestion using aqua regia and hydrofluoric acid was used as a comparison to the sums of the sequential extraction and as a means to check the mass balance.

INTRODUCTION

The Mississippi River from Minneapolis, Minn., to St. Louis, Mo., is characterized by a series of 29 locks and dams that make 29 navigation pools. This creates a very different hydrological system compared to the free-flowing Lower Mississippi River and hinders the transport and deposition of major and trace elements. The navigation pools of the Upper Mississippi act as traps for sediments transported into the Mississippi River by tributaries. Large proportions of the major and trace elements that exist in the river are associated on these sediments. This can result in the storage of these elements in the pools for long periods of time.

Major and trace elements in the Mississippi River come both from natural and anthropogenic sources. Naturally introduced elements are primarily from such sources as rock weathering, soil erosion, or the dissolution of water-soluble salts. Many tributaries along this stretch of river add significant amounts of material derived in this manner. Other elements are introduced as a result of human activities such as mining, sewage outfalls, and discharge from industry. The Upper Mississippi River flows through two major lead and zinc mining districts located along pools 9, 10, 11, and 12. Several major metropolitan areas including Minneapolis, Minn., near pools 1 and 2, Quad Cities area near pools 15 and 16, and St. Louis, Mo., downstream from pool 26, and numerous industries also are distributed along this reach of the river.

Many of the metallic elements categorized as lighter metals, or those with a specific gravity of less than 5, which include sodium, magnesium, and potassium, are found in the tissue of living organisms and are essential to life. The heavy elements have a specific gravity of greater than 5 and include such elements as copper, iron, and lead. Some of these heavy metals in very small amounts are also essential to human life, but in larger amounts are toxic. Several of these metals such as cadmium, lead, and mercury are not needed in any amount, are toxic at extremely low concentrations, and can accumulate in body tissues to toxic levels over long periods of exposure.

PURPOSE AND SCOPE

The purpose of the bed-sediment sampling was to determine the concentrations of major and trace elements in representative samples from each navigation pool. Samples were collected during July 1991-April 1992, from 25 of the 29 navigation pools between Minneapolis, Minn., and St. Louis, Mo. Sampling locations are shown in figure 1.1 of this report.

METHODS

Surficial Bed Sediment

A detailed description of the core collection method and the gravity corer used to collect the bed-sediment cores is given in Chapter 1. After the core was collected, the water column above the core in the plastic core cylinder was decanted and the ends capped. The core cylinder was put in plastic bags then placed in a cooler and later frozen no more than 3 hours after collection. The integrity of the vertical layering in the core sample was maintained through all aspects of sample collection and preservation. The cores were shipped to the laboratory frozen and stored in this condition until they were subsampled and composited.

Subsampling

Each of the individual cores collected from the same pool were thawed around the edges only and extruded from the core tube. Only the top 2 cm was subsampled by cutting the measured core with a perpendicular cut in order to sample a consistent section of the core. The core was then divided longitudinally into two equal sections, one for analysis and the other for archiving. The core sections for each transect were combined and sieved through a 2-mm nylon mesh screen to produce a transect composite sample. The transect composite sample was then representatively subsampled through a Jones-type splitter made of Teflon, and the correct amount from each transect was combined proportionally, according to the number of cores collected per transect, producing a pool composite.

Dewatering of the pool composite sample was accomplished by centrifugation at 35,800 times the force of gravity, and the resulting paste was mixed by coning (a mixing technique that requires the paste to be folded over on itself by alternating the fold axis by 90 degrees until the sample is homogeneous) then subsampled with Teflon utensils. Two or more subsamples were taken from the pool composite sample and weighed wet. One was used for chemical analysis while the other was used to determine the percent moisture to obtain a final dry weight for the sample that was used in the chemical analysis. The sediment digestion follows the method outlined by Hayes (1993).

Sequential Extraction and Total Digestion

The data from a sediment extraction listed in this chapter represent a sum of three different phase extractions of a single sample. The first two extractions were a leaching of the various coatings found on the particles; the third was a total digestion of the leftover residual. The additional handling may increase the error of the final value; however, this value represents a complete digestion of the sediment sample and can be checked against a single-step total digestion. The sum of the extraction-phase concentrations and total digestion concentrations are listed in table 4.1. Additional information about the sequential extraction is described by Hayes (1993).

Table 4.1--Comparison of certified values, total digestion, and the sum of the sequential extraction concentrations for National Institute of Standards and Technology standard reference material

[Reference material was No. 2704 Buffalo River Sediment; ±, the uncertainty represents 1 standard deviation of the analysis of 4 samples for the total digestion and 19 samples for the sum of sequential extraction; and nd, below detection limits in the individual extracts]

Element	Concentration (micrograms of analyte per gram of dry sediment)								
	Certified value			Total digestion			Sum of sequential extraction		
Aluminum	61,100	±	1,600	60,300	±	200	50,600	±	3,200
Barium	414	±	12	424	±	29	388	±	14
Cadmium	3.45	±	0.22	3.56	±	0.08	nd	±	nd
Calcium	26,000	±	300	26,600	±	2,000	26,000	±	2,000
Chromium	135	±	5	138	±	10	120	±	8
Cobalt	14.0	±	0.6	21.9	±	4.0	13.5	±	0.8
Copper	99	±	5.0	92.0	±	4.2	113.5	±	6.8
Iron	41,100	±	1,000	42,200	±	4,600	40,200	±	2,600
Lead	161	±	17	130	±	17	141	±	8
Magnesium	12,000	±	200	11,800	±	200	11,700	±	480
Manganese	555	±	19	561	±	33	554	±	31
Silicon	291,000	±	1,300	161,000	±	14,000	144,200	±	11,000
Titanium	4,570	±	180	2,600	±	600	1,980	±	350
Vanadium	95	±	4	90	±	5	82	±	4
Zinc	438	±	12	446	±	36	447	±	27

The total digestion was identical to the final step of the extraction procedure. It was a one-step aqua regia/hydrofluoric microwave digestion of the sample. Reagent quantities were adjusted to account for the additional material to be digested because of the absence of any previous leaching treatments (Hayes, 1993).

Analysis of Bed-Sediment Digestion Extracts

Analytical methods used for the analysis of the extract of the digestion included inductively coupled plasma-atomic emission spectrometry, inductively coupled plasma-mass spectrometry, and cold vapor-atomic fluorescence spectrometry. Elements determined by the inductively coupled plasma-atomic emission spectrometry method (Garbarino and Taylor, 1979) included aluminum, barium, calcium, iron, magnesium, manganese, silicon (as silica), strontium, and vanadium. Elements analyzed by inductively coupled plasma-atomic emission spectrometry were all well above the analytical detection limits. Cadmium, chromium, copper, lead, and zinc were determined using an inductively coupled plasma-mass spectrometry method described by Garbarino and Taylor (1993) and Hayes (1993). The detection limits for cadmium, chromium, copper, lead, and zinc are 1.3, 2.7, 1.1, 1.7, and 9.1 μg/g of sediment dry weight, respectively (Hayes, 1993). Mercury was determined following the method outlined by Roth (1994). The detection limit for mercury is 0.006 μg/g of sediment dry weight. All detection limits were calculated assuming a dry sediment weight of 0.100 g.

Accuracy and Precision

Accuracy and precision data for the sum of the sequential extractions and the total digestions (based on the analysis of Standard Reference Material, National Institute of Standards and Technology No. 2704 Buffalo River Sediment) for selected major and trace elements are in table 4.1; for mercury they are in table 4.2. All samples were analyzed in a random fashion, background-corrected, and reagent blank subtracted.

To ensure that a mass balance of the extracted elements was obtained during the sequential extraction procedure, element concentrations in the total digestion were compared to the concentrations of the sum of the sequential extraction for 15 Mississippi River sediment samples. The sum of the sequential extractions divided by the total digestion concentrations yields a value of between 96 and 120 percent for all the elements analyzed with the exception of silicon. The results are shown in table 4.3. In addition, for the National Institute of Standards and Technology Standard Reference Material No. 2704 Buffalo River sediment, the sum of extracted element concentrations were compared to the total digestion concentrations as well as to the certified values. The results, tabulated in table 4.1, show the comparison between values of the total digestion and sum of sequential extraction concentrations.

To evaluate the precision of the sequential extraction, a National Institute of Standards and Technology standard reference material, No. 2704 Buffalo River sediment sample was extracted along with each set of sample extractions. The reference material samples were analyzed in the same manner as the samples and distributed periodically throughout the analysis run sequence. The resulting precision represents the variability associated with the entire process, from subsampling and extracting the sediment to the analysis of the sample extracts. The relative standard deviations for the sum of sequential extraction data were 7.7 percent or less for all the elements analyzed except titanium (see tables 4.1 and 4.2). The relative standard deviations can be also used to measure the precision of the total digestion results (see data in table 4.1). The relative standard deviations for these results were less than 11 percent, with the exception of cobalt and titanium.

Table 4.2--Accuracy and precision data for the sum of sequential extractions for mercury

[Concentrations for the bed-sediment samples are in micrograms of mercury per gram of dry sediment; units for water samples are in micrograms of mercury per liter; published values are based on the standard reference sediment and standard reference water samples used in the determination of mercury in surficial bed sediments; NIST represents National Institute of Standards and Technology; USGS-SRWS represents U.S. Geological Survey Standard Reference Water Samples]

Sample	Number of replicates	Published		Analytical	
		Mean	Standard deviation	Mean	Standard deviation
Standard Reference Sediment Sample					
NIST No. 2704 Buffalo River Sediment	8	1.47	0.07	1.47	0.11
Standard Reference Water Samples					
USGS-SRWS Hg 7	47	0.022[1]	0.006[2]	0.022	0.003
USGS-SRWS Hg 10	43	0.140[1]	0.008[2]	0.150	0.005

[1]Standard concentration based on a 1:10 dilution.
[2]Calculated by dividing the original standard deviation by 10 assuming no change in relative standard deviation.

Table 4.3--Mass balance results of sequential extractions

[Sum is the summation of the concentrations in the hydroxylamine, persulfate, and residual extracts; total is the concentration in the total digestion of the sample; ±, the uncertainty represents 1 standard deviation of 15 Mississippi River samples; %, percent]

Element	Sum/Total (%)
Aluminum	98 ± 2
Barium	96 ± 2
Calcium	103 ± 5
Chromium	107 ± 6
Copper	120 ± 11
Iron	104 ± 1
Lead	112 ± 3
Magnesium	99 ± 1
Manganese	98 ± 2
Silicon	135 ± 4
Vanadium	99 ± 2
Zinc	115 ± 10

Surface Water

Surface-water grab samples were collected at every site where a bed-sediment core sample was collected, and all surface-water grab samples from the same pool region were composited. One composite surface-water sample was collected from each pool except for Lake Pepin, from which a lower and an upper Lake Pepin composite were obtained. The water was collected in a clean 1-L Teflon beaker and composited in a 20-L Teflon-coated stainless-steel churn splitter (Leenheer and others, 1989). The 1-L Teflon beaker was rinsed with river water at each site a minimum of two times before the sample was collected. The beaker was inverted as it passed through the water-air interface, then turned upright to collect the water sample just below the surface of the water. The water in the beaker was carefully poured into the churn splitter, and the cover of the splitter was replaced. Individual subsamples were split from the composite for major cations (including silicon as silica) and trace elements, mercury, major anions and alkalinity, nutrients, and dissolved organic-carbon analyses.

Subsampling

The major cation and trace-element subsample was filtered to remove the greater than 0.04-µm particulate matter using an all-Teflon, vacuum filter apparatus described in Garbarino and others (1995). Protocols for this method were as follows:

1. The filter funnel was thoroughly cleaned and rinsed with deionized water with a minimum resistivity of 17.8 Mohms/cm.
2. A new membrane filter was placed on the filter support using Teflon-coated tweezers and was precleaned by filtering 20 mL of 0.1 percent (volume/volume) ultrapure nitric acid rinse solution into a waste bottle.
3. The filter was then rinsed by filtering 50 mL of deionized water.
4. About 25 mL of the shaken, composited subsample was then filtered to prerinse the sample bottle and also to preload the filter with particulate from the sample for more uniform filtration, the rinse was then discarded.
5. The filter funnel was filled to a volume equal to the volume of the sample bottle and the vacuum was applied.
6. The approximately 225-mL filtered sample was preserved by adding 1 mL of concentrated ultrapure nitric acid (to a pH less than 2) from a Teflon dispensing bottle.
7. The sample was labeled; and
8. All filter apparatus was cleaned with deionized water in preparation for the next sample.

Two types of mercury subsamples were split from the composite surface-water sample. A 125-mL subsample was filtered into a precleaned glass bottle following the protocol listed for major cations and trace elements above and preserved by adding 5 mL of a solution that contains 0.04 percent (weight/volume) potassium dichromate and 4 percent (volume/volume) concentrated nitric acid. Using the same filter, a second subsample from the composite surface-water sample was filtered into an amber glass bottle, left unpreserved, and immediately chilled.

The major anion and alkalinity subsamples were split from the composite surface-water sample into a 250-mL deionized rinsed, polyethylene bottle and immediately chilled to about 4°C without any additional preservatives. These raw water samples were transported on ice to the laboratory.

From the composite surface-water sample a nutrient subsample for nitrate, nitrite, ammonium, and orthophosphate was split into a 250-mL opaque polyethylene holding bottle. The subsample was pressure-filtered with argon gas through a 47-mm-diameter silver-membrane filter with a nominal pore size of 0.45 µm. The filtrate was collected into a clean 250-mL opaque polyethylene bottle and immediately chilled. On the cruise, during the period of July-August 1991, two types of subsamples were filtered. The first for shipboard analysis, and the second was sent back to the laboratory where it was frozen until analysis. Only one subsample was collected per pool on the October-November 1991 cruise. The filtered samples were chilled immediately and every few days they were shipped to the laboratory and analyzed within a week. On the April-May 1992 cruise, the filtered subsamples were frozen and shipped to the laboratory where they were analyzed within a month.

The dissolved organic-carbon subsamples were filtered into preburned 125-mL amber glass bottles using the same silver-membrane filter previously described for the nutrient sample. The filtered subsamples were immediately chilled to 4°C until they were analyzed.

Analysis of the Surface-Water Composite Samples

Analytical methods used for the determination of major cations and trace elements included inductively coupled plasma-atomic emission spectrometry, inductively coupled plasma-mass spectrometry, flame atomic absorption spectrometry, and cold vapor-atomic fluorescence spectrometry. The major cations [calcium, iron, magnesium, silicon (as silica), sodium, and strontium] were analyzed by inductively coupled plasma-atomic emission spectrometry following the method outlined by Garbarino and Taylor (1979), Garbarino and Taylor (1980), and Skougstad and others (1979). Trace elements including aluminum, arsenic, boron, barium, beryllium, cadmium, cobalt, chromium, copper, lead, lithium, manganese, molybdenum, nickel, thallium, uranium, vanadium, and zinc were analyzed using an inductively coupled plasma-mass spectrometry following the methods of Taylor and Garbarino (1991) and Garbarino and Taylor (1993). Potassium was determined by flame atomic absorption spectrometry using an air-acetylene oxidizing flame. Details of the methodology can be found in Skougstad and others (1979). Detection limits and analytical precision for the major cations and trace elements are in table 4.4. Mercury was determined using the method outlined by Roth (1994). The detection limits for mercury were based on the blank levels found in the preservative ampoules and are listed in table 4.5.

Table 4.4--Detection limits, quantitation limits, and analytical precision data of major elements and trace elements for the determination of dissolved constituents in water

[Units are in micrograms of element per liter; --, not determined]

Element	Detection limit	Quantitation limit[1]	Concentration at 5 times detection limit[1]	Percent relative standard deviation
Aluminum	0.2	0.42	1.4	11
Arsenic	0.6	2.4	3.1	17
Barium	0.1	0.34	0.53	14
Beryllium	0.02	0.078	0.10	17
Boron	0.4	2.4	2.2	23
Cadmium	0.1	0.46	0.45	22
Calcium	20	--	100	3.2
Chromium	0.2	0.54	1.0	12
Cobalt	0.008	0.028	0.051	12
Copper	0.02	0.096	0.14	15
Iron	5	--	100	16.1
Lead	0.06	0.29	0.33	19
Lithium	0.03	0.064	0.08	14
Magnesium	4	--	100	0.4
Manganese	0.06	0.23	0.30	17
Molybdenum	0.09	0.22	0.39	13
Nickel	0.03	0.16	0.20	17
Potassium	100	--	500	3.5
Selenium	3	14	17	17
Silica	40	--	100	24.3
Sodium	10	--	100	1.8
Strontium	0.01	0.084	0.059	31
Thallium	0.05	0.14	0.26	12
Uranium	0.06	0.26	0.39	14
Vanadium	0.07	0.19	0.40	10
Zinc	0.08	0.39	0.36	24

[1]Concentration at approximately 5 times the detection limit or as otherwise stated for Calcium, Iron, Magnesium, and Silica.

Table 4.5--Quantitation limits of mercury for surface-water samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River during three cruises, July 1991-May 1992

[Units in micrograms of mercury per liter]

Cruise	Quantitation limit[1]
July-August 1991	0.008
October-November 1991	0.004
April-May 1992	0.004

[1]The quantitation limit for mercury was based on the square root of 2 times the variance calculated from the field blanks from the same lot of mercury preservative ampoules.

Analysis methods for anionic species and dissolved organic carbon include ion chromatography, titration, absorption spectrometry, and infrared absorption spectrometry. The major anions, chloride and sulfate, were determined following the ion chromatography techniques described by Brinton and others (1995). Alkalinity was calculated using titration data from unfiltered but settled aliquots from the major anions and alkalinity subsample. Carbonate and bicarbonate concentrations were calculated from the alkalinity and field pH data (Hem, 1989; Skougstad and others, 1979). Nutrients, including nitrate, nitrite, orthophosphate, and ammonium, were determined using the method of Antweiler and others (1993) on a segmented-flow, colorimetric nutrient autoanalyzer. For more information on the accuracy, precision, and detection limits see table 4.6 and table 4.7.

Table 4.6--Detection limits and analytical precision data of major anions and nutrients for the determination of dissolved constituents in water

[Sulfate and chloride are in milligrams per liter; nitrate and nitrite are in milligrams of nitrogen per liter; orthophosphate is in milligrams of phosphorus per liter; --, not determined]

Constituent	Detection limit	Concentration at 5 times detection limit[1]	Percent relative standard deviation
Sulfate	0.02	0.1	7.0
Chloride	0.02	0.1	16.0
Alkalinity[2]	--	176.3	0.4
Nitrate plus nitrite[3]	0.02	0.2	17.9
Nitrite	0.0016	0.020	14.1
Orthophosphate	0.0019	0.010	15.6
Ammonium	0.006	0.033	17.5

[1]Concentration at approximately 5 times the detection or as otherwise stated for bicarbonate and carbonate.

[2]Alkalinity concentration is used to calculate both bicarbonate and carbonate. Analytical method is a titration for bicarbonate and carbonate, and all samples were well above unmeasurable levels; therefore, no detection limit is given.

[3]Nitrate plus nitrite and nitrite are the two concentrations that are actually measured; therefore, nitrate is calculated by taking the difference.

Table 4.7--Accuracy and precision data for major anions and nutrients

[Published values are based on the U.S. Geological Survey Standard Reference Water Samples for the determination of dissolved constituents in water; sulfate and chloride are in milligrams per liter; nitrate and nitrite are in milligrams of nitrogen per liter; orthophosphate is in milligrams of phosphorus per liter; alkalinity is in milligrams bicarbonate per liter; --, not determined]

Constituent	Standard[1]	Published		Analytical		Number of samples
		Mean	Standard deviation	Mean	Standard deviation	
Sulfate	M104	225	4	226.1	4.5	26
	M112	25.0	1.5	24.8	1.1	10
Chloride	M104	69.2	0.7	71.5	1.2	26
	M112	46.0	0.7	48.7	1.2	10
Alkalinity[2]	M102	176	4	176.3	0.7	28
	M104	123	3	118.9	0.4	15
Nitrate plus nitrite	N-30	0.442	0.012	0.43	0.03	125
Nitrite	N-34	0.030	--	0.046	0.003	22
Orthophosphate	N-30	0.260	0.006	0.277	0.009	90
Ammonium	N-30	0.210	0.005	0.20	0.03	106

[1]Standards are U.S. Geological Survey Standard Reference Water Samples.
[2]Alkalinity concentration is used to calculate both bicarbonate and carbonate.

Quality Control and Quality Assurance

In all sampling methods, extreme care was used to minimize possible contamination by employing Teflon, high-density polyethylene, and where necessary, Teflon-coated stainless-steel sample-processing equipment. The use of Teflon or non-talc, polyvinyl chloride gloves was required for all sample-handling and processing procedures. The 20-L churn coated with Teflon and all other processing devices used to collect the sample were cleaned with deionized water with a minimum resistivity of 15.0 MΩ/cm prior to sampling. The 1-L Teflon beaker was washed thoroughly with deionized water prior to each sampling excursion and rinsed several times with sample water before the sample was composited.

Field blanks were used to identify possible sources of contamination during the collecting and processing of samples. One to two times during each cruise, a series of field blanks was processed in the same manner as the samples collected from the pools. All aspects of the sample-collection procedure were included and isolated to identify possible sources of contamination. Prior to processing the field blank, a sample of the shipboard deionized water was collected. While processing the shipboard deionized water through the entire procedure, subsamples were taken at various steps to isolate possible contamination sources. All field blanks were preserved and treated in the same manner as the samples.

Additional blanks for mercury were processed to allow for correction of measurable levels of mercury found in the potassium dichromate/nitric acid ampoules used as a preservative. The mercury concentration levels varied among ampoule lots making it necessary to use blanks preserved from the same lot to compute averages and error analyses for blank subtraction and limits of quantitation. A complete listing of blank concentrations for all dissolved sample processing and collection steps can be found in Garbarino and others (1995).

Reference standards were used to monitor the accuracy of the analyses. Multiple analyses of the same samples were used to check analytical precision. The accuracy of the sample data was ensured by analyzing 1 to 3 standard reference materials periodically within each set of unknown samples. Reference standards routinely composed about 15 to 30 percent of the suite of samples for analysis, or about 1 or 2 in every 6. Calibration of the instruments varied depending on the particular instrument, and the appropriate reference should be consulted for further information. Sample unknowns were reanalyzed whenever the duplicates deviated from one another by an amount that depended on the particular instrument and analyte (see the reference for the applicable method) or when standard reference water samples deviated more than 1.5 standard deviations from the certified value. Data for some of the standard reference water samples used for quality control of the dissolved-phase species for these analyses are listed in table 4.7 and listed in a report by Garbarino and others (1995). Table 4.2 contains quality-control data for mercury from the standard reference sediment and from the analytical standard reference water samples for the bed-sediment analyses. Quality-control data from the standard reference sediment used in the analysis of the extracts from the sediment digests for metals other than mercury are listed in table 4.1 and by Hayes (1993).

RESULTS

Results for the sum of sequential extractions of surficial bed sediment are listed in table 4.8. They are the mean of two or more replicate analyses from a single sequential extraction. These numbers represent the total amount of analyte found in the sediment sample. When sample concentrations are less than or equal to the detection limit the results are identified as "less than values" with "<" preceding the detection limit value. Parameters that were not determined for a particular sample or that were in error are identified by "--."

The results of the dissolved major and trace elements in surface-water grab samples listed in tables 4.9 through 4.12 represent a mean of two or more replicate analyses.

Table 4.8--Concentration of major and trace elements as the sum of sequential extractions of surficial bed-sediment samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991–April 1992

[--, not determined; <, less than the detection limit; units in micrograms per gram dry sediment weight]

Pool	Date	Alumi-num	Barium	Cadmium	Calcium	Chromium	Copper	Iron
1	07-04-91	42,000	350	<1.3	13,900	17	12	12,000
2	07-07-91	56,000	470	<1.3	36,800	34	26	20,000
	10-09-91	29,000	480	<1.3	41,800	32	28	18,000
	04-09-92	32,000	500	<1.3	44,100	44	37	21,000
3	10-11-91	35,000	520	1.3	44,200	47	44	24,000
[1]4	10-14-91	41,000	610	2.4	34,600	68	57	36,000
[2]4	10-12-91	46,000	600	2.3	27,900	92	59	43,000
5	07-11-91	37,000	300	<1.3	9,900	17	17	15,000
5A	07-11-91	25,000	420	<1.3	14,000	34	26	19,000
6	04-13-92	15,000	300	<1.3	6,400	14	16	12,100
7	07-13-91	49,000	450	<1.3	8,200	33	33	20,000
8	07-14-91	27,000	530	<1.3	19,500	28	29	19,000
	10-17-91	26,000	500	<1.3	18,200	25	23	15,000
	04-16-92	21,000	370	<1.3	12,400	20	22	14,000
9	10-19-91	62,000	560	<1.3	15,500	48	32	25,000
10	07-16-91	25,000	410	<1.3	17,200	34	29	20,000
11	10-20-91	27,000	450	<1.3	24,600	26	22	17,000
12	04-18-92	36,000	570	<1.3	16,800	42	44	23,000
13	10-21-91	26,000	470	<1.3	19,200	25	28	14,000
14	07-19-91	16,000	260	<1.3	7,200	19	18	10,000
15	04-20-92	33,000	280	<1.3	6,900	15	12	11,000
16	10-24-91	23,000	380	<1.3	12,500	20	26	14,000
18	04-22-92	19,000	290	3.4	14,800	24	25	12,000
19	10-29-91	39,000	610	<1.3	23,000	56	49	26,000
20	07-22-91	23,000	340	<1.3	8,700	23	25	12,000
21	04-24-92	36,000	320	<1.3	7,400	13	7.3	10,000
22	07-23-91	21,000	360	<1.3	8,700	20	21	11,000
24	10-29-91	53,000	430	<1.3	8,800	33	20	18,000
25	04-25-92	25,000	370	<1.3	9,300	31	25	16,000
26	11-01-91	70,000	550	<1.3	10,100	47	42	30,000
Illinois River[3]	10-31-91	77,000	520	<1.3	12,800	58	50	34,000

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.
[3]Sediment grab sample taken from midchannel on the Illinois River.

Table 4.8--Concentration of major and trace elements as the sum of sequential extracts from surficial bed-sediment samples collected from the downstream one-third of each navigation pool of the Upper Mississippi River, July 1991–April 1992--Continued

Pool	Date	Lead	Magnesium	Manganese	Mercury	Silica	Strontium	Vanadium	Zinc
1	07-04-91	13	3,800	280	0.036	492,000	180	31	27
2	07-07-91	16	13,600	730	0.092	824,000	191	72	61
	10-09-91	18	15,800	840	0.095	31,000	175	54	68
	04-09-92	21	16,900	980	0.123	56,000	169	62	80
3	10-11-91	23	17,700	1,390	0.136	39,000	153	75	97
[1]4	10-14-91	38	12,200	1,640	0.295	43,000	88	98	148
[2]4	10-12-91	45	11,400	1,880	0.281	68,000	115	108	166
5	07-11-91	9.0	3,200	430	0.038	--	89	43	34
5A	07-11-91	12	6,900	710	0.063	47,000	98	43	48
6	04-13-92	7.5	3,100	490	0.047	19,000	69	27	22
7	07-13-91	13	3,700	570	0.065	--	115	58	63
8	07-14-91	11	6,600	770	0.054	37,000	109	42	50
	10-17-91	11	5,600	660	0.039	34,000	118	38	42
	04-16-92	10	3,900	530	0.056	42,000	87	33	39
9	10-19-91	16	6,200	760	0.068	--	151	76	56
10	07-16-91	14	5,400	740	0.070	45,000	88	45	62
11	10-20-91	13	10,700	770	0.082	29,000	113	42	57
12	04-18-92	38	7,500	990	0.130	41,000	122	60	243
13	10-21-91	14	8,500	670	0.070	31,000	120	40	66
14	07-19-91	10	2,800	370	0.047	30,000	67	23	36
15	04-20-92	9.0	3,300	310	0.029	--	117	30	39
16	10-24-91	12	5,000	540	0.033	38,000	93	34	44
18	04-22-92	13	4,700	520	0.073	23,000	75	29	49
19	10-29-91	24	6,700	1,410	0.067	48,000	105	76	123
20	07-22-91	10	2,600	420	0.026	34,000	97	29	35
21	04-24-92	10	2,100	260	0.040	--	126	30	29
22	07-23-91	10	3,000	430	0.071	25,000	105	28	30
24	10-29-91	12	3,600	530	0.032	--	122	59	43
25	04-25-92	12	3,400	620	0.045	44,000	95	37	51
26	11-01-91	20	5,500	920	0.077	--	127	105	87
Illinois River[3]	11-10-91	22	8,400	870	0.057	--	121	113	94

Table 4.9--Concentration of dissolved major elements including silicon as silica in composited surface-water grab samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991–April 1992

[<, less than the detection limit; units in milligrams per liter]

Pool	Date	Calcium	Magnesium	Potassium	Silica	Sodium
1	07-04-91	48.6	17.5	2.7	12.2	7.2
2	07-07-91	71.7	28.0	3.8	18.5	12.2
	10-09-91	78.4	31.8	4.6	14.6	21.2
	04-09-92	75.5	30.8	3.1	9.7	15.0
3	10-11-91	60.7	23.9	3.6	14.2	15.4
[1]4	10-14-91	62.0	25.8	3.7	15.0	13.5
[2]4	10-12-91	64.2	24.8	3.8	16.7	14.2
5	07-11-91	69.9	26.7	3.3	18.0	11.7
5A	07-11-91	68.6	26.1	1.6	17.6	11.4
6	04-13-92	51.3	19.7	2.3	10.7	8.7
7	07-13-91	63.8	23.9	3.1	16.9	10.5
8	07-14-91	67.8	25.4	3.2	16.9	11.1
	10-17-91	55.2	21.0	3.2	14.2	11.1
	04-16-92	50.0	19.5	2.5	9.2	8.7
9	10-19-91	53.9	20.9	3.3	13.7	10.7
10	07-16-91	64.3	24.6	3.0	13.7	10.7
11	10-20-91	48.4	20.9	3.0	11.2	9.2
12	04-18-92	43.2	18.0	2.7	6.8	8.0
13	10-21-91	51.6	20.5	3.1	11.0	10.5
14	07-19-91	62.9	24.4	3.0	11.0	11.4
15	04-20-92	44.6	18.0	2.7	6.6	8.2
16	10-24-91	49.9	23.2	3.2	8.7	11.6
18	04-22-92	47.8	21.2	2.7	6.1	9.0
19	10-29-91	48.9	22.0	3.3	9.2	11.7
20	07-22-91	59.6	23.1	2.9	9.1	9.8
21	04-24-92	48.2	19.1	2.7	7.3	9.2
22	07-23-91	57.7	23.0	3.3	6.7	10.5
24	10-29-91	52.7	21.6	3.6	9.1	14.9
25	04-25-92	51.6	19.9	3.1	7.8	10.2
26	11-01-91	51.4	21.3	3.4	9.0	15.7

[1]Sample from the upper reaches of Lake Pepin (pool 4).
[2]Sample from the lower reaches of Lake Pepin (pool 4).

Table 4.10--Concentration of dissolved trace elements in composited surface-water grab samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991–April 1992

[--, not determined; <, less than the detection limit; units in micrograms per liter]

Pool	Date	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead
1	07-04-91	2.2	3.0	48.2	0.05	36.1	<0.1	<0.2	0.08	1.25	11	<0.06
2	07-07-91	2.5	3.2	70.7	0.02	65.3	<0.1	<0.2	0.12	1.42	6	<0.06
	10-09-91	4.0	2.7	61.9	0.07	77.4	<0.1	0.5	<0.01	1.58	8	0.06
	04-09-92	2.9	<0.6	55.0	0.04	51.2	<0.1	1.5	0.13	1.58	18	0.06
3	10-11-91	122.1	2.2	48.8	0.03	64.2	<0.1	0.7	0.19	1.85	252	0.41
[1]4	10-14-91	6.7	2.3	53.3	<0.02	52.4	<0.1	<0.2	0.18	1.66	30	0.25
[2]4	10-12-91	6.1	2.7	51.3	<0.02	63.3	<0.1	0.3	<0.01	2.34	10	<0.06
5	07-11-91	3.1	1.7	57.8	<0.02	49.6	<0.1	<0.2	<0.01	1.48	5	<0.06
5A	07-11-91	1.7	2.1	58.0	<0.02	45.3	<0.1	<0.2	<0.01	1.36	<5	<0.06
6	04-13-92	5.8	0.6	35.2	0.02	28.7	<0.1	<0.2	<0.01	1.39	43	<0.06
7	07-13-91	6.3	2.3	51.4	<0.02	43.1	<0.1	<0.2	0.02	1.36	13	<0.06
8	07-14-91	2.4	2.7	52.9	0.05	46.2	<0.1	<0.2	0.02	1.49	<5	<0.06
	10-17-91	4.1	2.4	39.7	0.08	93.2	<0.1	14.6	<0.01	1.68	<5	<0.06
	04-16-92	5.0	0.9	34.8	<0.02	23.3	<0.1	<0.2	0.05	1.04	53	<0.06
9	10-19-91	74.6	2.2	42.0	<0.02	48.6	<0.1	0.3	0.06	1.84	67	0.13
10	07-16-91	2.8	1.7	55.5	0.04	39.5	<0.1	<0.2	0.01	2.42	6	<0.06
11	10-20-91	142.0	1.8	43.9	0.03	33.1	<0.1	0.6	0.21	1.84	205	0.36
12	04-18-92	4.6	1.4	32.6	0.05	22.5	<0.1	<0.2	0.24	1.33	24	0.08
13	10-21-91	11.5	1.7	41.8	0.03	48.4	<0.1	0.3	0.13	1.90	8	0.06
14	07-19-91	3.5	2.5	57.5	0.04	42.1	<0.1	<0.2	0.06	1.69	<5	<0.06
15	04-20-92	52.9	<0.6	36.6	<0.02	20.8	<0.1	<0.2	0.10	1.33	11	<0.06
16	10-24-91	12.5	1.5	48.1	<0.02	44.3	<0.1	0.3	0.20	1.62	7	<0.06
18	04-22-92	8.7	1.8	42.2	<0.02	24.9	<0.1	<0.2	0.14	2.32	14	<0.06
19	10-29-91	4.0	2.2	48.7	<0.02	39.3	<0.1	<0.2	0.13	1.82	<5	0.12
20	07-22-91	4.2	3.0	73.8	<0.02	45.4	<0.1	<0.2	0.10	1.31	<5	<0.06
21	04-24-92	8.1	1.1	58.6	0.04	28.6	<0.1	0.8	0.13	1.87	11	<0.06
22	07-23-91	4.5	2.7	67.6	0.03	45.6	<0.1	0.2	0.26	1.43	<5	<0.06
24	10-29-91	6.8	2.3	53.7	0.02	56.0	<0.1	<0.2	0.10	1.93	<5	0.15
25	04-25-92	29.0	1.9	55.2	<.02	30.5	<0.1	1.4	0.13	1.72	34	<0.06
26	11-01-91	3.9	2.2	54.0	<.02	61.3	<0.1	0.3	0.13	2.27	<5	0.15

[1]Sample from the upper reaches of Lake Pepin (pool 4).
[2]Sample from the lower reaches of Lake Pepin (pool 4).

Table 4.10--Concentration of dissolved trace elements in composited surface-water grab samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991–April 1992--Continued

Pool	Date	Lithium	Manganese	Mercury	Molybdenum	Nickel	Strontium	Thallium	Uranium	Vanadium	Zinc
1	07-04-91	6.17	0.70	<0.008	1.8	1.60	110	<0.05	1.56	0.72	1.40
2	07-07-91	19.03	3.16	<0.008	3.4	0.79	223	<0.05	6.98	3.90	3.36
	10-09-91	19.93	11.02	<0.004	3.5	<0.03	230	0.05	7.07	3.14	3.92
	04-09-92	17.81	18.89	0.005	2.8	<0.03	216	<0.05	8.08	3.97	2.42
3	10-11-91	14.97	44.40	<0.004	2.4	<0.03	168	<0.05	4.68	3.81	4.08
[1]4	10-14-91	13.24	1.82	<0.004	2.9	1.42	168	<0.05	5.37	1.84	6.54
[2]4	10-12-91	15.96	2.33	<0.004	2.8	<0.03	175	<0.05	5.34	3.03	11.41
5	07-11-91	14.38	1.63	<0.008	2.4	<0.03	199	<0.05	4.78	1.99	1.57
5A	07-11-91	13.17	2.64	--	2.5	<0.03	197	<0.05	5.64	1.56	1.18
6	04-13-92	9.96	3.71	<0.004	1.7	<0.03	127	<0.05	4.18	0.16	3.40
7	07-13-91	11.98	5.07	<0.008	2.1	<0.03	179	<0.05	4.42	0.51	1.27
8	07-14-91	12.61	1.51	<0.008	2.3	<0.03	189	<0.05	4.56	0.93	1.01
	10-17-91	10.47	0.11	<0.004	2.1	<0.03	139	<0.05	3.74	--	1.04
	04-16-92	7.74	5.70	<0.004	1.4	<0.08	120	<0.05	4.13	<0.07	1.13
9	10-19-91	11.34	11.68	0.004	1.8	<0.03	131	<0.05	3.65	2.91	1.88
10	07-16-91	10.53	2.04	0.008	2.2	<0.03	532	<0.05	3.82	2.44	1.22
11	10-20-91	7.28	37.02	--	1.8	0.75	109	<0.05	2.92	3.42	2.67
12	04-18-92	5.89	22.28	<0.004	1.1	2.06	91	<0.05	2.41	<0.07	1.58
13	10-21-91	9.98	1.84	<0.004	1.8	<0.03	119	<0.05	3.15	3.16	1.40
14	07-19-91	10.39	1.05	<0.008	2.3	0.31	157	<0.05	3.96	2.62	1.36
15	04-20-92	5.74	1.64	<0.004	1.3	<0.03	96	<0.05	3.18	<0.07	1.90
16	10-24-91	6.70	1.16	0.004	1.8	2.02	108	<0.05	2.96	3.20	1.94
18	04-22-92	4.96	5.50	<0.004	1.2	1.46	98	<0.05	2.81	0.20	1.51
19	10-29-91	6.44	0.81	0.006	1.9	0.80	115	<0.05	2.64	1.98	6.57
20	07-22-91	9.97	0.64	<0.008	2.6	0.39	155	<0.05	4.37	4.44	3.03
21	04-24-92	5.81	1.24	<0.004	1.6	1.22	109	<0.05	2.40	2.93	1.23
22	07-23-91	9.79	1.31	<0.008	2.8	0.96	146	<0.05	3.96	5.05	1.69
24	10-29-91	8.77	3.53	<0.004	2.1	<0.03	129	<0.05	2.67	3.23	2.24
25	04-25-92	5.58	3.53	<0.004	1.4	0.58	117	<0.05	2.45	4.38	11.00
26	11-01-91	8.50	1.77	<0.004	2.3	<0.03	129	0.06	2.61	3.36	1.73

[1]Sample from the upper reaches of Lake Pepin (pool 4).
[2]Sample from the lower reaches of Lake Pepin (pool 4).

Table 4.11--Concentration of dissolved anions in surface-water grab samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991–April 1992

[--, not determined; <, less than detection limit; and units in milligrams per liter]

Pool	Date	Chloride	Sulfate	Bicarbonate	Carbonate
1	07-04-91	11	23	189	1.9
2	07-07-91	16	93	--	--
	10-09-91	28	78	264	4.0
	04-09-92	24	77	252	2.5
3	10-11-91	20	53	213	2.1
[1]4	10-14-91	21	56	222	2.8
[2]4	10-12-91	19	56	219	2.2
5	07-11-91	15	70	189	1.9
5A	07-11-91	15	73	197	1.0
6	04-13-92	15	43	174	1.7
7	07-13-91	13	62	178	1.8
8	07-14-91	14	65	185	1.9
	10-17-91	14	40	188	1.9
	04-16-92	14	40	167	1.7
9	10-19-91	14	38	192	1.0
10	07-16-91	14	61	183	1.8
11	10-20-91	13	32	194	1.9
12	04-18-92	14	36	157	2.4
13	10-21-91	15	36	190	1.9
14	07-19-91	16	57	185	1.9
15	04-20-92	15	34	157	1.6
16	10-24-91	20	38	206	2.1
18	04-22-92	19	36	176	2.7
19	10-26-91	20	38	228	<0.5
20	07-22-91	18	53	199	2.0
21	04-24-92	18	37	175	0.9
22	07-23-91	18	55	194	2.0
24	10-29-91	20	38	191	--
25	04-25-92	18	37	173	1.7
26	11-01-91	19	36	189	1.9

[1]Sample from the upper reaches of Lake Pepin (pool 4).
[2]Sample from the lower reaches of Lake Pepin (pool 4).

Table 4.12--Concentration of dissolved nutrients and dissolved-organic carbon in surface-water grab samples collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991–April 1992

[Differences in significant figures is a result of measurements computed by different software used by different operators; --, not determined; <, less than the detection limit; mg N/L, milligrams of nitrogen per liter; mg P/L, milligrams of phosphorus per liter; mg C/L, milligrams of carbon per liter]

Pool	Date	Nitrate (mg N/L)		Nitrite (mg M/L)		Ammonium (mg N/L)		Orthophosphate (mg P/L)		Dissolved organic carbon (mg C/L)
		Chilled	Frozen	Chilled	Frozen	Chilled	Frozen	Chilled	Frozen	
1	07-04-91	0.82	0.92	<0.005	0.010	<0.01	0.03.	0.093	0.050	13.0
2	07-07-91	4.48	4.32	0.065	0.060	<0.01	0.06	0.177	0.050	--
	10-09-91	3.37	--	0.02	--	<0.02	--	0.11	--	11.4
	04-09-92	5.02	--	0.024	--	0.014	--	0.007	--	8.0
3	10-11-91	2.07	--	0.03	--	<0.02	--	0.08	--	12.6
[1]4	10-14-91	2.33	--	0.02	--	0.02	--	0.09	--	12.2
[2]4	10-12-91	2.58	--	0.03	--	0.02	--	0.12	--	12.6
5	07-11-91	--	3.11	0.077	0.080	0.04	0.03	0.097	0.035	9.5
5A	07-11-91	--	3.31	0.065	0.070	<0.01	<0.01	0.103	0.035	9.9
6	04-13-92	3.27	--	0.018	--	0.010	--	0.012	--	7.9
7	07-13-91	1.69	2.72	0.060	0.050	0.03	0.02	0.114	0.050	9.6
8	07-14-91	2.10	2.65	--	0.050	0.02	0.02	0.074	0.055	9.6
	10-17-91	1.80	--	0.02	--	<0.02	--	0.09	--	10.8
	04-16-92	2.82	--	0.017	--	0.005	--	0.012	--	7.3
9	10-19-91	1.64	--	0.02	--	<0.02	--	0.08	--	9.3
10	07-16-91	1.76	2.15	--	0.030	0.06	0.02	0.073	0.025	9.1
11	10-20-91	1.46	--	0.01	--	<0.02	--	0.06	--	8.5
12	04-18-92	1.40	--	0.013	--	0.007	--	0.011	--	6.8
13	10-21-91	1.51	--	0.01	--	<0.02	--	0.07	--	8.3
14	07-19-91	1.22	1.79	0.038	0.030	--	0.04	0.061	0.020	8.9
15	04-20-92	2.16	--	0.018	--	0.035	--	0.021	--	6.5
16	10-24-91	1.42	--	0.01	--	0.04	--	0.07	--	8.3
18	04-22-92	2.96	--	0.026	--	0.033	--	0.037	--	6.1
19	10-26-91	1.57	--	0.01	--	0.06	--	0.08	--	7.9
20	07-22-91	3.86	3.94	0.019	0.020	--	0.04	0.080	0.030	7.1
21	04-24-92	3.89	--	0.051	--	0.070	--	0.073	--	5.7
22	07-23-91	2.62	2.62	0.015	0.020	--	0.04	0.079	0.025	7.9
24	10-29-91	1.57	--	0.02	--	0.07	--	0.10	--	7.8
25	04-25-92	3.38	--	0.054	--	0.057	--	0.072	--	6.2
26	11-01-91	1.66	--	0.02	--	0.08	--	0.10	--	7.3

[1]Sample from the upper reaches of Lake Pepin (pool 4).

[2]Sample from the lower reaches of Lake Pepin (pool 4).

SUMMARY

The bed-sediment data listed in this report represent a complete digestion of the <2-mm fraction of surficial bed sediment. These samples were composited from a number of individual cores collected from the downstream one-third of the 25 sampled navigation pools on the Upper Mississippi River. Results summarizing the spatial distribution of these bed-sediment data are shown in figure 4.1 to 4.4 for a selected number of representative or interesting elements.

Surface-water data included in this report are a composite of 1-L volumes collected from each site that a bed-sediment sample was collected. This sample is not weighted according to discharge but rather is an equal volume of water from each collection point. The composite sample is indicative of the average water overlying the collection sites in the pool backwaters.

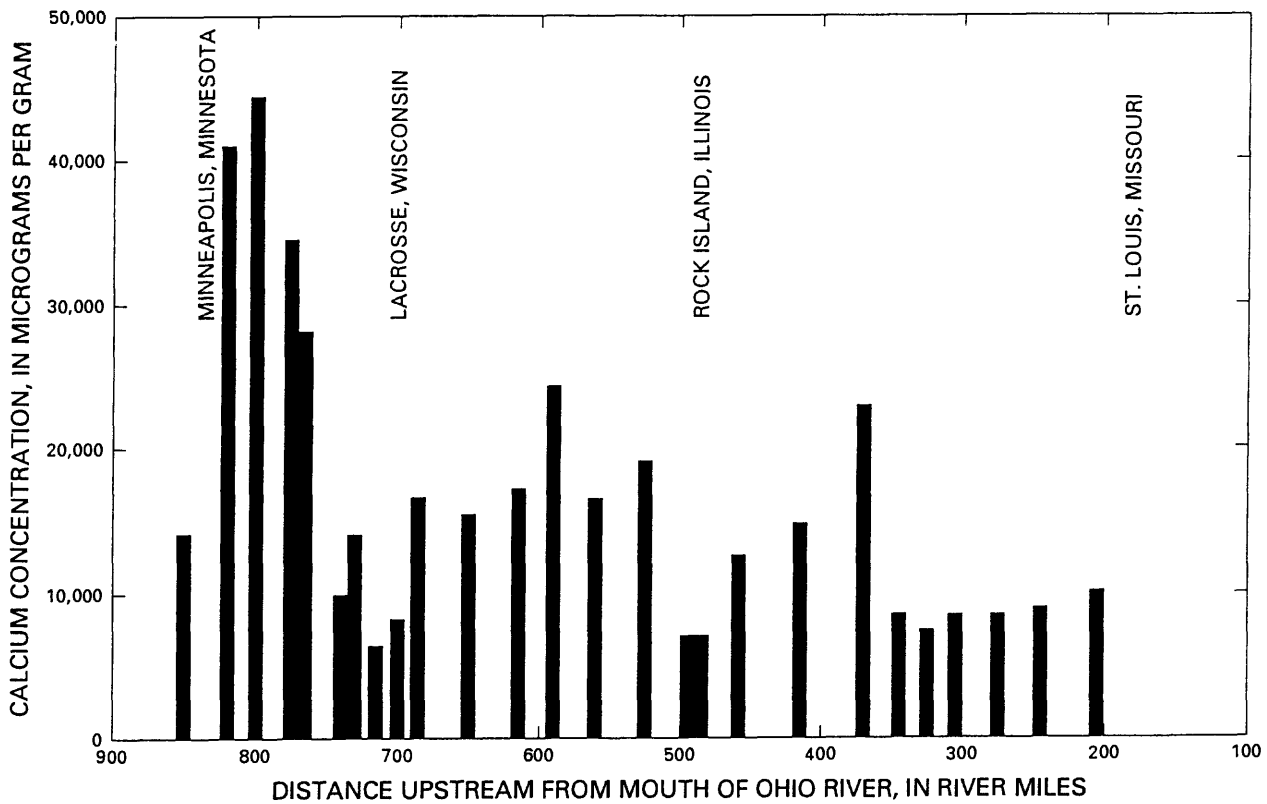

Figure 4.1--Concentration of calcium in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for location of pools.

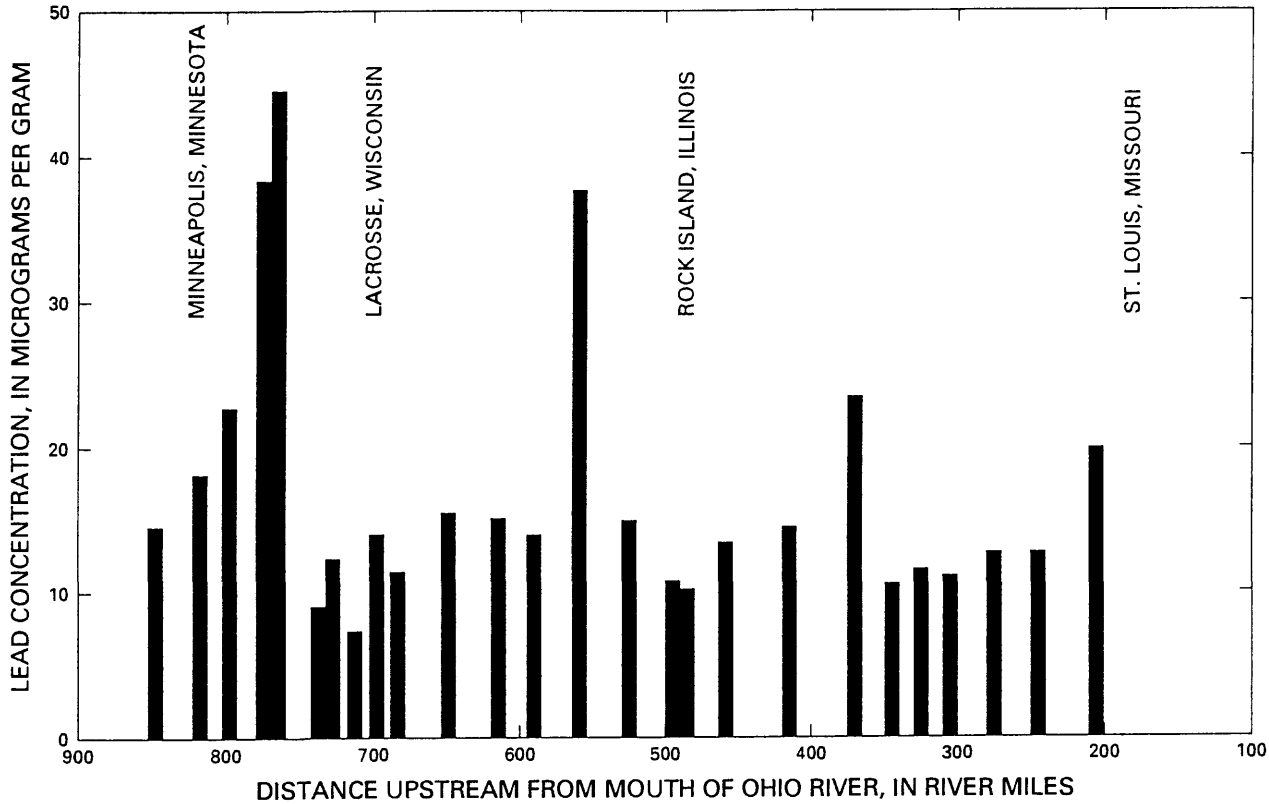

Figure 4.2--Concentration of lead in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River,

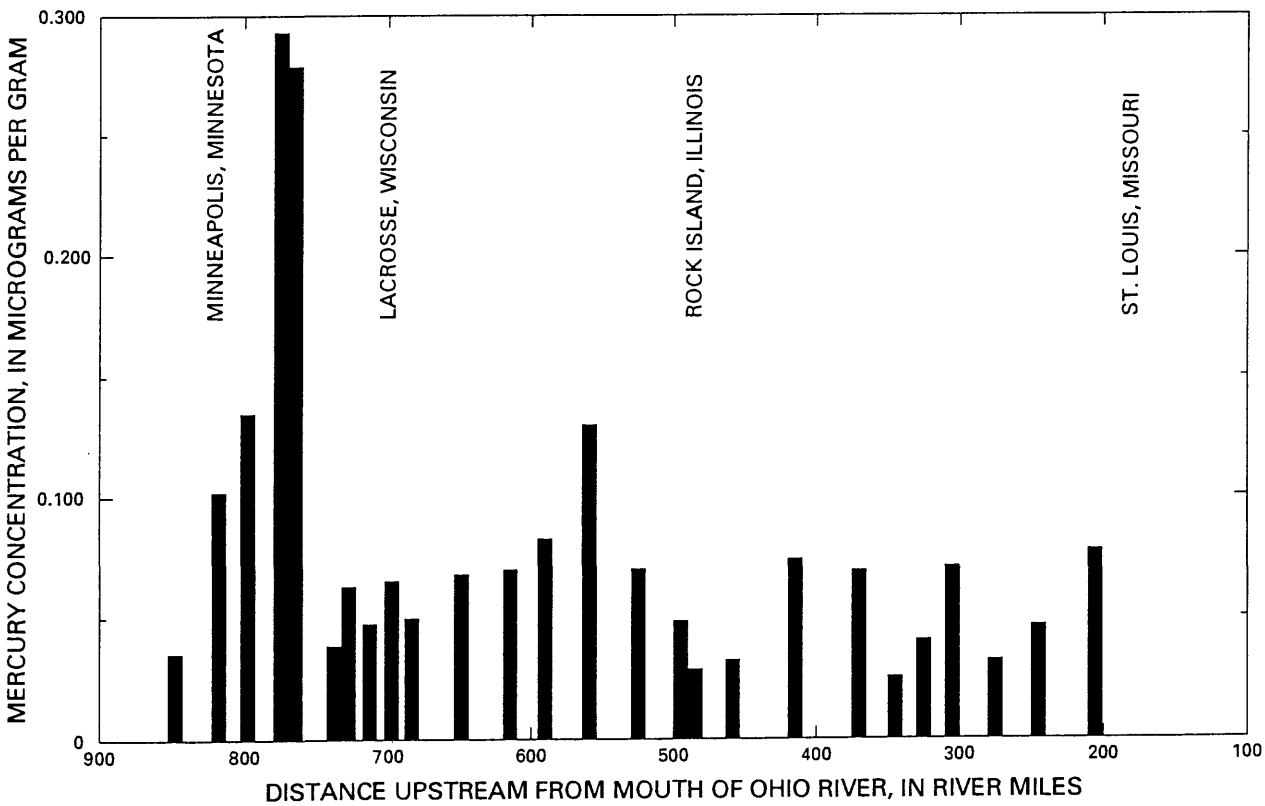

Figure 4.3--Concentration of mercury in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for location of pools.

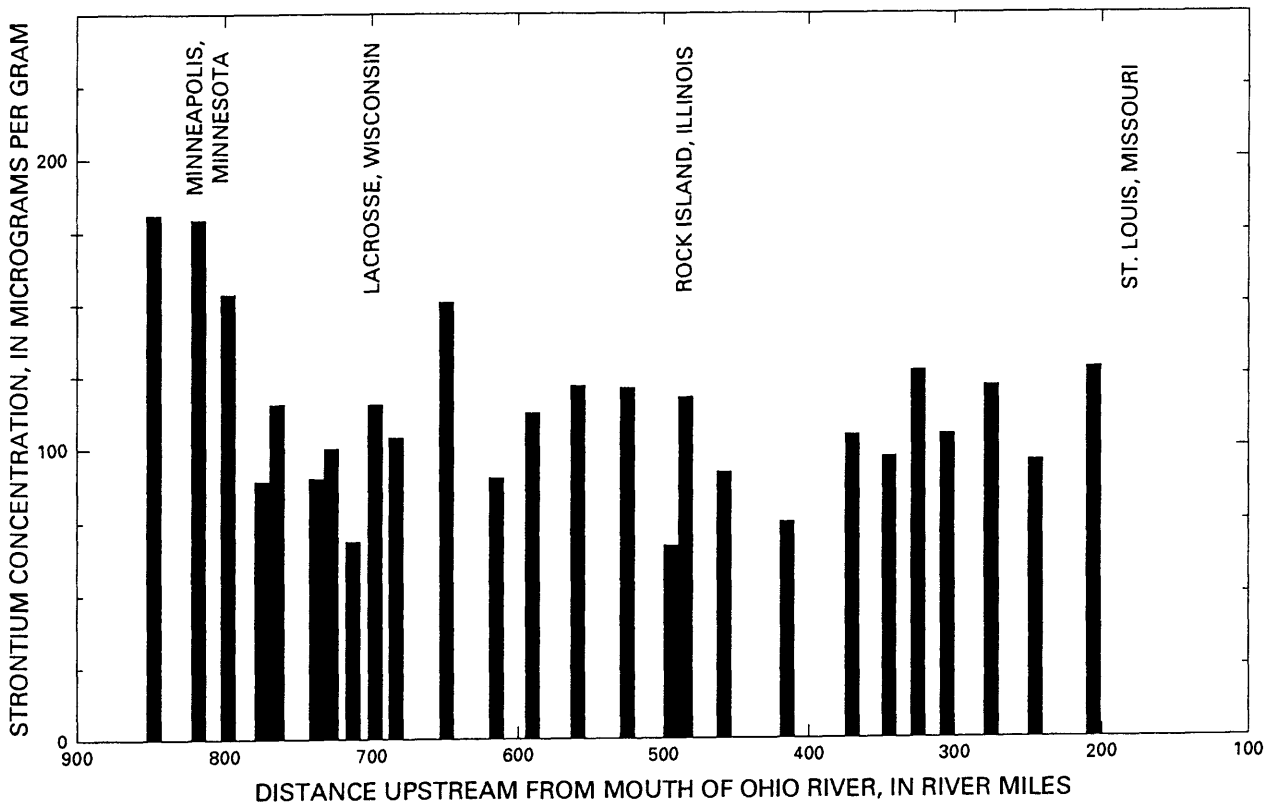

Figure 4.4--Concentration of strontium in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, July 1991-April 1992. See table 1.2 for location of pools.

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Chapter 5 - Sampling-Site Information

By John A. Moody, Robert H. Meade, and Mary A. Kidd

ABSTRACT

One purpose of this study was to locate the individual sampling sites so that the sampling could be repeated at a future time. With this in mind, sampling-site information is presented in three ways: (1) a map showing the location of sampling sites in each pool, (2) a vertical profile of each transect in each pool showing the water depth at each sampling site, and (3) a table that lists the latitude and longitude of each sampling site and field data collected at each site.

EXPLANATION

The sampling-site information consists of three parts for each pool:

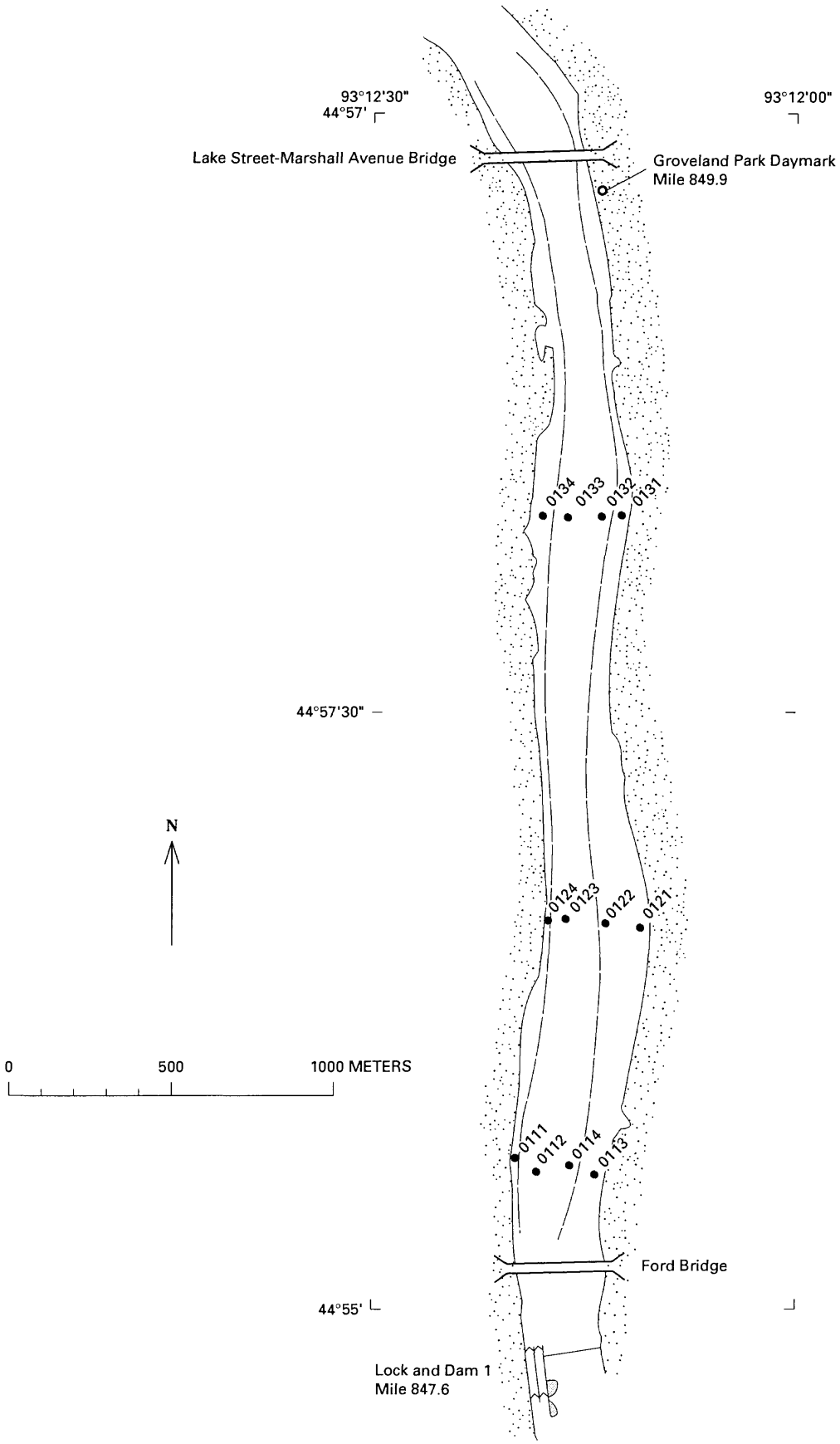
A map was adapted from U.S. Geological Survey 7.5-minute quadrangle maps, which shows the transects and location of each individual sampling site (a solid circle) where a sample was collected and combined to make a composite sample for each pool. The navigation lights and daymarks are shown as open circles and their locations are approximate. Island locations and shapes are approximate because they are constantly changing. The center line of the navigation channel is also approximate and is shown as two dashed lines.

A profile of each transect in each pool shows the location of each sampling site and the water depth.

A table for each transect in a pool lists the sampling sites and field data collected at each site. Each individual sampling site is identified by a number, under the column labeled "Site." The first two digits are the pool number, the third digit is the transect number, and the last one or two digits is the sample number. Single-digit numbers identify additional sites where only velocity measurements were made. The field data are: latitude and longitude, the distance from the *Acadiana* or from the left edge of water along the transect, or the distances from two landmarks on the shore (Pools 4 and 19 only), the depth, the mean velocity measured at 0.6 of the water depth, the estimated magnetic direction of the velocity, the water discharge (if the transect went from left edge of water to right edge of water), the surface temperature, and surface specific conductance. Gage heights are listed in feet for ease of comparison with data published by U.S. Army Corps of Engineers.

The following additional abbreviations are used:

BM = benchmark
cm = centimeters
°C = degrees Celsius
ft = foot
m = meters
m/s = meters per second
m^3/s = cubic meters per second
LEW = left edge of water
N = North
NAD27 = North American Datum 1927
rev/s = revolutions per second
S = South
T = Township
TW = Tailwater
UMR = Upper Mississippi River
USGS = United States Geological Survey
W = West
~ = approximate
µS/cm = microsiemens per centimeter at 25 degrees Celsius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44°57'30"
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Ford Bridge
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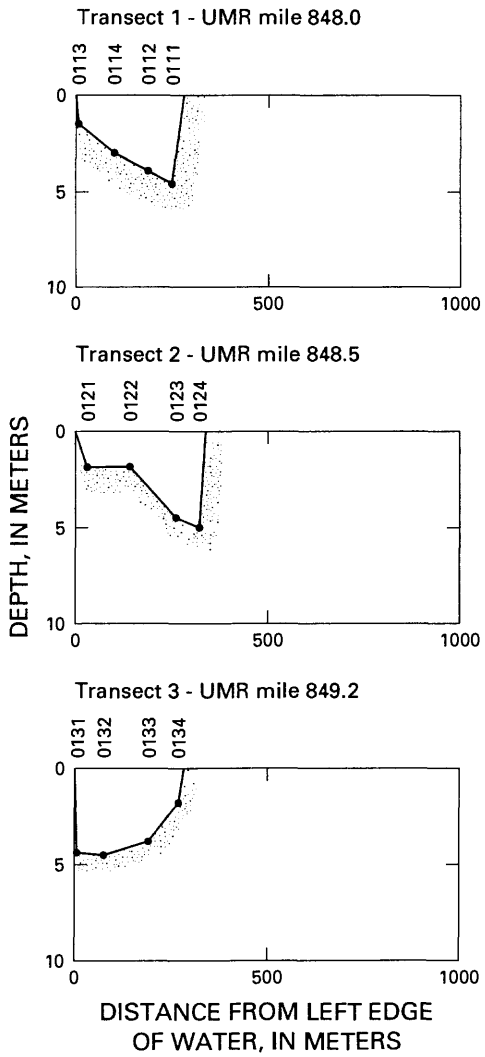
Lock and Dam 1
Mile 847.6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0122
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0124
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5
10
0
500
1000
Transect 3 - UMR mile 849.2
0131
0132
0133
0134
0
5
10
0
500
1000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE
OF WATER, IN METERS

STATION: Mississippi River in Pool 1, Transect 1--UMR mile 848.0
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 4, 1991
GAGE HEIGHT at TW St. Anthony Falls Lower Dam: 726.95 ft
GAGE HEIGHT at Dam 1: 725.80 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 36 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:

Anchored at four verticals in small boat while collecting bed-sediment samples. Vertical locations were estimated from radar on *Acadiana* which was moored to auxiliary lockwall. Velocity measured at 0.6 times the depth.

CURRENT METER EQUATION: V(m/s) = 0.667* rev/s + 0.006
BEARING OF TRANSECT: 096° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0113	44°55.220	093°11.975	10	1.6	--	--	--	23.6	380
0114	55.225	12.050	100	3.0	--	--	--	23.5	381
0112	55.215	12.110	190	3.5	--	--	--	23.5	382
0111	44°55.235	093°12.165	250	4.6	--	--	--	23.7	383
REW			270	0.0					
Mean				2.7					

STATION: Mississippi River in Pool 1, Transect 2--UMR mile 848.5
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 4, 1991
GAGE HEIGHT at TW St. Anthony Falls Lower Dam: 726.95 ft
GAGE HEIGHT at Dam 1: 725.80 ft
SUSPENSION: 15-pound weight
RIVER SLOPE:36 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:

Anchored at four verticals in small boat while collecting bed-sediment samples. Vertical locations were estimated from radar on *Acadiana* which was moored to auxiliary lockwall.

CURRENT METER EQUATION: V (m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 104° magnetic

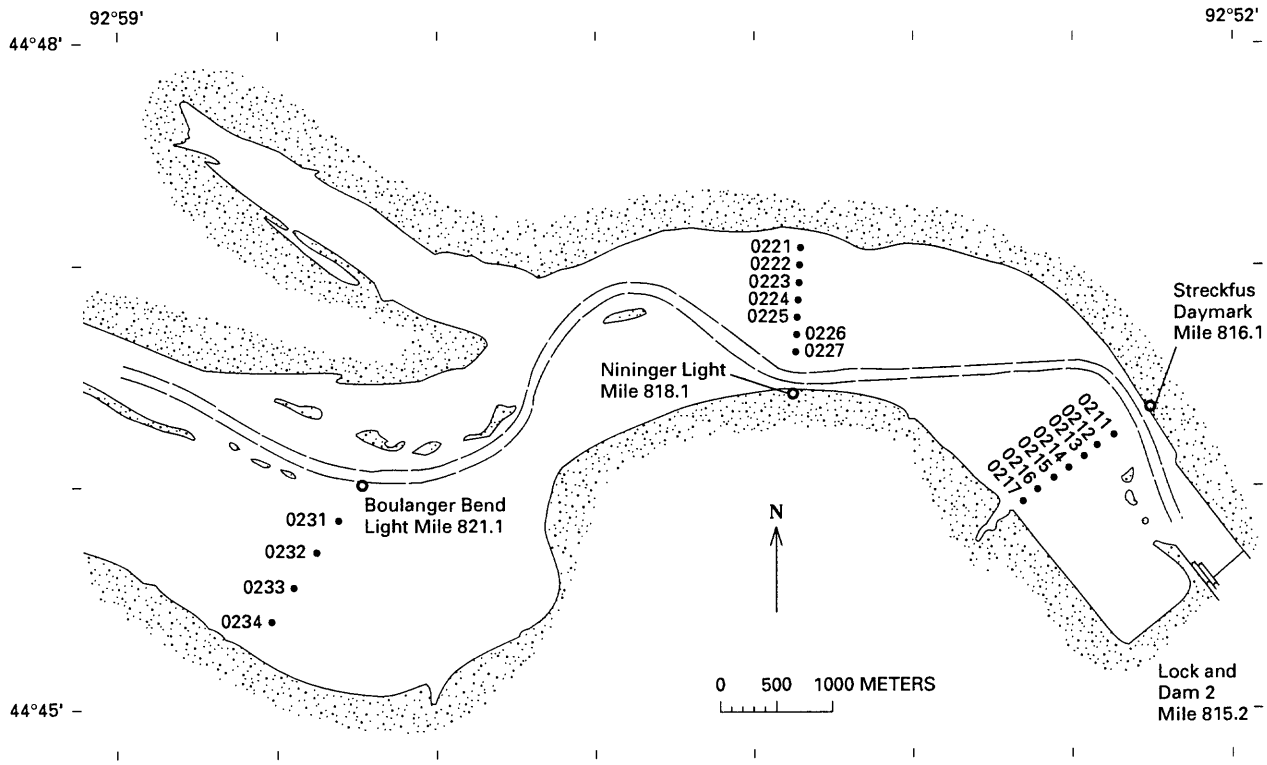
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0121	44 55.625	093°11.865	30	1.8	0.23	194	29	23.5	378
0122	55.630	11.950	140	1.8	0.48	194	99	23.5	380
0123	55.630	12.035	260	4.4	0.55	194	216	23.4	380
0124	44°55.635	093°12.085	320	5.0	0.60	194	104	23.4	386
REW			330	0.0					
Mean				2.7	0.49				
Total							448		

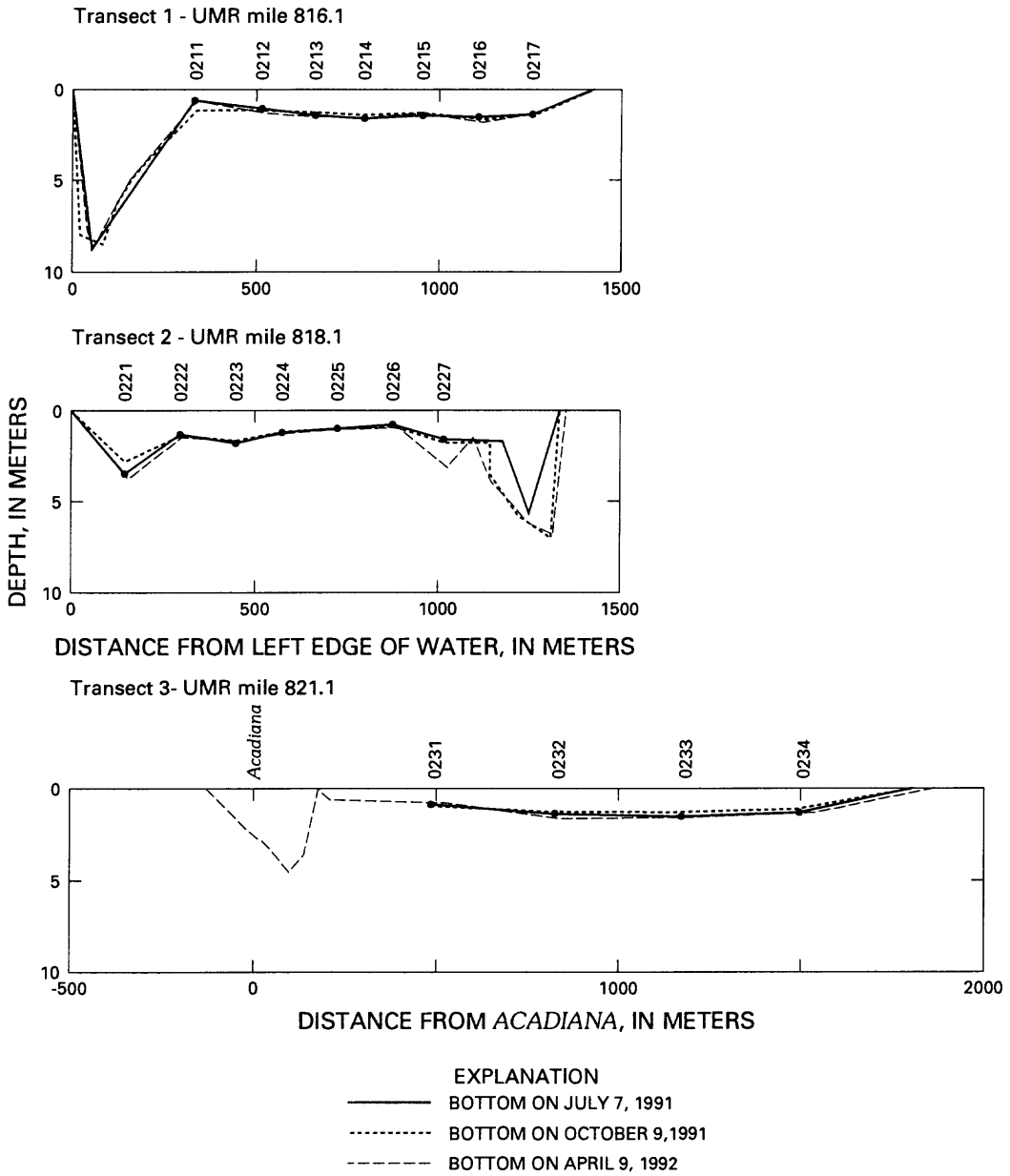
STATION: Mississippi River in Pool 1, Transect 3--UMR mile 849.2
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 4, 1991
GAGE HEIGHT at TW St. Anthony Falls Lower Dam: 726.95 ft
GAGE HEIGHT at Dam 1: 725.80 ft
SUSPENSION:15-pound weight
RIVER SLOPE: 36 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:

Anchored at four verticals in small boat while collecting bed-sediment samples. Vertical locations were estimated from radar on *Acadiana* which was moored to auxiliary lockwall. Velocity measured at 0.6 times the depth.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 100° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0131	44°56.310	093°11.920	10	4.1	0.35	190	57	23.4	377
0132	56.300	11.975	80	4.4	0.49	190	204	23.2	384
0133	56.305	12.065	200	3.8	0.46	190	165	23.2	385
0134	44°56.315	093°12.105	270	1.8	0.21	190	21	23.5	385
REW			290	0.0					
Mean				3.4	0.43				
Total							447		


92°59'
92°52'
44°48'
44°45'
0221
0222
0223
0224
0225
0226
0227
Streckfus
Daymark
Mile 816.1
Nininger Light
Mile 818.1
0211
0212
0213
0214
0215
0216
0217
Boulanger Bend
Light Mile 821.1
0231
0232
0233
0234
N
0 500 1000 METERS
Lock and
Dam 2
Mile 815.2


Transect 1 - UMR mile 816.1
0211
0212
0213
0214
0215
0216
0217
0
5
10
0
500
1000
1500
Transect 2 - UMR mile 818.1
0221
0222
0223
0224
0225
0226
0227
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 3- UMR mile 821.1
Acadiana
0231
0232
0233
0234
-500
2000
DISTANCE FROM ACADIANA, IN METERS
EXPLANATION
BOTTOM ON JULY 7, 1991
BOTTOM ON OCTOBER 9,1991
BOTTOM ON APRIL 9, 1992

STATION: Mississippi River in Pool 2, Transect 1--UMR mile 816.1
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 7, 1991
GAGE HEIGHT at TW Dam 1: 695.10 ft
GAGE HEIGHT at Dam 2: 686.50 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 49 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on green buoy line, 188 m from LEW, and 1,227 m from REW. Velocity measured at 0.6 times the depth while anchored. Current direction was estimated after section was completed.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 035° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
01	--	--	48	8.6	0.52	125	261	--	--
02	--	--	116	6.4	0.58	125	332	--	--
03	--	--	227	3.3	0.51	125	188	--	--
0211	44°46.240	092°52.760	339	0.5	0.16	125	11	25.3	609
0212	46.185	52.840	507	1.0	0.15	125	24	25.7	607
0213	46.140	52.950	654	1.2	0.21	125	36	25.6	610
0214	46.095	53.040	795	1.3	0.19	125	37	25.1	613
0215	46.045	53.130	955	1.2	0.20	125	37	25.6	606
0216	45.975	53.235	1,108	1.5	0.25	125	56	25.1	609
0217	44°45.930	44°53.330	1,258	1.2	0.25	125	46	23.9	623
REW			1,415	0.0					
Mean				1.9	0.39				
Total							1,028		

STATION: Mississippi River in Pool 2, Transect 2--UMR mile 818.1
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 7, 1991
GAGE HEIGHT at TW Dam 1: 695.10 ft
GAGE HEIGHT at Dam 2: 686.50 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 49 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on red buoy line, 1,158 m from LEW, and 180 m from REW. Velocity measured at 0.6 times the depth while anchored. Current direction was estimated after section was completed.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 000° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
0221	44°47.050	092°54.750	148	3.7	0.46	090	251	25.6	605
0222	46.970	54.750	295	1.2	0.27	090	49	25.7	606
0223	46.885	54.755	445	1.7	0.32	090	77	25.5	606
0224	46.820	54.765	578	1.1	0.31	090	49	25.3	608
0225	46.745	54.770	728	0.9	0.30	090	40	25.2	609
0226	46.660	54.775	879	0.8	0.29	090	33	25.3	609
0227	44°46.590	092°54.780	1,018	1.5	0.37	090	83	25.2	612
01	--	--	1,180	1.5	0.54	090	100	25.1	612
02	--	--	1,266	5.5	0.35	090	150	25.7	606
REW			1,338	0.0					
Mean				1.7	0.38				
Totals							832		

STATION: Mississippi River in Pool 2, Transect 3--UMR mile 821.1
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 7, 1991
GAGE HEIGHT at TW Dam 1: 695.10 ft
GAGE HEIGHT at Dam 2: 686.50 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 49×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on red buoy line, 225 m from LEW on spoil bank, 154 m to the left of the green side of the navigation channel, and 1,810 m from REW. Transect cut short because of darkness.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 019° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			2,035	0.0					
0231	44°45.805	092°57.695	480	0.9	--	--	--	24.3	622
0232	45.665	57.820	805	1.3	--	--	--	24.9	625
0233	45.510	57.950	1,140	1.4	--	--	--	24.6	627
0234	44°45.350	092°58.095	1,480	1.2	--	--	--	24.8	625
REW			0	0.0					
Mean				0.9					

STATION: Mississippi River in Pool 2, Transect 1--UMR mile 816.1
PARTY: Moody, Meade, Bishop, and Antweiler
DATE: October 9, 1991
GAGE HEIGHT at TW Dam 1: 689.10 ft
GAGE HEIGHT at Dam 2: 686.61 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 14×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on green buoy line, 1,128 m from upriver tip of longest guide wall at Lock 2, 437 m from mouth of gully on left bank near UMR mile 816.3, 205 m from LEW at Streckfus Daymark, and 1,216 m from point at downstream corner of prominent embayment on right bank.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 054° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
01	--	--	28	8.0	0.10	70	11	11.2	670
02	--	--	85	8.5	0.20	70	28	11.3	670
03	--	--	125	6.1	0.21	90	35	11.4	670
04	--	--	170	4.8	0.21	90	25	11.5	670
Ship	--	--	202	3.9	0.18	80	15	11.9	666
05	--	--	260	2.8	0.07	70	4	12.0	669
0211	44°46.240	092°52.760	340	0.6	0.04	70	1	12.0	669
0212	46.185	52.840	515	1.2	0.04	20	-4	12.1	665
0213	46.140	52.950	655	1.3	0.04	100	5	11.8	668
0214	46.095	53.040	795	1.4	0.07	80	7	11.9	667
0215	46.045	53.130	950	1.3	0.06	70	5	12.1	665
0216	45.975	53.235	1,125	1.7	0.08	80	10	11.9	667
0217	44°45.930	092°53.330	1,270	1.3	0.08	110	13	11.8	667
REW			1,421	0.0					
Mean				2.0	0.05				
Total							155		

STATION: Mississippi River in Pool 2, Transect 2--UMR mile 818.1
PARTY: Moody, Meade, Antweiler, Bishop
DATE: October 9, 1991
GAGE HEIGHT at TW Dam 1: 689.10 ft
GAGE HEIGHT at Dam 2: 686.61 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 14×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on red buoy line, 950 m from end of Jason Ave. in Nininger, 1,143 m from box culvert at mouth of gully on left bank, 260 m from REW at house on bluff, 212 m from REW at Nininger Light, and 1,130 m from LEW next to yellow brick building on left bank.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 001° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0221	44°47.050	092°54.750	150	3.9	0.20	30	61	12.2	668
0222	46.970	54.750	295	1.2	0.18	60	30	11.8	674
0223	46.885	54.755	460	1.7	0.14	50	28	11.8	674
0224	46.820	54.765	580	1.2	0.17	50	22	11.7	676
0225	46.745	54.770	730	0.9	0.23	80	32	11.8	676
0226	46.660	54.775	890	0.8	0.28	80	32	12.0	673
0227	44°46.590	092°54.780	1,020	1.7	0.28	80	61	11.9	676
04	--	--	1,150	3.4	0.20	60	58	11.7	678
03	--	--	1,210	5.7	0.16	60	53	12.6	663
02	--	--	1,280	6.0	0.15	30	29	12.5	670
01	--	--	1,325	7.0	0.19	10	9	12.9	677
REW			1,342	0.0					
Mean				2.2	0.14				
Total							415		

STATION: Mississippi River in Pool 2, Transect 3--UMR mile 821.1

PARTY: Moody, Meade, Antweiler, and Bishop

DATE: October 9, 1991

GAGE HEIGHT at TW Dam 1: 689.10 ft

GAGE HEIGHT at Dam 2: 686.61 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 14×10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.

REMARKS:

Acadiana anchored on red buoy line: 120 m from Boulanger Bend Light and Daymark (UMR mile 821.1), 1,815 m from the end of road at Sedil, Minn., 1,830 m from the NW corner of a prominent gully on the right shore (1 mile upstream from Sedil), and 1,805 m from REW on section through Boulanger Bend Light.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 019° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW		no measurement							
0231	44°45.805	092°57.695	475	0.8		no measurements		13.0	670
0232	45.665	57.820	795	1.3		no measurements		12.0	673
0233	45.510	57.950	1,135	1.3		no measurements		12.6	670
0234	44°45.350	092°58.095	1,475	1.2		no measurements		13.0	670
REW			0	0.0					
Mean				0.9					

STATION: Mississippi River in Pool 2, Transect 1--UMR mile 816.1
PARTY: Moody, Meade, and Roth
DATE: April 9, 1992
GAGE HEIGHT at TW Dam 1: 691.21 ft
GAGE HEIGHT at Dam 2: 686.60 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 26×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 816.1, on line between Streckfus Daymark (UMR mile 816.1) and downstream corner of prominent embayment on right bank, 1,265 m from embayment corner, and 155 m from LEW at Streckfus Daymark. Small squall passed.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 054° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0				10.4	670
04	--	--	30	7.8	0.20	150	39	10.3	669
05	--	--	50	8.7	0.20	140	67	10.4	666
03	--	--	105	7.0	0.24	150	86	10.4	666
02	--	--	155	5.0	0.29	130	78	10.4	664
01	--	--	215	3.5	0.30	120	89	10.4	663
0211	44°46.240	092°52.760	335	0.5	0.29	140	22	10.0	669
0212	46.185	52.840	515	1.2	0.22	120	40	10.1	668
0213	46.140	52.950	655	1.3	0.27	120	49	10.4	667
0214	46.095	53.040	810	1.4	0.19	110	35	10.0	666
0215	46.045	53.130	950	1.2	0.14	120	24	10.2	667
0216	45.975	53.235	1,115	1.7	0.16	90	27	10.2	666
0217	44°45.930	092°53.330	1,260	1.3	0.13	150	26	10.4	666
REW			1,420	0.0				11.3	660
Mean				2.0	0.21				
Total							582		

STATION: Mississippi River in Pool 2, Transect 2--UMR mile 818.1
PARTY: Moody, Meade, and Roth
DATE: April 9, 1992
GAGE HEIGHT at TW Dam 1: 691.21 ft
GAGE HEIGHT at Dam 2: 686.60 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 26 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 818.1, 190 m from REW at Nininger Light, and 1,150 m from LEW at yellow brick blockhouse at end of powerline that comes along the street next to the water tank.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 001° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0221	44°47.050	092°54.750	155	3.8	0.21	70	115	10.7	663
0222	46.970	54.750	300	1.2	0.16	90	31	11.3	667
0223	46.885	54.755	465	1.7	0.23	80	55	11.3	651
0224	46.820	54.765	580	1.1	0.17	80	25	11.2	658
0225	46.745	54.770	735	0.9	0.19	100	26	11.6	651
0226	46.660	54.775	890	0.7	0.15	100	15	11.4	659
0227	44°46.590	092°54.780	1,020	1.5	0.23	110	32	10.9	660
06	--	--	1,090	1.3	0.27	100	22	10.8	658
05	--	--	1,150	3.8	0.25	110	42	10.2	663
04	--	--	1,185	5.1	0.21	120	39	9.8	671
03	--	--	1,235	6.1	0.17	100	49	9.3	674
02	--	--	1,280	6.5	0.20	100	51	9.2	679
01	--	--	1,315	6.7	0.30	80	60	9.3	679
REW			1,340	0.0				9.9	676
Mean				2.1	0.20				
Total							562		

STATION: Mississippi River in Pool 2, Transect 3--UMR mile 821.1

PARTY: Moody, Meade, and Roth

DATE: April 9, 1992

GAGE HEIGHT at TW Dam 1: 691.21 ft

GAGE HEIGHT at Dam 2: 686.60 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 26×10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.

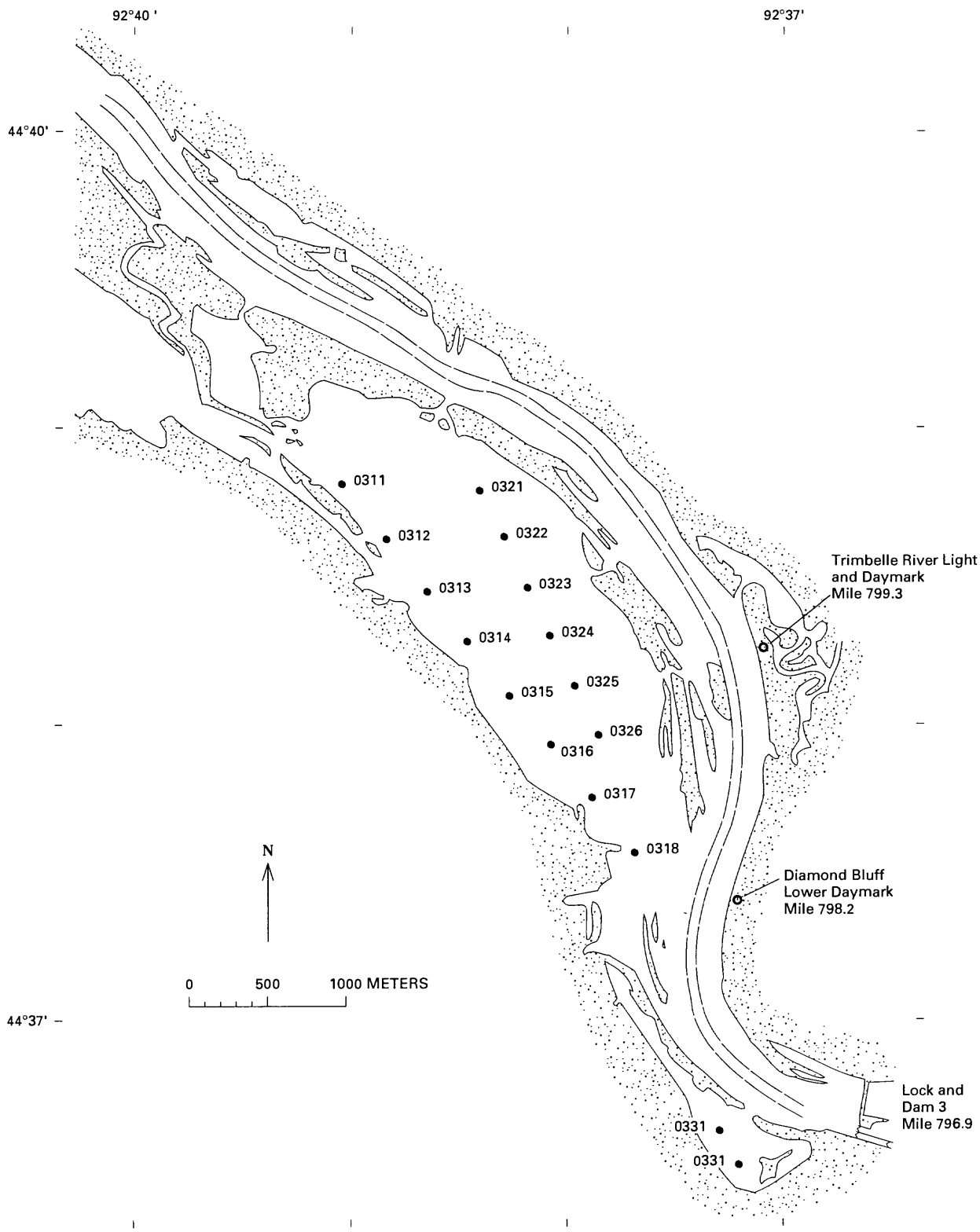
REMARKS:

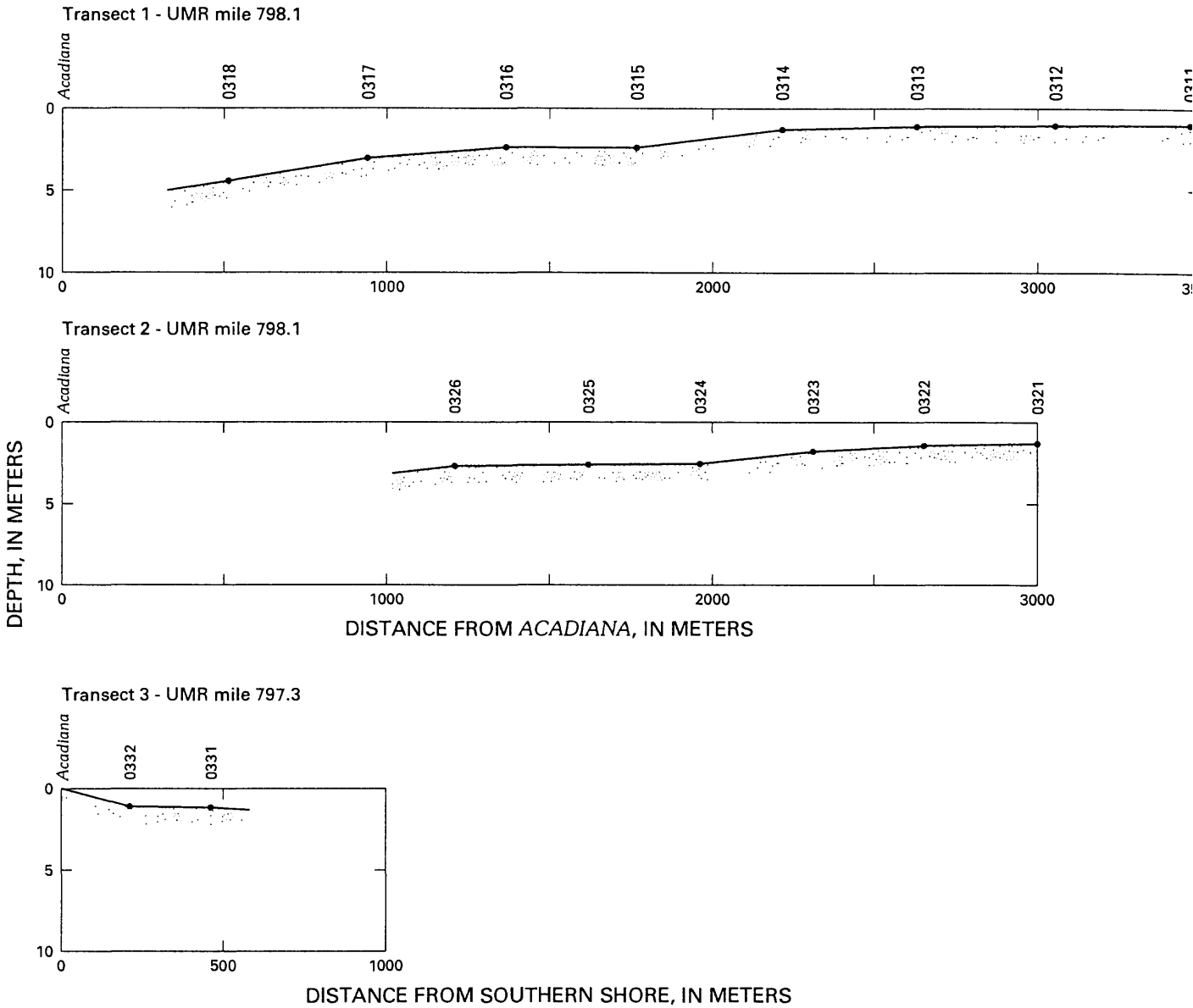
Acadiana anchored on red buoy line at UMR mile 821.1 (Boulanger Bend Light), 169 m from the light, 1,845 m from REW at large willow tree on shoreline at Sedil, Minn., and on line of section. Discharge does not include flow on the other side of the island at LEW.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 019° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
05	--	--	55	1.0	0.26	110	16	9.9	665
06	--	--	124	2.5	0.32	100	38	--	665
04	--	--	150	3.0	0.36	100	51	9.8	665
03	--	--	220	4.5	0.48	100	123	9.9	664
02	--	--	265	3.8	0.36	100	78	10.0	663
01	--	--	335	0.5	0.15	120	14	10.1	662
0231	44°45.805	092°57.695	645	0.7	0.09	90	19	10.2	659
0232	45.665	57.820	965	1.4	0.09	90	39	8.9	678
0233	45.510	57.950	1,300	1.5	0.10	90	50	9.6	670
0234	44°45.350	092°58.095	1,640	1.2	0.09	90	37	9.7	672
REW			1,975	0.0					
Mean				1.3	0.19				
Total							465		


92°40'
92°37'
44°40'
44°37'
0311
0321
0312
0322
0313
0323
0314
0324
0315
0325
0326
0316
0317
0318
0331
0331
Trimbelle River Light
and Daymark
Mile 799.3
Diamond Bluff
Lower Daymark
Mile 798.2
Lock and
Dam 3
Mile 796.9
N
0
500
1000 METERS


Transect 1 - UMR mile 798.1
Acadiana
0318
0317
0316
0315
0314
0313
0312
0
5
10
0
1000
2000
3000
Transect 2 - UMR mile 798.1
Acadiana
0326
0325
0324
0323
0322
0321
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
DISTANCE FROM ACADIANA, IN METERS
Transect 3 - UMR mile 797.3
Acadiana
0332
0331
0
5
10
0
500
1000
DISTANCE FROM SOUTHERN SHORE, IN METERS

STATION: Mississippi River in Pool 3, Transect 1--UMR mile 798.1
PARTY: Moody, Meade, Antweiler, and Bishop
DATE: October 11, 1991
GAGE HEIGHT at TW Dam 2: 675.8 ft
GAGE HEIGHT at Dam 3: 674.05 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 18×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Diamond Bluff West, Wis.-Minn.
REMARKS:

Acadiana anchored on shallow side of green buoy line at UMR mile 798.1: 1,338 m from downriver point of entrance to lagoon on right bank at UMR mile 797.3; 579 m from tip of eastward-protruding finger of land about 600 m NNE of main powerplant building; 585 m from wall corner on section line about 100 m NE of main powerplant building. No discharge was calculated because flow was nearly parallel to the transect.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 140° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
0311	44°38.775	092°39.055	3,470	1.0	0.26	130	--	11.4	524
0312	38.600	38.835	3,050	1.0	0.12	130	--	11.3	526
0313	38.425	38.655	2,625	1.1	0.12	120	--	11.2	534
0314	38.220	38.475	2,210	1.1	0.07	120	--	11.3	530
0315	38.075	38.250	1,785	2.3	0.10	120	--	11.3	533
0316	37.910	38.065	1,365	2.3	0.09	150	--	11.3	541
0317	37.735	37.865	940	3.0	0.20	150	--	11.3	541
0318	44°37.560	092°37.665	510	4.6	0.20	170	--	11.6	525
Acadiana			0						

STATION: Mississippi River in Pool 3, Transect 2--UMR mile 798.1
PARTY: Moody, Meade, Antweiler, and Bishop
DATE: October 11, 1991
GAGE HEIGHT at TW Dam 2: 675.8 ft
GAGE HEIGHT at Dam 3: 674.05 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 18×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Diamond Bluff West, Wis.-Minn.
REMARKS:

Acadiana anchored on shallow side of green buoy line at UMR mile 798.1: 1,338 m from downriver point of entrance to lagoon on right bank at UMR mile 797.3; 579 m from tip of eastward-protruding finger of land about 600 m NNE of main powerplant building; 585 m from wall corner on section line ~100 m NE of main powerplant building. No discharge was calculated because flow was nearly parallel to the transect.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 153° magnetic

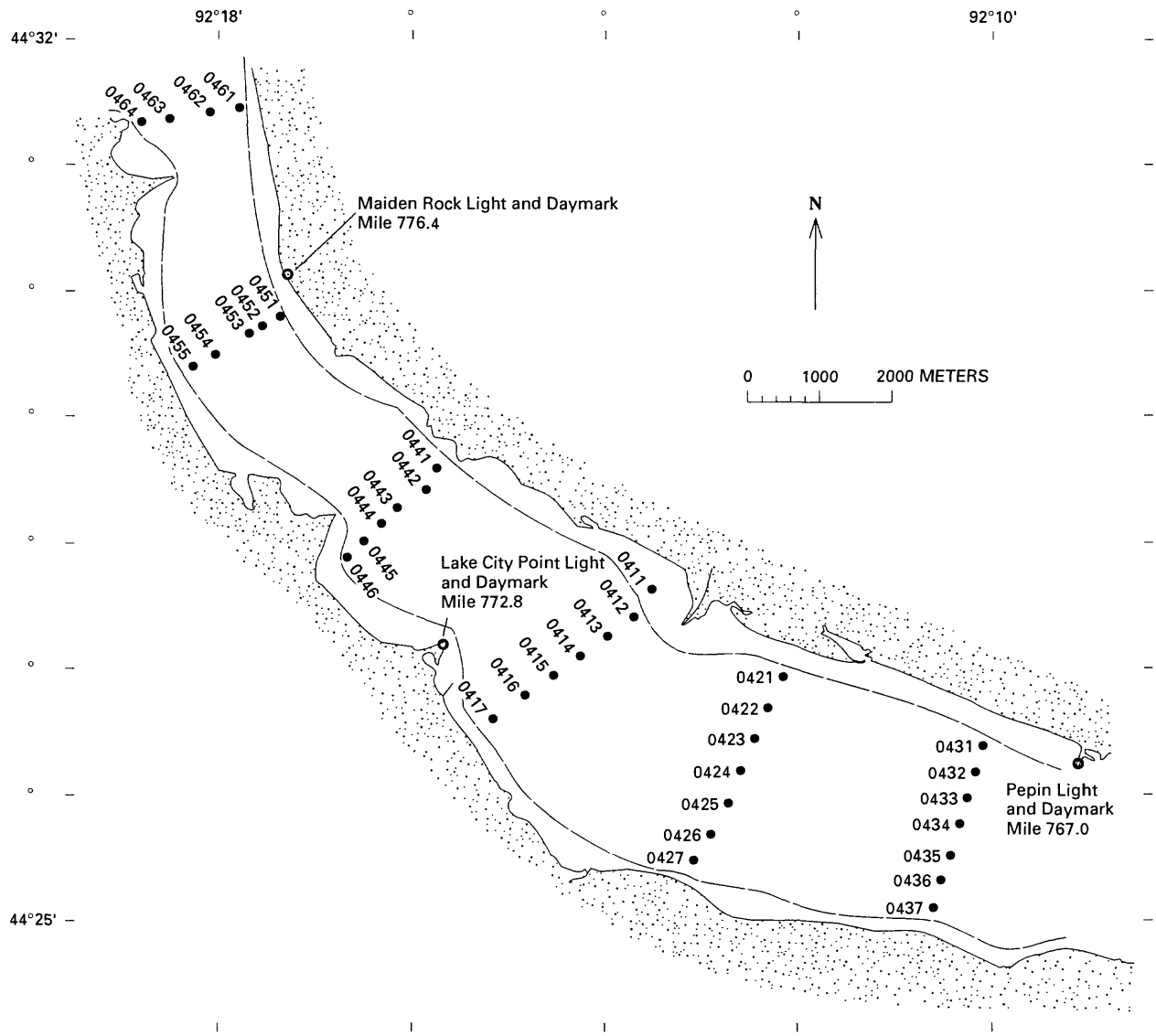
Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
0321	44°38.780	092°38.410	3,000	1.2	0.07	050	--	13.0	516
0322	38.610	38.290	2,650	1.3	0.08	120	--	12.9	517
0323	38.450	38.180	2,305	1.7	0.10	130	--	13.1	517
0324	38.300	38.075	1,960	2.5	0.06	120	--	13.0	517
0325	38.120	37.945	1,620	2.3	0.09	150	--	12.9	515
0326	44°37.945	092°37.830	1,260	2.4	0.13	270	--	12.9	518
Acadiana			0						

STATION: Mississippi River in Pool 3, Transect 3--UMR mile 797.3
PARTY: Moody, Meade, Antweiler, and Bishop
DATE: October 11, 1991
GAGE HEIGHT at TW Dam 2: 675.8 ft
GAGE HEIGHT at Dam 3: 674.05 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 18×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Red Wing, Minn.
REMARKS:

Acadiana secured to upstream corner of dock on right bank at UMR mile 797.3. No discharge was calculated because flow was nearly parallel to the transect. Distances are from southern shore of cove.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 148° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
0331	44°36.630	092°37.325	460	1.0	0.11	150	--	14.6	530
0332	44°36.525	092°37.155	210	1.0	0.07	160	--	14.9	530
Acadiana			0						


92°18'
92°10'
44°32'
44°25'
Maiden Rock Light and Daymark
Mile 776.4
Lake City Point Light
and Daymark
Mile 772.8
Pepin Light
and Daymark
Mile 767.0
N
0 1000 2000 METERS
0461
0462
0463
0464
0451
0452
0453
0454
0455
0441
0442
0443
0444
0445
0446
0411
0412
0413
0414
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0416
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0434
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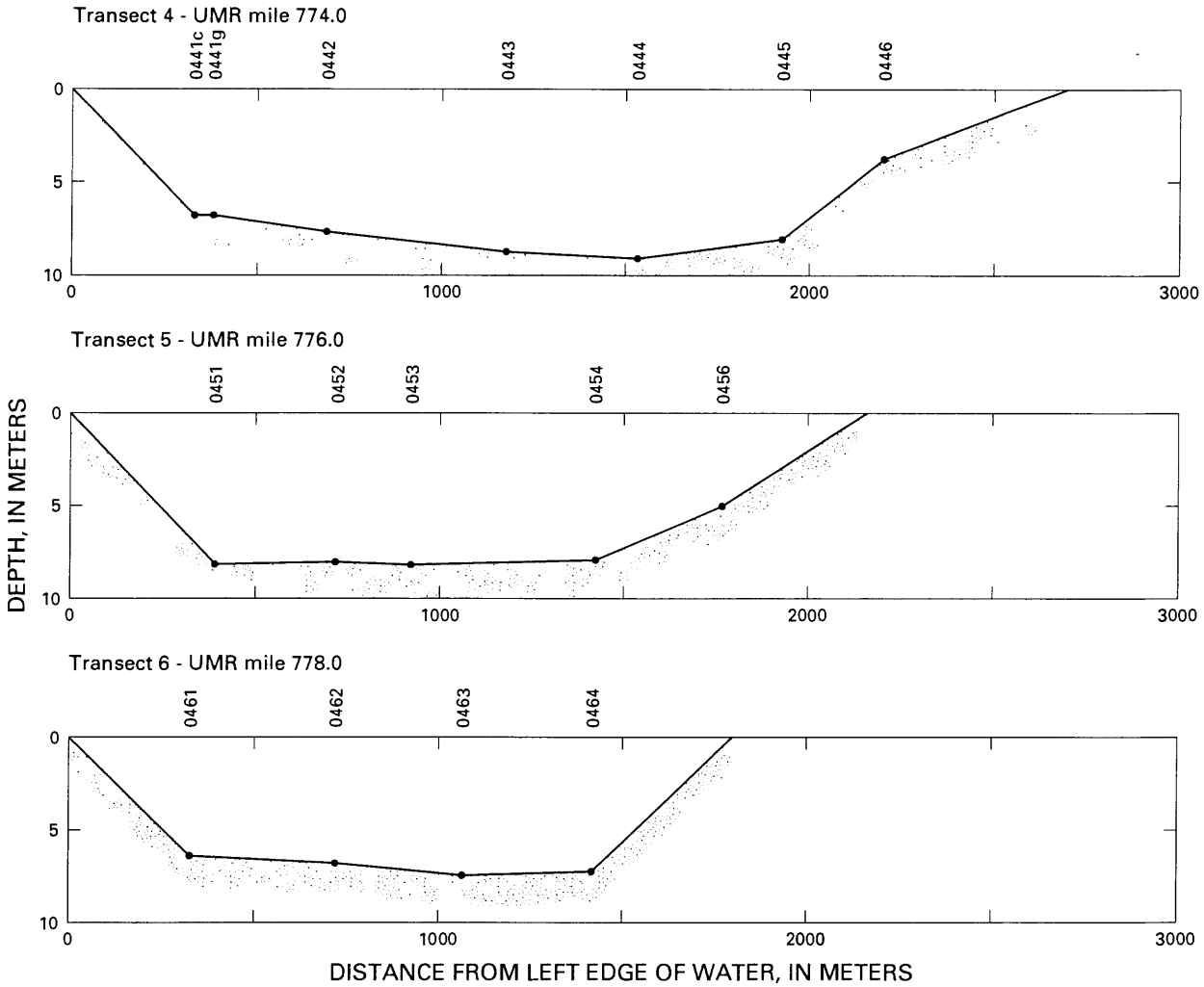
0436
0437


Transect 4 - UMR mile 774.0
0441c
0441g
0442
0443
0444
0445
0446
0
5
10
0
1000
2000
3000
Transect 5 - UMR mile 776.0
0451
0452
0453
0454
0456
0
5
10
0
1000
2000
3000
Transect 6 - UMR mile 778.0
0461
0462
0463
0464
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 4, Transect 6--UMR mile 778.0
PARTY: Moody, Simoneaux, Noyes, Antweiler, and Bishop DATE: October 14, 1991
GAGE HEIGHT at Lake City: 667.58 ft
MAP: USGS 7.5-minute quadrangle is Maiden Rock, Wis.-Minn. RIVER SLOPE: 1.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore at the northeastern tip of Long Point (X-remote) and at the downstream lobe of the delta of Skunk Hollow (Y-remote). Samples were collected from *Acadiana*, and distances east from the remotes to *Acadiana* are listed below. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured since the estimated speeds were less than 6 cm/s. Latitude and longitude correspond to location of the grab. River slope was estimated from river profiles privided by U.S. Army Corps of Engineers, St. Paul District.

BEARING OF TRANSECT: 084° magnetic

Site	NAD27		Distance		Distance (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
	Latitude N	Longitude W	X remote	Y remote				
LEW					0			
0461g	44°31.215	092°17.835	1,352	1,080	300	6.3	9.6	545
0461c			1,387	1,110	330	--	--	--
0462g	31.215	18.150	1,052	1,325	720	6.8	10.0	540
0462c			1,061	1,336	--	--	--	--
0463g	31.220	18.420	909	1,609	1,070	7.5	9.8	546
0463c			900	1,611	--	--	--	--
0464g	44°31.190	092°18.670	814	1,859	1,420	7.2	9.9	541
0464c			807	1,852	--	--	--	--
REW					1,810			

STATION: Mississippi River in Pool 4, Transect 5--UMR mile 776.0
PARTY: Moody, Simoneaux, Noyes, Antweiler, and Bishop DATE: October 14, 1991
GAGE HEIGHT at Lake City: 667.58 ft
MAP: USGS 7.5-minute quadrangle is Lake City, Wis.-Minn. RIVER SLOPE: 1.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore at the northeastern tip of Central Point (X-remote) and at the downstream lobe of the delta of a small creek flowing through Stockholm, Wisconsin (Y-remote). Samples were collected from *Acadiana*, and distances east from the remotes to *Acadiana* are listed below. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured since the estimated speeds were less than 4 cm/s. Latitude and longitude correspond to the location of the grab. River slope was estimated from river profiles provided by U.S. Army Corps of Engineers, St. Paul District.

BEARING OF TRANSECT: 056° magnetic

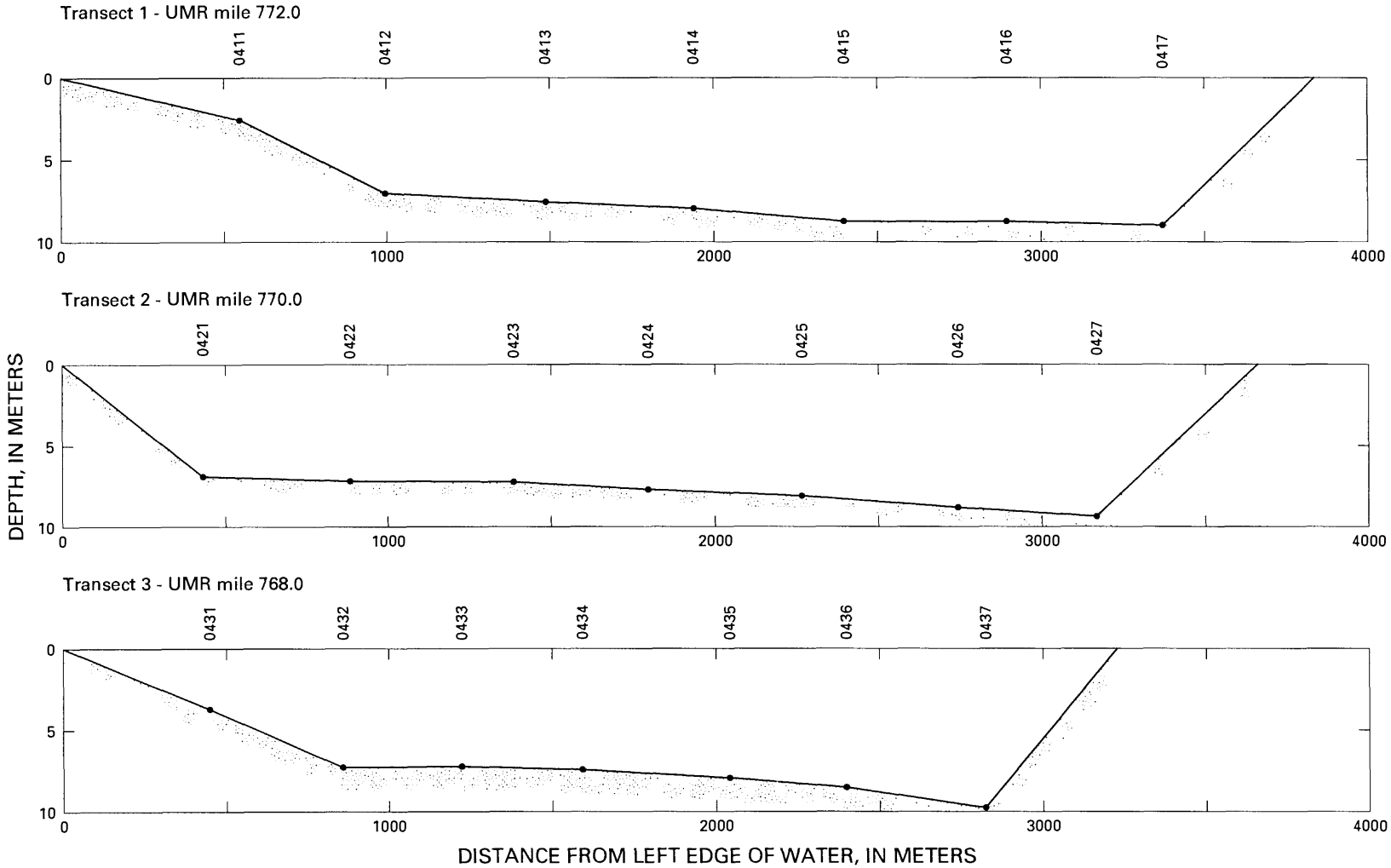
Site	NAD27		Distance					
	Latitude N	Longitude W	X remote	Y remote	Distance (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW					0			
0451g	44°29.715	092°17.425	2,881	2,594	390	7.9	10.4	544
0451c			2,889	2,599	--			
0452g	29.625	17.620	2,815	2,739	720	8.0	10.6	549
0452c			2,824	2,745	--			
0453g	29.565	17.730	2,791	2,822	920	8.1	10.4	547
0453c			2,771	2,804	--			
0454g	29.435	18.085	2,822	3,154	1,440	7.8	10.5	552
0454c			2,826	3,154	--			
0455g	44°29.350	092°18.310	2,899	3,400	1,770	5.0	10.6	560
0455c			2,902	3,400	--	--	--	--
REW					2,170			

STATION: Mississippi River in Pool 4, Transect 4--UMR mile 774.0
PARTY: Moody, Simoneaux, Noyes, Antweiler, and Bishop DATE: October 14, 1991
GAGE HEIGHT at Lake City: 667.58 ft
MAP: USGS 7.5-minute quadrangle is Lake City, Wis.-Minn. RIVER SLOPE: 1.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore at the northeastern tip of Central Point (X-remote) and at the downstream lobe of the delta of a small creek flowing through Stockholm, Wisconsin (Y-remote). Samples were collected from *Acadiana*, and distances east from the remotes to *Acadiana* are listed below. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured since the estimated speeds were less than 3 cm/s. Latitude and longitude correspond to the location of the grab. River slope was estimated from river profiles provided by U.S. Army Corps of Engineers, St. Paul District.

BEARING OF TRANSECT: 041° magnetic

Site	NAD27		Distance					
	Latitude N	Longitude W	X remote	Y remote	Distance (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW					0			
0441g	44°28.550	092°15.730	1,527	582	400	6.7	10.8	545
0441c			1,576	629	--	6.5	--	--
0442g	28.395	15.855	1,286	859	700	7.8	10.9	546
0442c			1,278	853	--	--	--	--
0443g	28.250	16.150	836	1,205	1,170	8.7	11.0	550
0443c			836	1,205	--	--	--	--
0444g	28.115	16.365	589	1,551	1,530	9.0	11.0	548
0444c			583	1,550	--	--	--	--
0445g	27.970	16.575	537	1,929	1,920	8.0	10.8	546
0445c			526	1,917	--	--	--	--
0446g	44°27.835	092°16.730	705	2,214	2,200	3.7	10.7	548
0446c			705	2,214	--	--	--	--
REW					2,700			


Transect 1 - UMR mile 772.0
0411
0412
0413
0414
0415
0416
0417
Transect 2 - UMR mile 770.0
0421
0422
0423
0424
0425
0426
0427
Transect 3 - UMR mile 768.0
0431
0432
0433
0434
0435
0436
0437
DEPTH, IN METERS
0
5
10
0
1000
2000
3000
4000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 4, Transect 1--UMR mile 772.0
PARTY: Moody, Simoneaux, Noyes, Antweiler, and Bishop DATE: October 12, 1991
GAGE HEIGHT at Lake City: 667.58 ft
MAP: USGS 7.5-minute quadrangles are Lake City, and Pepin, Wis-Minn. RIVER SLOPE: 1.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore at the western lobe of the Handshaw Coulee delta (X-remote) and at the western lobe of the Bogus Creek delta (Y-remote). Samples were collected from *Acadiana*, and distances west from the remotes to *Acadiana* are listed below. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured since the estimated speeds were less than 3 cm/s. Distances from LEW were scaled from the map. River slope was estimated from river profiles provided by U.S. Army Corps of Engineers, St. Paul District.

BEARING OF TRANSECT: 047° magnetic

Site	NAD27		Distance					
	Latitude N	Longitude W	X remote	Y remote	Distance (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW					0			
0411g,c	44°27.575	092°13.455	3,930	665	550	2.4	10.4	543
0412g,c	27.420	13.620	3,609	686	960	7.2	11.0	541
0413g,c	27.255	13.970	3,287	1,077	1,450	7.6	11.2	544
0414g,c	27.105	14.245	2,979	1,496	1,910	8.0	11.0	544
0415g,c	26.950	14.445	2,749	1,946	2,370	8.7	11.0	545
0416g	26.785	14.815	2,525	2,401	2,870	8.7	11.1	542
0416c	--	--	2,520	2,399	--	--	--	--
0417g	44°26.620	092°15.105	2,421	2,876	3,350	8.9	11.2	538
0417c	--	--	2,429	2,862	--	--	--	--
REW					3,800			

STATION: Mississippi River in Pool 4, Transect 2--UMR mile 770.0
PARTY: Moody, Simoneaux, Noyes, Antweiler, and Bishop DATE: October 12, 1991
GAGE HEIGHT at Lake City: 667.58 ft
MAP: USGS 7.5-minute quadrangle is Lake City and Pepin, Wis.-Minn. RIVER SLOPE: 1.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore at the western lobe of the Handshaw Coulee delta (X-remote) and at the western lobe of the Bogus Creek delta (Y-remote). Samples were collected from *Acadiana*, and distances east from the remotes to *Acadiana* are listed below. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured since the estimated speeds were less than 2 cm/s. Latitude and longitude correspond to the location of the grab. River slope was estimated from river profiles provided by U.S. Army Corps of Engineers, St. Paul District.

BEARING OF TRANSECT: 021° magnetic

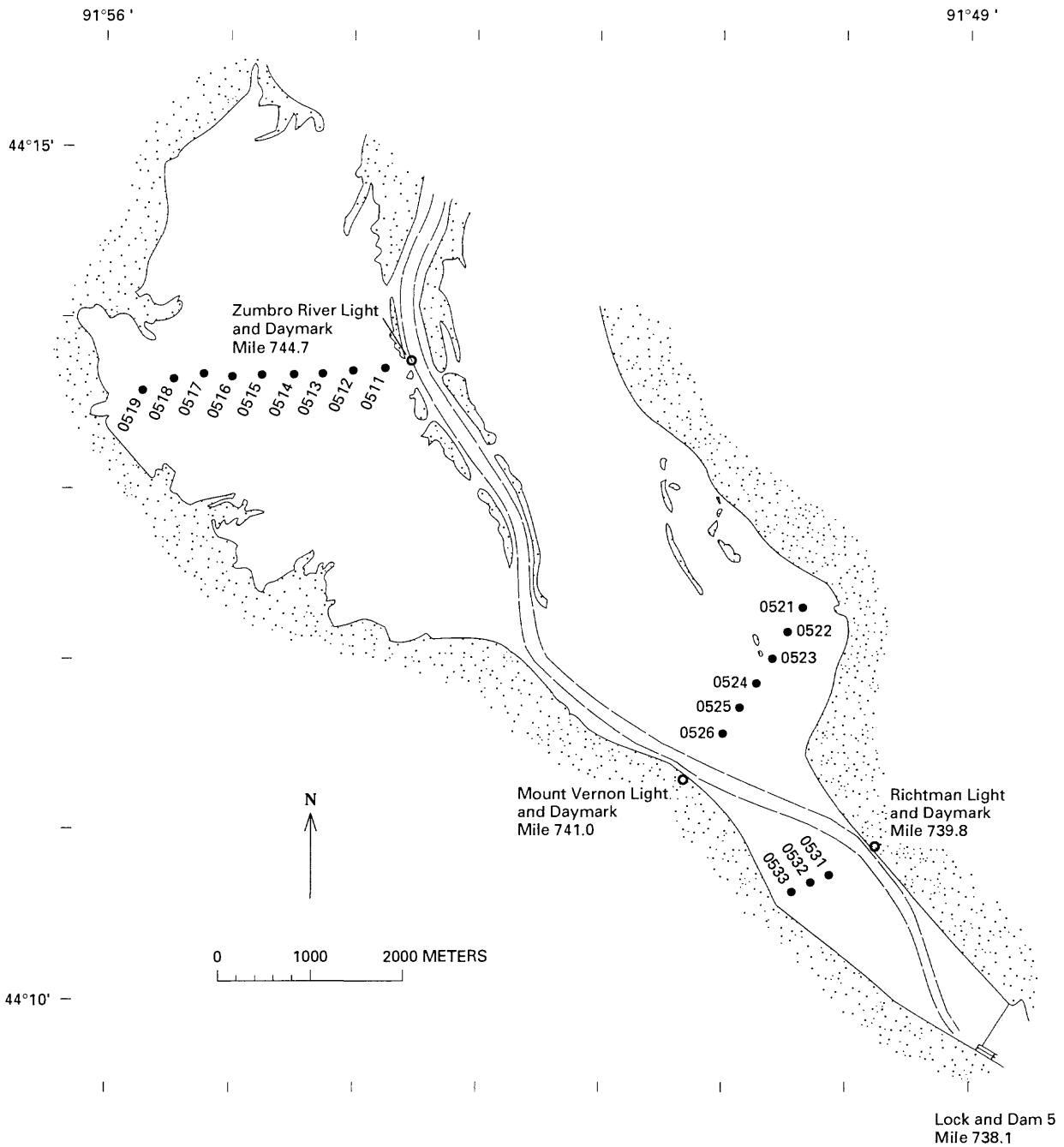
Site	NAD27		Distance					
	Latitude N	Longitude W	X remote	Y remote	Distance (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW					0			
0421g	44°26.905	092°12.060	3,807	1,603	450	6.9	11.5	536
0421c			3,806	1,597	--	--	--	--
0422g	26.685	12.220	3,392	1,668	880	7.2	11.2	545
0422c			3,369	1,664	--	--	--	--
0423g	26.440	12.355	2,959	1,894	1,370	7.3	11.3	540
0423c			2,962	1,885	--	--	--	--
0424g	26.220	12.505	2,575	2,154	1,800	7.8	11.1	542
0424c			2,571	2,149	--	--	--	--
0425g	25.985	12.650	2,193	2,491	2,270	8.0	11.1	543
0425c			2,188	2,485	--	--	--	--
0426g	25.750	12.775	1,886	2,870	2,740	8.8	11.3	535
0426c			1,878	2,865	--	--	--	--
0427g	44°25.535	092°12.940	1,606	3,242	3,150	9.2	11.3	540
0427c			1,606	3,242	--	--	--	--
REW					3,630			

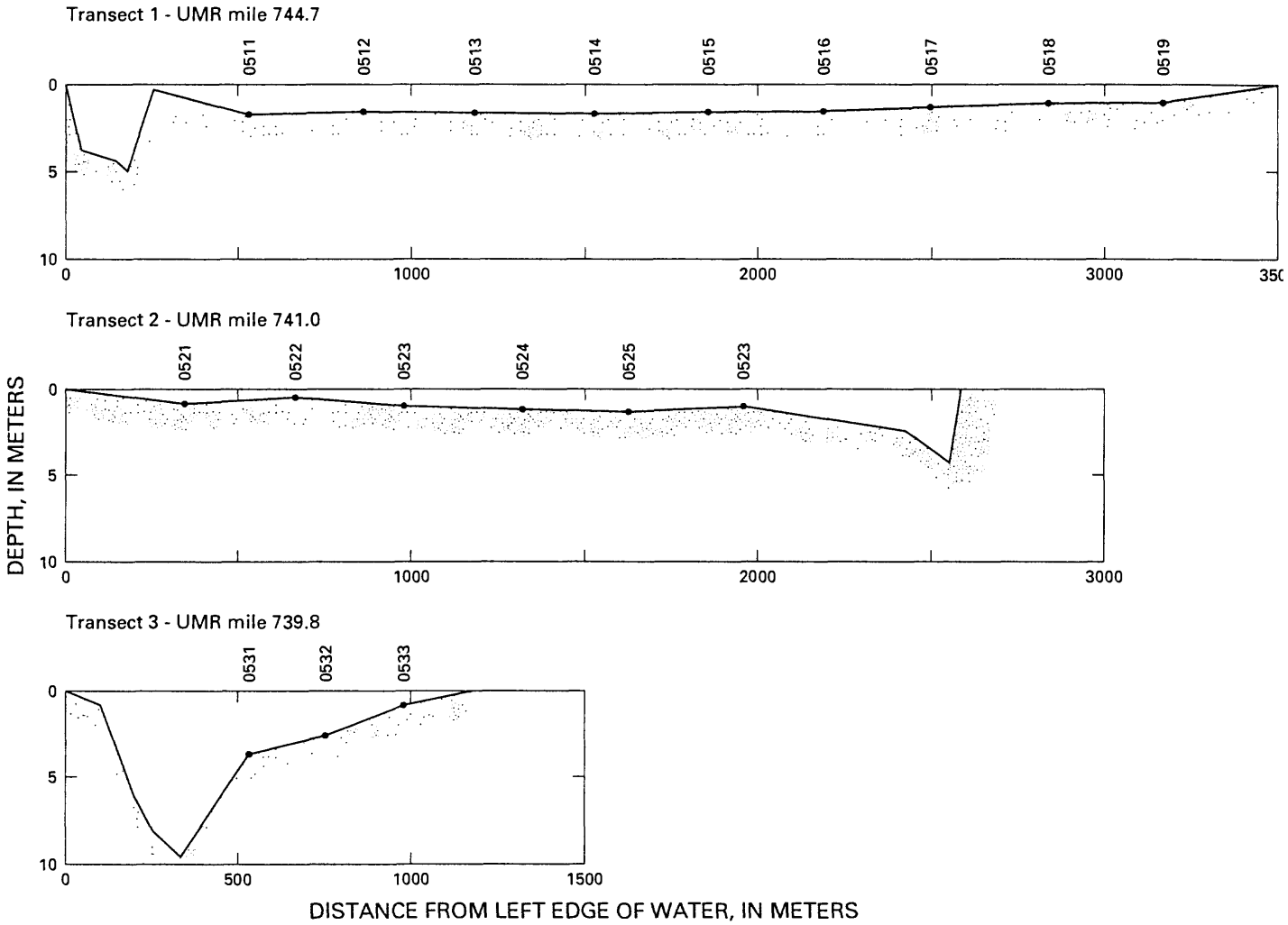
STATION: Mississippi River in Pool 4, Transect 3--UMR mile 768.0
PARTY: Moody, Simoneaux, Noyes, Antweiler, and Bishop DATE: October 12, 1991
GAGE HEIGHT at Lake City: 667.58 ft
MAP: USGS 7.5-minute quadrangle is Pepin, Wis.-Minn. RIVE SLOPE: $1.5x10^{-6}$
REMARKS:

Microwave trisponders were located ashore at the northern tip of the Dutchman Coulee delta (X-remote) and at the southern tip of the western jetty at Pepin harbor (Y-remote). Samples were collected from *Acadiana*, and distances east from the remotes to *Acadiana* are listed below. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured since the estimated speeds were less than 2 cm/s. Latitude and longitude correspond to the location of the grab sample. River slope was estimated from river profiles provided by U.S. Army Corps of Engineers, St. Paul District.

BEARING OF TRANSECT: 013° magnetic

Site	NAD27		Distance					
	Latitude N	Longitude W	X remote	Y remote	Distance (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW					0			
0431g	44°26.370	092°09.980	3,599	1,355	450	3.7	12.2	534
0431c			3,595	1,334	--	--	--	--
0432g	26.175	10.065	3,343	1,423	850	7.2	12.1	537
0432c			3,351	1,429	--	--	--	--
0433g	25.975	10.160	3,132	1,602	1,220	7.2	12.1	538
0433c			3,141	1,600	--	--	--	--
0434g	25.765	10.260	2,947	1,851	1,620	7.4	12.1	539
0434c			2,952	1,851	--	--	--	--
0435g	25.525	10.335	2,774	2,160	2,050	7.9	12.1	541
0435c			2,778	2,168	--	--	--	--
0436g	25.345	10.445	2,748	2,495	2,410	8.4	12.4	526
0436c			2,751	2,496	--	--	--	--
0437g	44°25.100	092°10.530	2,699	2,846	2,830	9.9	12.4	528
0437c			2,701	2,850	--	--	--	--
REW					3,240			


91°56 '
91°49 '
44°15'
44°10'
Zumbro River Light
and Daymark
Mile 744.7
0519
0518
0517
0516
0515
0514
0513
0512
0511
0521
0522
0523
0524
0525
0526
N
Mount Vernon Light
and Daymark
Mile 741.0
Richtman Light
and Daymark
Mile 739.8
0531
0532
0533
0 1000 2000 METERS
Lock and Dam 5
Mile 738.1


Transect 1 - UMR mile 744.7
0511
0512
0513
0514
0515
0516
0517
0518
0519
0
5
10
0
1000
2000
3000
Transect 2 - UMR mile 741.0
0521
0522
0523
0524
0525
0523
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
Transect 3 - UMR mile 739.8
0531
0532
0533
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 5, Transect 1--UMR mile 744.7
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 11, 1991
GAGE HEIGHT at TW Dam 4: 663.19 ft
GAGE HEIGHT at Dam 5: 659.44 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Weaver, Minn.-Wis.
REMARKS:
Acadiana at anchor, 104 m from LEW on spoil bank, and 3,400 m from REW of marsh. Discharge at Dam 5 was 1,700 m^3/s. Velocity measured at 0.6 depth while the small boat was anchored.
CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 082° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge[1] (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
01	--	--	54	3.7	0.70	122	119	24.3	514
02	--	--	132	4.0	0.90	122	162	24.2	522
03	--	--	184	4.8	0.86	122	183	24.3	528
04	--	--	260	0.1	0.01	306	0	--	--
0511	44°13.660	091°53.800	534	1.6	0.15	230	33	--	525
0512	13.650	54.045	864	1.2	0.12	180	47	25.0	530
0513	13.640	54.295	1,189	1.2	0.06	140	23	24.8	532
0514	13.635	54.535	1,524	1.4	0.07	150	31	24.8	532
0515	13.640	54.775	1,854	1.3	0.08	180	32	25.1	536
0516	13.625	55.025	2,184	1.1	0.07	180	26	25.2	544
0517	13.665	55.255	2,504	1.0	0.09	270	-6	25.5	546
0518	13.620	55.505	2,839	0.9	0.07	270	-4	25.4	510
0519	44°13.570	091°55.709	3,169	0.8	0.26	270	-14	25.3	509
REW			3,504	0.0					
Mean				1.2	0.15				
Total							632		

[1]Discharge is only part of the total discharge.

STATION: Mississippi River in Pool 5, Transect 2--UMR mile 741.0
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 11, 1991
GAGE HEIGHT at TW Dam 4: 663.19 ft
GAGE HEIGHT at Dam 5: 659.44 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Cochrane, Wis.-Minn.
REMARKS:

Acadiana at anchor, 190 m from REW, and 2,400 m from LEW. Velocity measured at 0.6 depth while the small boat was anchored. Discharge at Dam 5 was 1,700 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 032° magnetic

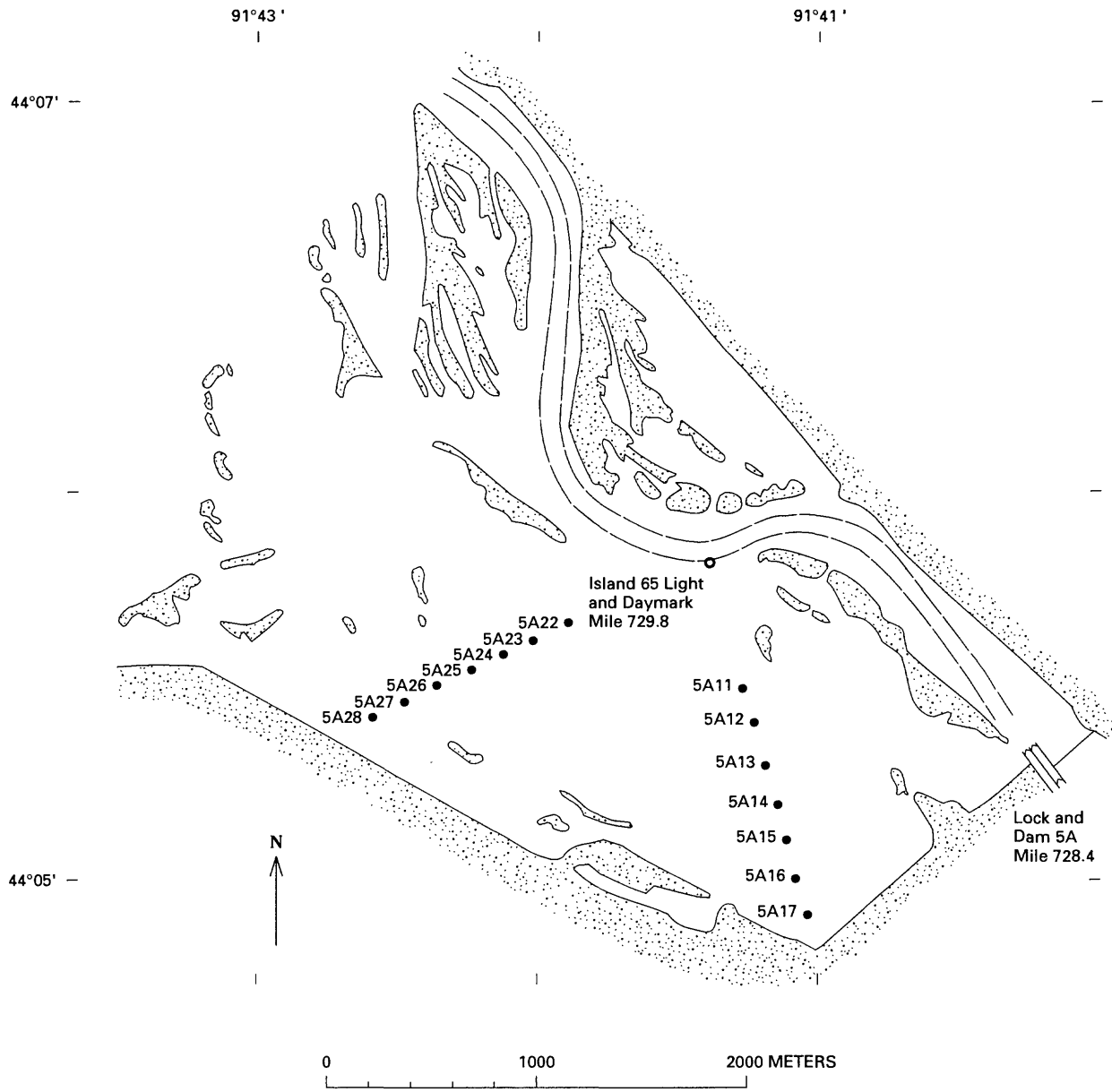
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0521	44°12.220	091°50.230	340	1.1	0.07	160	18	25.8	440
0522	12.080	50.365	665	0.7	0.12	170	16	25.9	441
0523	11.950	50.435	990	1.4	0.14	180	30	25.9	444
0524	11.795	50.625	1,325	1.8	0.33	150	162	26.2	431
0525	11.655	50.760	1,640	2.0	0.37	90	207	25.7	450
0526	44°11.515	091°50.885	1,965	1.4	0.32	90	144	25.8	487
01	--	--	2,365	3.2	0.39	122	292	25.1	515
02	--	--	2,440	4.0	0.52	122	149	25.1	519
03	--	--	2,510	5.8	0.58	122	192	25.2	520
04	--	--	2,555	6.8	0.51	122	137	25.6	520
REW			2,590	0.0					
Mean				1.7	0.30				
Total							1,347		

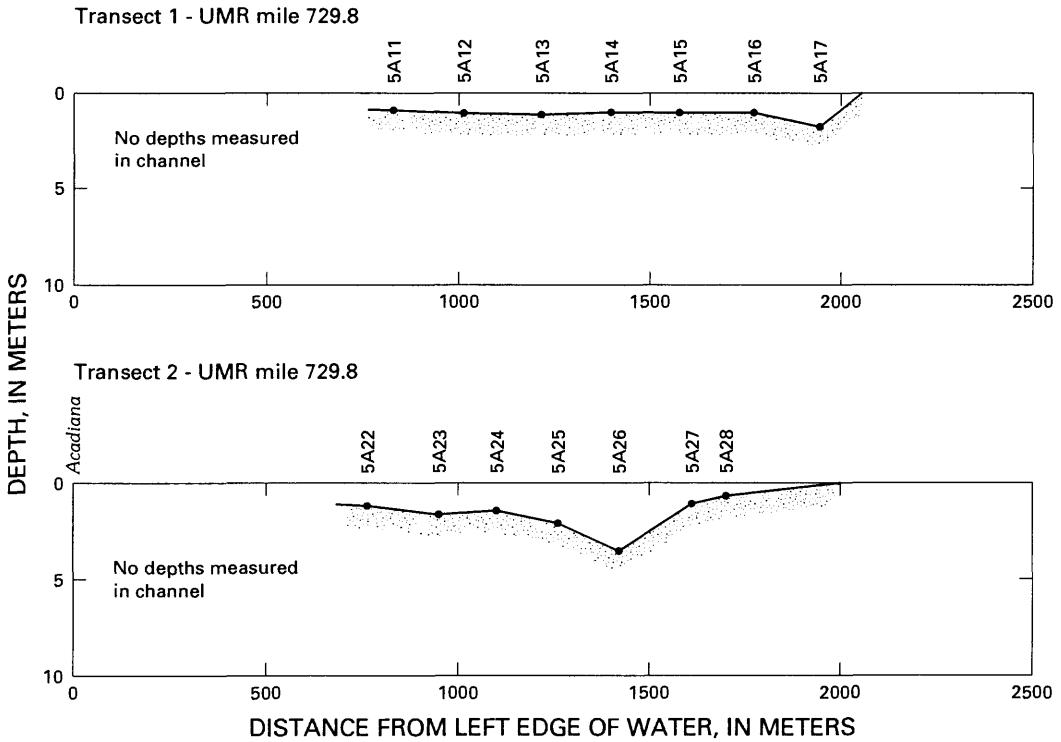
STATION: Mississippi River in Pool 5, Transect 3--UMR mile 739.8
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 11, 1991
GAGE HEIGHT at TW Dam 4: 663.19 ft
GAGE HEIGHT at Dam 5: 659.445 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Cochrane, Wis.-Minn.
REMARKS:

Acadiana at anchor, 160 m from LEW, and 1,1015 m from REW. Velocity measured at 0.6 depth while the small boat was anchored. Discharge at Dam 5 was 1,700 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 060° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
01	--	--	100	0.6	0.25	220	4	27.6	426
02	--	--	205	6.0	0.51	150	246	26.3	437
03	--	--	260	8.0	0.56	150	290	26.2	450
04	--	--	335	9.2	0.30	150	363	26.0	481
0531	44°10.665	091°49.970	525	3.5	0.41	130	286	25.6	516
0532	10.615	50.125	750	2.3	0.28	100	104	25.6	517
0533	44°10.650	091°50.280	980	0.6	0.22	160	28	26.1	516
REW			1,175	0.0					
Mean				3.1	0.36				
Total							1,320		


91°43 '
91°41 '
44°07'
44°05'
Island 65 Light
and Daymark
Mile 729.8
5A22
5A23
5A24
5A25
5A26
5A27
5A28
5A11
5A12
5A13
5A14
5A15
5A16
5A17
Lock and
Dam 5A
Mile 728.4
N
0
1000
2000 METERS


Transect 1 - UMR mile 729.8
5A11
5A12
5A13
5A14
5A15
5A16
5A17
No depths measured in channel
Transect 2 - UMR mile 729.8
Acadiana
5A22
5A23
5A24
5A25
5A26
5A27
5A28
No depths measured in channel
DEPTH, IN METERS
0
5
10
0
500
1000
1500
2000
2500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 5A, Transect 1--UMR mile 729.8
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 11, 1991
GAGE HEIGHT at TW Dam 5: 653.80 ft
GAGE HEIGHT at Dam 5A: 650.11 ft
SUSPENSION: none
RIVER SLOPE: 78×10^{-6}
CURRENT METER No: None
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Winona West, Minn.-Wis.
REMARKS:

Acadiana anchored at UMR mile 729.8, 103 m from LEW on spoil bank, 225 m from upstream tip of Island 65, and 2,030 m from southwest corner of spillway of Dam 5A. No velocities were measured.

CURRENT METER EQUATION: None
BEARING OF TRANSECT: 015° magnetic

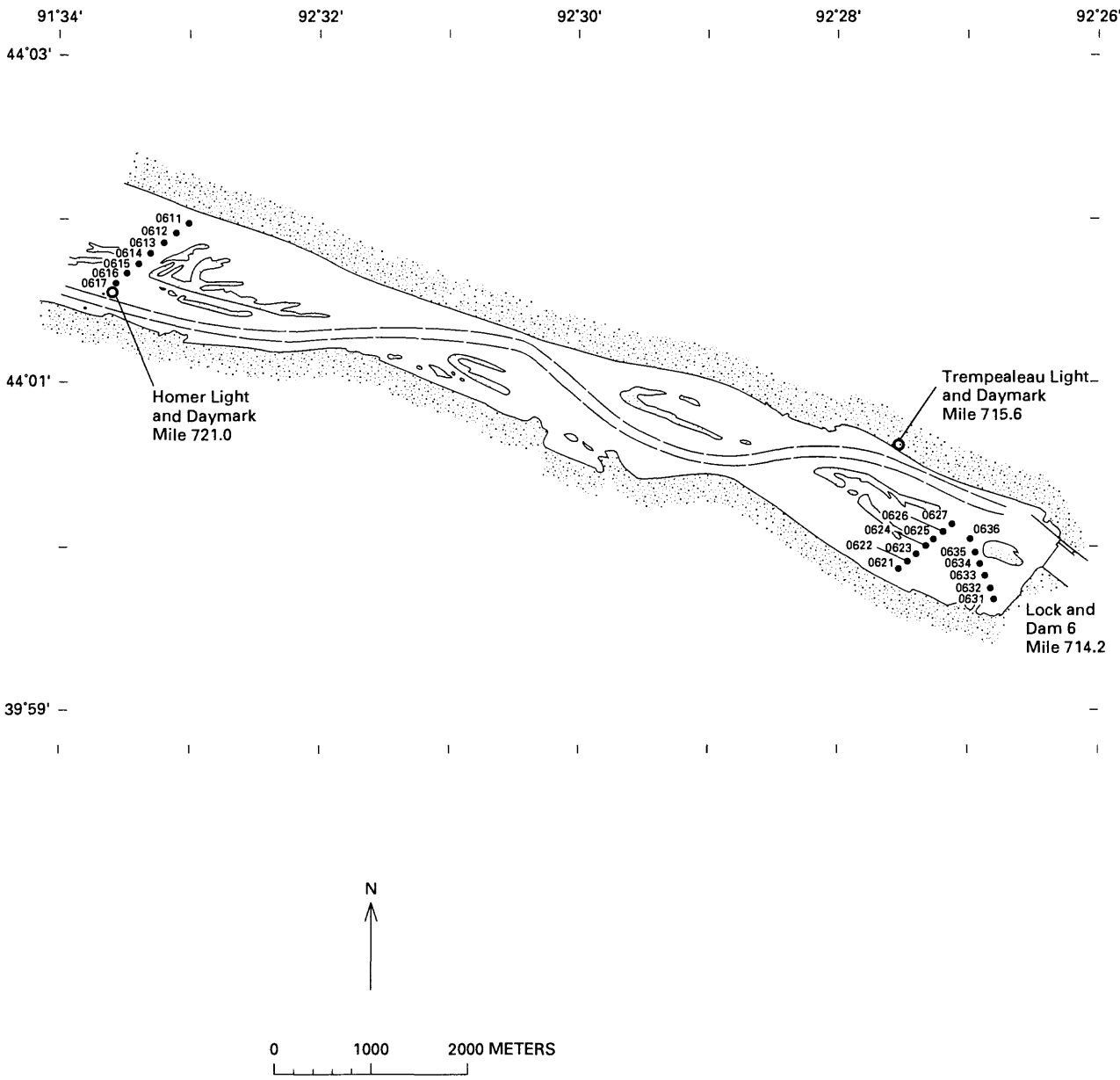
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
05A11	44°05.485	092°41.250	838	0.9	--	--	--	25.5	515
05A12	05.400	41.220	1,013	1.0	--	--	--	25.6	513
05A13	05.300	41.175	1,213	1.0	--	--	--	25.6	514
05A14	05.195	41.145	1,403	1.0	--	--	--	25.7	515
05A15	05.115	41.110	1,573	1.0	--	--	--	25.8	515
05A16	05.010	41.070	1,773	1.0	--	--	--	26.0	516
05A17	44°04.905	092°41.035	1,953	1.8	--	--	--	27.0	510
REW			2,045	0.0					
Mean				1.2					

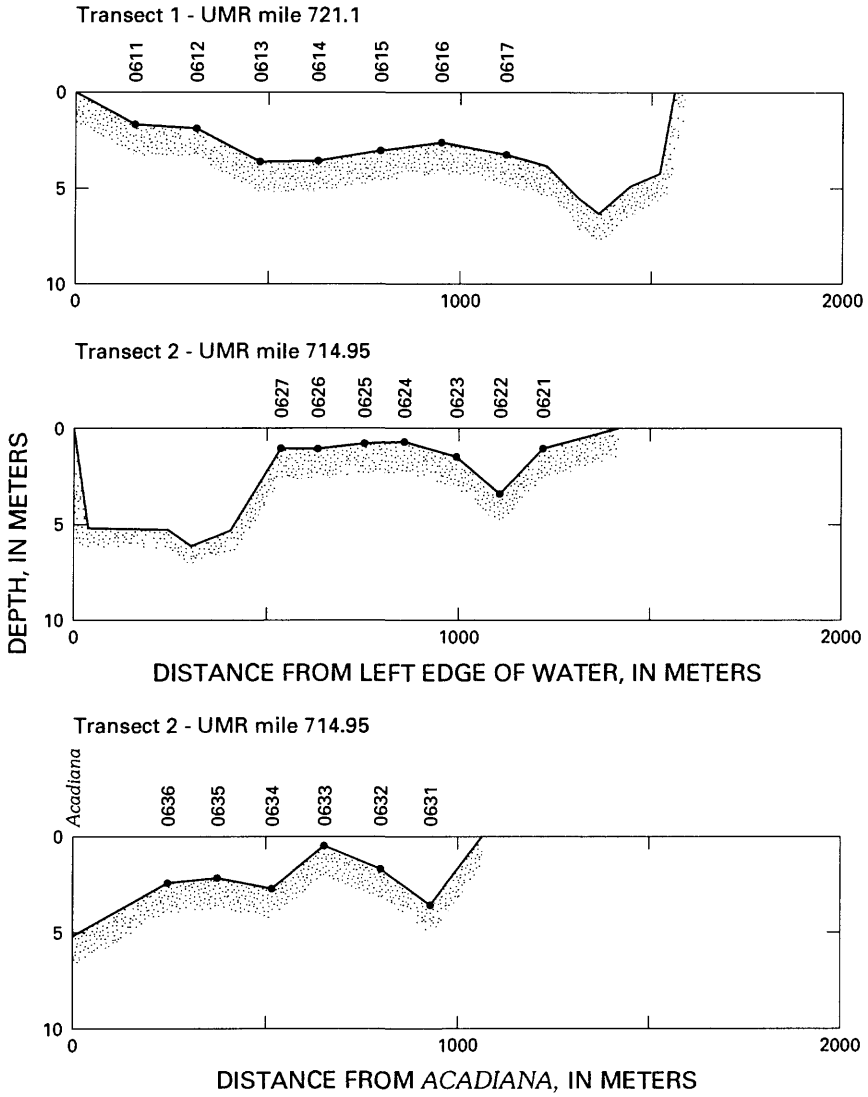
STATION: Mississippi River in Pool 5A, Transect 2--UMR mile 729.8
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 11, 1991
GAGE HEIGHT at TW Dam 5: 653.80 ft
GAGE HEIGHT at Dam 5A: 650.11 ft
SUSPENSION: None
RIVER SLOPE: 78×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Winona West, Minn.-Wis.
REMARKS:

Acadiana anchored at UMR mile 729.8, 103 m from LEW on spoil bank, 255 m from upstream tip of Island 65, and 2,030 m from southwest corner of spillway of Dam 5A. Positions along a line connecting the channel markers at UMR mile 729.5 and 729.8. Distances measured from *Acadiana* which was not on transect. Station 05A21 was skipped due to thunderstorm and darkness.

CURRENT METER EQUATION: None
BEARING OF TRANSECT: 151° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
05A22	44°05.670	092°41.885	765	1.3	--	--	--	25.0	514
05A23	05.625	41.020	950	1.8	--	--	--	25.2	515
05A24	05.590	41.120	1,100	1.4	--	--	--	25.3	520
05A25	05.550	41.230	1,265	2.0	--	--	--	25.5	516
05A26	05.510	41.350	1,435	3.6	--	--	--	25.3	513
05A27	05.470	41.470	1,615	1.0	--	--	--	25.6	520
05A28	44°05.430	092°41.950	1,700	0.8	--	--	--	25.5	520
REW			1,960	0.0					


91°34'
92°32'
92°30'
92°28'
92°26'
44°03'
44°01'
39°59'
0611
0612
0613
0614
0615
0616
0617
Homer Light
and Daymark
Mile 721.0
Trempealeau Light
and Daymark
Mile 715.6
0626
0627
0624
0625
0636
0622
0623
0635
0621
0634
0633
0632
0631
Lock and
Dam 6
Mile 714.2
N
0
1000
2000 METERS


Transect 1 - UMR mile 721.1
0611
0612
0613
0614
0615
0616
0617
0
5
10
0
1000
2000
Transect 2 - UMR mile 714.95
0627
0626
0625
0624
0623
0622
0621
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 714.95
Acadiana
0636
0635
0634
0633
0632
0631
DISTANCE FROM ACADIANA, IN METERS

STATION: Mississippi River in Pool 6, Transect 1--UMR mile 721.1
PARTY: Moody, Meade, Roth, and Writer
DATE: April 13, 1992
GAGE HEIGHT at TW Dam 5A: 648.27 ft
GAGE HEIGHT at Dam 6: 644.52 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.4 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Winona East, Minn.-Wis.
REMARKS:

Acadiana anchored on right bank at UMR mile 721.1: 21 m off REW, 245 m from Homer Light and Daymark (UMR mile 721.0); 237 m upstream from mouth of small creek that enters Mississippi River on upstream side of Homer, Minn. Velocity direction estimated by local landmarks.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 047° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0611	44°01.955	091°33.020	155	1.6	0.46	100	99	5.0	422
0612	01.900	33.110	316	1.7	0.47	90	94	5.3	428
0613	01.845	33.195	472	3.5	0.56	50	38	5.3	430
0614	01.785	33.300	634	3.6	0.57	50	41	5.3	434
0615	01.735	33.395	797	3.0	0.62	50	36	5.2	437
0616	01.680	33.485	956	2.5	0.67	60	78	5.1	436
0617	44°01.630	091°33.570	1,113	3.1	0.53	80	138	4.9	442
01	--	--	1,236	3.8	0.76	90	207	4.8	445
02	--	--	1,310	5.6	0.77	90	179	5.0	452
03	--	--	1,349	5.9	0.73	90	156	4.9	460
04	--	--	1,409	5.2	0.77	90	196	5.0	464
05	--	--	1,483	4.5	0.69	90	128	4.9	472
06	--	--	1,522	4.3	0.54	90	61	5.1	472
REW			1,554	0.0					
Mean				3.0	0.31				
Total							1,451		

STATION: Mississippi River in Pool 6, Transect 2--UMR mile 714.95

PARTY: Moody, Meade, Roth, and Writer

DATE: April 13, 1992

GAGE HEIGHT at TW Dam 5A: 648.27 ft

GAGE HEIGHT at Dam 6: 644.52 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 47.4×10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangle is Trempealeau, Wis.

REMARKS:

Acadiana anchored on green buoy line at UMR mile 714.95: 717 m from upstream tip of longest guidewall at Lock 6, 342 m from LEW on line with one-block-long street at west end of Trempealeau, and 1,038 m from west abutment of railroad bridge on right bank near BM 656.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 049° magnetic

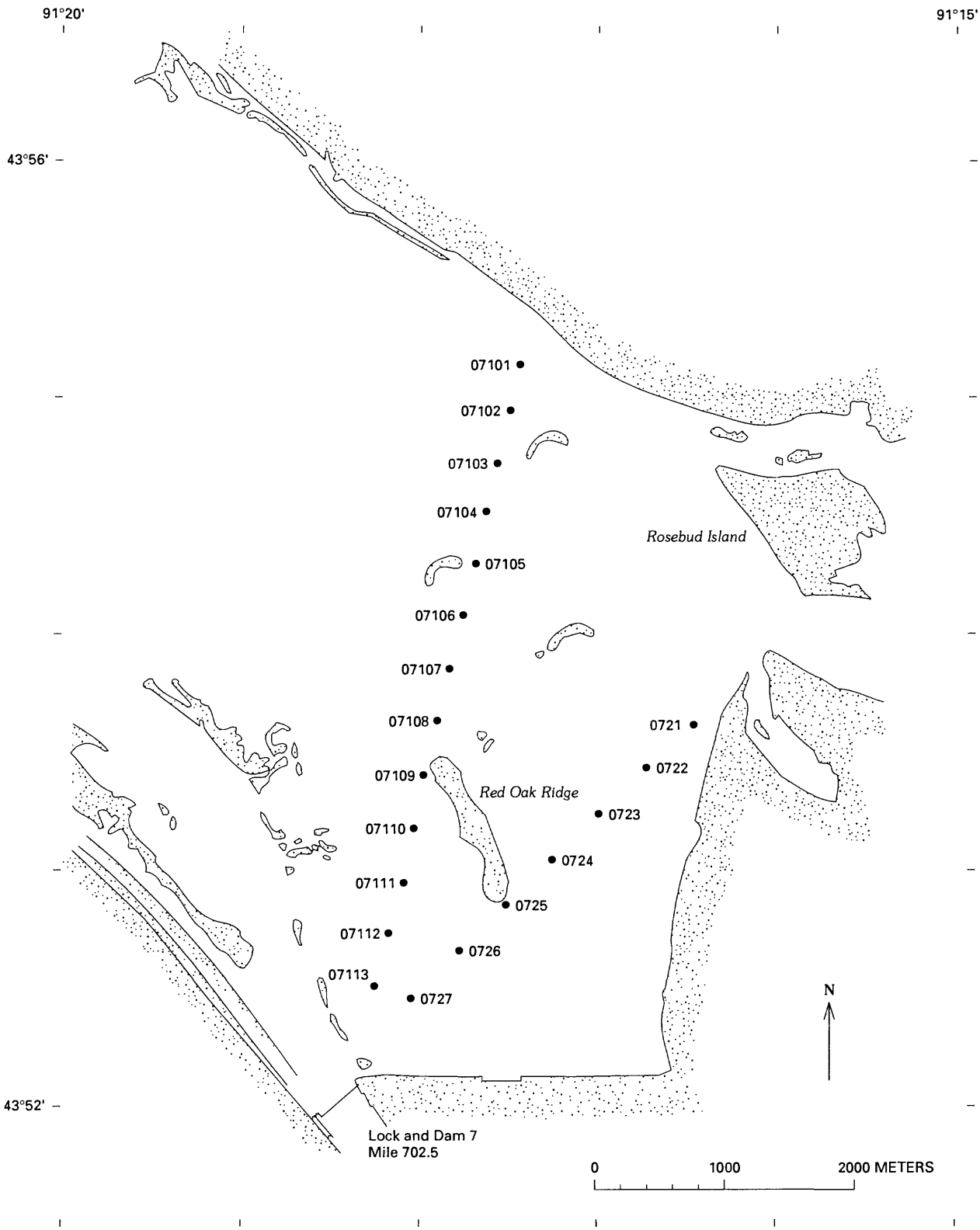
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0				5.3	420
06	--	--	35	5.1	0.44	120	167	5.2	420
05	--	--	155	5.1	0.71	130	368	5.4	431
04	--	--	240	5.1	0.75	160	250	5.5	446
03	--	--	300	6.0	0.49	140	199	5.3	459
02	--	--	375	5.3	0.43	160	103	5.3	464
01	--	--	400	5.3	0.38	140	145	5.4	467
0627	44°00.085	091°27.080	520	1.0	0.29	100	28	5.4	469
0626	00.050	27.150	635	1.0	0.12	80	8	5.5	469
0625	44°00.010	27.220	755	0.6	0.12	60	2	5.4	470
0624	43°59.975	27.285	865	0.5	0.28	80	9	5.5	472
0623	59.935	27.360	985	1.5	0.41	120	69	5.4	472
0622	59.900	27.430	1,100	3.3	0.31	90	82	4.8	477
0621	43°59.870	091°27.500	1,211	1.0	0.36	100	50	4.6	476
REW			1,438	0.0					
Mean				2.4	0.43				
Total							1,480		

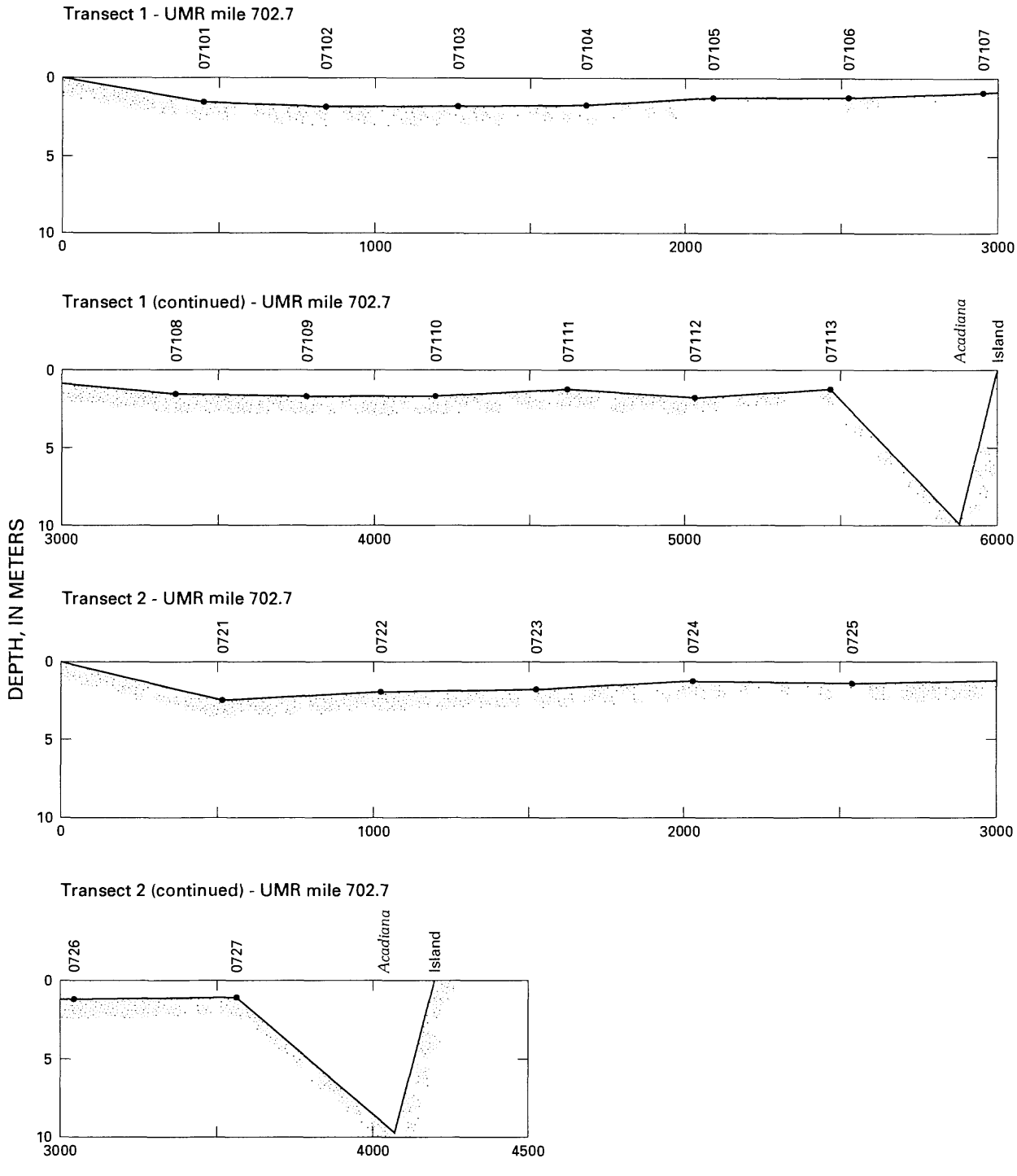
STATION: Mississippi River in Pool 6, Transect 3--UMR mile 714.95
PARTY: Moody, Meade, Roth, and Writer
DATE: April 13, 1992
GAGE HEIGHT at TW Dam 5A: 648.27 ft
GAGE HEIGHT at Dam 6: 644.52 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.4 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Trempealeau, Wis.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 714.95: 717 m from upstream tip of longest guidewall at Lock 6, 342 m from LEW on line with one-block-long street at west end of Trempealeau, and 1,038 m from west abutment of railroad bridge on right bank near BM 656.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 156° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana	--	--	0	5.3					
0636	44°00.005	091°26.945	245	2.2	0.22	110	63	5.2	470
0635	43°59.935	26.905	385	1.9	0.19	110	32	5.2	470
0634	59.870	26.870	515	2.5	0.22	110	49	5.2	469
0633	59.795	26.825	655	0.3	0.10	90	4	5.2	472
0632	59.725	26.795	795	1.6	0.12	70	27	5.2	475
0631	43°59.660	091°26.755	930	3.5	0.31	90	126	5.2	475
REW			1,060	0.0					
Mean				1.6	0.17				
Total							301		


91°20'
91°15'
43°56'
43°52'
07101
07102
07103
07104
07105
07106
07107
07108
07109
07110
07111
07112
07113
0721
0722
0723
0724
0725
0726
0727
Rosebud Island
Red Oak Ridge
N
Lock and Dam 7
Mile 702.5
0
1000
2000 METERS


Transect 1 - UMR mile 702.7
07101
07102
07103
07104
07105
07106
07107
0
5
10
0
1000
2000
3000
Transect 1 (continued) - UMR mile 702.7
07108
07109
07110
07111
07112
07113
Acadiana
Island
0
5
10
3000
4000
5000
6000
DEPTH, IN METERS
Transect 2 - UMR mile 702.7
0721
0722
0723
0724
0725
0
5
10
0
1000
2000
3000
Transect 2 (continued) - UMR mile 702.7
0726
0727
Acadiana
Island
0
5
10
3000
4000
4500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 7, Transect 1--UMR mile 702.7
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 13, 1991
GAGE HEIGHT at TW Dam 6: 642.13 ft
GAGE HEIGHT at Dam 7: 639.00 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 54×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Holmen, Wis., and La Crescent, Minn-Wis.
REMARKS:
Acadiana anchored in southwest corner of Lake Onalaska: 1,240 m from west end of spillway; 1,500 m from south tip of Red Oak Ridge Island. Velocity was measured at 0.6 depth while anchored.
CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 013° magnetic

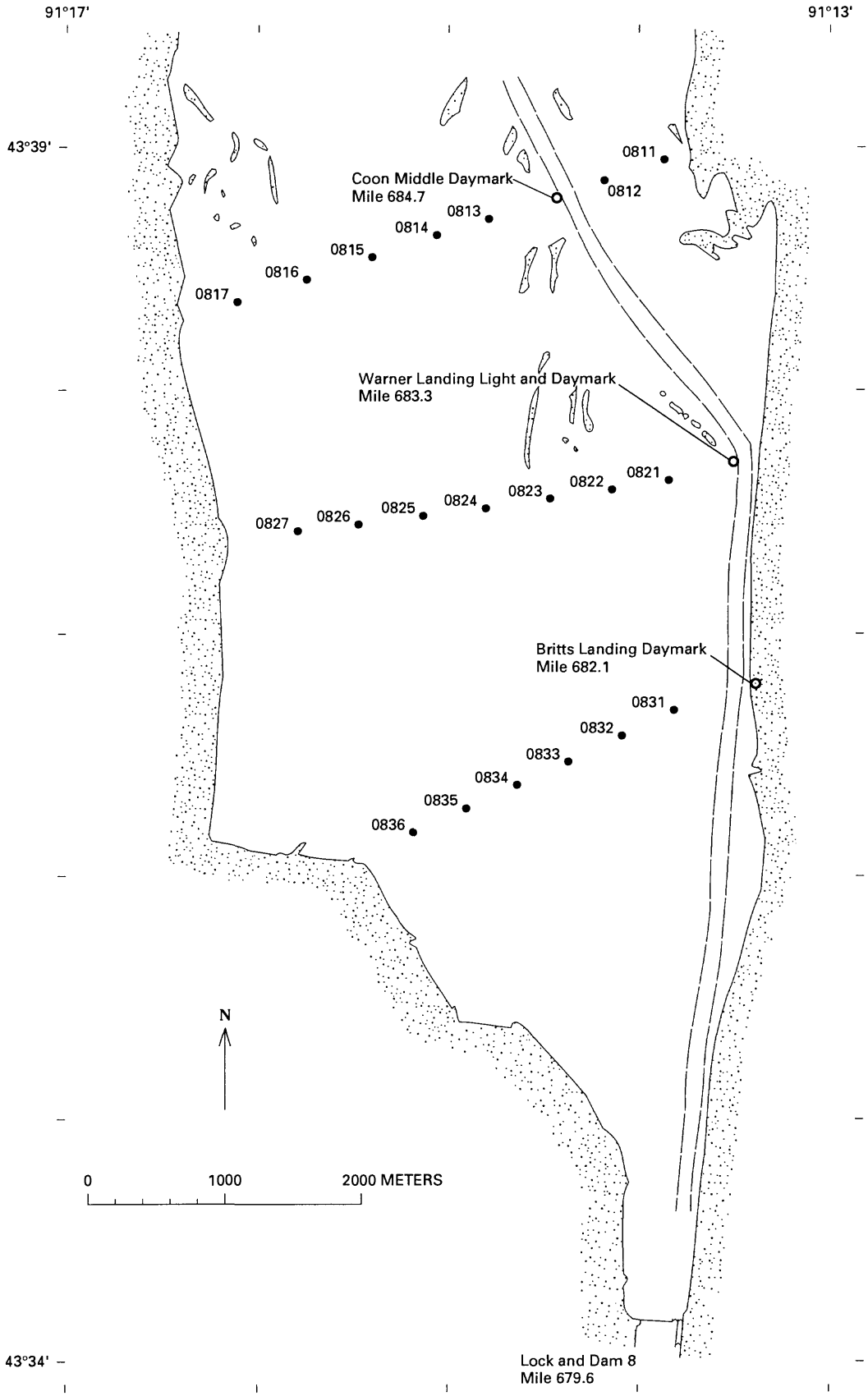
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
07101	43°55.055	091°17.450	450	1.6	0.11	120	68	22.9	405
07102	54.910	17.495	840	1.7	0.11	130	65	22.8	479
07103	54.690	17.565	1,270	1.8	0.12	120	84	23.4	476
07104	54.475	17.625	1,680	1.9	0.15	120	108	23.5	478
07105	54.265	17.695	2,090	1.1	0.19	100	88	23.2	480
07106	54.030	17.760	2,515	1.2	0.10	30	19	23.2	476
07107	53.810	17.830	2,950	0.8	0.14	130	39	23.9	474
07108	53.600	17.890	3,360	1.2	0.14	180	11	23.6	477
07109	53.375	17.960	3,780	1.6	0.25	170	54	23.7	476
07110	53.150	18.030	4,200	1.4	0.14	160	40	23.8	475
07111	52.925	18.100	4,620	1.0	0.15	180	10	23.9	475
07112	52.715	18.165	5,040	1.7	0.16	225	-66	23.7	476
07113	43°52.490	091°18.225	5,460	1.1	0.22	210	-37	23.9	476
Acadiana	--	--	5,880	9.8	0.28	230	-491	23.7	478
Island			6,000	0.0					
Mean				1.7	0.00				
Total							-8		

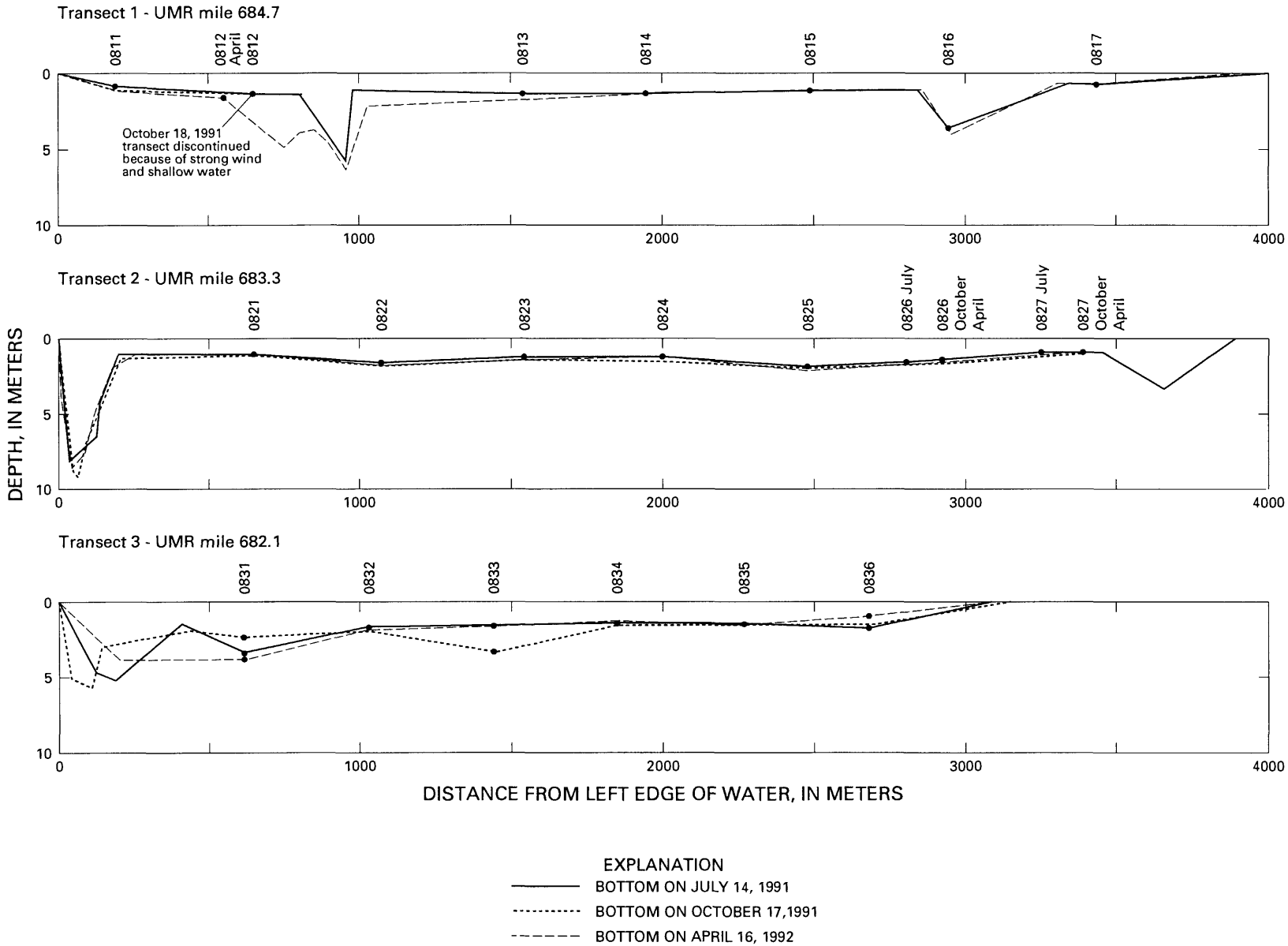
STATION: Mississippi River in Pool 7, Transect 2--UMR mile 702.7
PARTY: Moody, Meade, Bishop, and Garbarino
DATE: July 13, 1992
GAGE HEIGHT at TW Dam 6: 642.13 ft
GAGE HEIGHT at Dam 7: 639.00 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 54×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Holmen, Wis., and La Crescent, Minn.-Wis.
REMARKS:

Acadiana anchored in southwest corner of Lake Onalaska: 1,240 m from west end of spillway; 1,500 m from south tip of Red Oak Ridge Island. Velocity was measured at 0.6 depth while anchored. Current direction at *Acadiana* is relative to dogleg in transect.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 046° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
0721	--	--	520	2.1	0.13	170	109	25.2	450
0722	43°53.610	091°16.420	1,020	1.8	0.14	160	112	24.6	472
0723	53.425	16.690	1,530	1.7	0.14	140	124	24.6	470
0724	53.240	16.945	2,035	1.2	0.15	160	82	24.6	470
0725	53.035	17.225	2,540	1.4	0.24	200	64	24.8	470
0726	52.850	17.485	3,045	1.2	0.15	220	3	24.8	469
0727	52.655	17.750	3,560	1.0	0.22	190	59	24.6	472
Acadiana	43°52.465	091°18.020	4,070	9.8	0.28	265	-605	23.7	478
Island	--	--	4,200	0.0					
Main channel	--	--		--				24.1	485
Mean				2.0	-0.01				
Total							-52		


91°17'
91°13'
43°39'
43°34'
0811
0812
Coon Middle Daymark
Mile 684.7
0813
0814
0815
0816
0817
Warner Landing Light and Daymark
Mile 683.3
0821
0822
0823
0824
0825
0826
0827
Britts Landing Daymark
Mile 682.1
0831
0832
0833
0834
0835
0836
N
0
1000
2000 METERS
Lock and Dam 8
Mile 679.6


Transect 1 - UMR mile 684.7
0811
0812 April
0812
0813
0814
0815
0816
0817
October 18, 1991 transect discontinued because of strong wind and shallow water
Transect 2 - UMR mile 683.3
0821
0822
0823
0824
0825
0826 July
0826 October
April
0827 July
0827 October
April
Transect 3 - UMR mile 682.1
0831
0832
0833
0834
0835
0836
DEPTH, IN METERS
0
5
10
0
1000
2000
3000
4000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
EXPLANATION
BOTTOM ON JULY 14, 1991
BOTTOM ON OCTOBER 17,1991
BOTTOM ON APRIL 16, 1992

STATION: Mississippi River in Pool 8, Transect 1--UMR mile 684.7
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 14, 1991
GAGE HEIGHT at TW Dam 7: 634.51 ft
GAGE HEIGHT at Dam 8: 629.74 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 38×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis., and Stoddard, Wis.
REMARKS:

Acadiana anchored 125 m from daymark at UMR 684.7; 840 m from east shore and 3,030 m from west shore (delta of small creek). Velocity was measured at 0.6 depth while anchored. Edges of channel estimated by E01, E02, E03, and E04.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 067° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0811	43°38.840	091°13.795	190	0.8	0.30	180	69	26.6	454
0812	38.760	14.120	645	1.3	0.28	190	88	25.5	455
E03	--	--	800	1.3	0.28	190	30	--	--
01	--	--	855	3.2	0.56	170	73	25.7	464
02	--	--	885	4.2	0.61	150	82	25.6	465
03	--	--	920	4.7	0.65	160	106	25.5	469
04	--	--	955	5.8	0.63	150	101	26.4	463
E04	--	--	975	1.2	0.50	190	139	--	--
0813	38.615	14.745	1,540	1.2	0.50	190	231	26.3	467
0814	38.545	15.035	1,945	1.1	0.19	150	94	26.9	466
0815	38.465	15.395	2,440	0.9	0.21	160	84	28.1	470
E01	--	--	2,845	0.9	0.21	160	47	--	--
0816	38.380	15.745	2,945	3.6	0.58	200	357	26.8	465
E02	--	--	3,345	0.5	0.08	190	8	--	--
0817	43°38.300	091°16.100	3,435	0.5	0.08	190	9	29.4	466
REW			3,870	0.0					
Mean				1.2	0.33				
Total							1,518		

STATION: Mississippi River in Pool 8, Transect 2--UMR mile 683.3
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 14, 1991
GAGE HEIGHT at TW Dam 7: 634.51 ft
GAGE HEIGHT at Dam 8: 629.74 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 38×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis., Stoddard, Wis., Genoa, Wis., and Reno, Minn.
REMARKS:

Acadiana anchored 85 m from daymark at UMR 683.3; 141 m from east shore and 3,740 m from west shore near Fairy Rock. Velocity was measured at 0.6 depth while anchored. Edges of channel were estimated by E01, E02.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 078° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
01	--	--	41	8.1	0.36	170	111	28.3	452
02	--	--	76	7.6	0.57	170	161	27.0	451
03	--	--	116	6.3	0.57	170	112	26.6	455
04	--	--	139	4.1	0.49	180	81	26.7	457
E01	--	--	200	1.0	0.13	120	23	--	--
0821	43°37.555	091°13.795	651	1.0	0.13	120	40	27.1	466
0822	37.530	14.100	1,071	1.6	0.28	180	191	27.1	463
0823	37.500	14.445	1,551	1.0	0.20	170	91	27.6	464
0824	37.470	14.785	2,006	1.0	0.18	170	85	27.2	467
0825	37.435	15.125	2,476	1.7	0.24	180	156	27.3	466
0826	37.410	15.455	2,800	1.5	0.18	180	103	27.2	475
0827	43°37.380	091°15.795	3,250	0.8	0.10	150	23	27.0	477
E02	--	--	3,400	0.8	0.10	150	15	--	--
05	--	--	3,658	3.2	0.37	170	286	28.0	483
REW	--	--	3,881	0.0					
Mean				1.5	0.26				
Total							1,478		

STATION: Mississippi River in Pool 8, Transect 3--UMR mile 682.1
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 14, 1991
GAGE HEIGHT at TW Dam 7: 634.51 ft
GAGE HEIGHT at Dam 8: 629.74 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 38 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Reno, Minn., and Genoa, Wis.
REMARKS:

Acadiana anchored 195 m from east shoreline; 210 m from shoreline at UMR mile 682.1 marker; 590 m from mouth of Spring Creek; 2,900 m from corner (marked 640) of earth-dam part of Dam 8. Velocity was measured at 0.6 depth while anchored.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 064° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
03	--	--	130	4.7	0.54	190	179	26.8	458
02	--	--	185	5.3	0.53	190	81	26.7	462
04	--	--	205	5.2	0.50	190	228	26.8	462
01	--	--	415	1.5	0.17	170	49	26.0	469
0831	43°36.625	091°13.785	620	3.2	0.29	180	250	26.8	462
0832	36.530	14.070	1,035	1.5	0.22	180	117	26.8	466
0833	36.425	14.365	1,450	1.4	0.24	160	138	27.3	472
0834	36.330	14.630	1,860	1.1	0.17	130	74	27.2	474
0835	36.245	14.880	2,275	1.2	0.17	150	84	27.9	472
0836	43°36.145	091°15.160	2,690	1.8	0.16	120	105	27.9	474
REW			3,110	0.0					
Mean				1.7	0.24				
Total							1,305		

STATION: Mississippi River in Pool 8, Transect 1--UMR mile 684.7

PARTY: Moody, Meade, Brinton, and Writer

DATE: October 17, 1991

GAGE HEIGHT at TW Dam 7: 631.30 ft

GAGE HEIGHT at Dam 8: 630.37 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 7.3×10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis. and Stoddard, Wis.

REMARKS:

Acadiana anchored on red buoy line at UMR mile 684.7; 785m from LEW; 770 m from southernmost peninsula of Coon Creek; 575 m from southeastern tip of island north of UMR mile 684.7. Only two stations were sampled due to southwesterly winds that exceeded 30 miles per hour, very choppy water, and shallow water.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 067° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
0811	43°38.84	091°13.80	190	1.0	<0.05	350	--	9.9	457
0812	43°38.76	091°14.12	655	1.4	0.24	270	--	10.2	435

STATION: Mississippi River in Pool 8, Transect 2--UMR mile 683.3
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 17, 1991
GAGE HEIGHT at TW Dam 7: 631.30 ft
GAGE HEIGHT at Dam 8: 630.37 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 7.3×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis., and Stoddard, Wis., and Genoa, Wis., and Reno, Minn.
REMARKS:

Acadiana anchored 60 m from daymark at UMR mile 683.3; 141 m from LEW; 3,750 m from west shore at cluster of houses near Fairy Rock. Velocities were measured at 0.6 depth and at surface while anchored. Only 0.6 measurements are listed. Wind from southwest decreased from 15 to 0 mph. Discharge through Dam 8 was 600 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 078° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
03	--	--	32	8.5	0.35	200	53	12.4	429
01	--	--	44	8.7	0.29	200	57	11.5	429
02	--	--	89	7.0	0.23	200	52	11.5	440
04	--	--	124	5.3	0.24	160	356	11.2	438
0821	43°37.555	091°13.795	654	1.0	0.01	100	1	11.5	440
0822	37.530	14.100	1,069	1.7	0.19	120	104	12.3	438
0823	37.500	14.445	1,554	1.2	0.14	70	-6	12.9	435
0824	37.470	14.785	1,999	1.2	0.05	60	-7	12.0	438
0825	37.435	15.125	2,474	1.8	0.15	120	91	12.2	447
0826	37.410	15.455	2,944	1.6	0.13	20	-79	12.4	449
0827	43°37.380	091°15.795	3,394	0.8	0.10	330	-37	12.5	449
REW			3,884	0.0					
Mean				1.7	0.09				
Total							585		

STATION: Mississippi River in Pool 8, Transect 3--UMR mile 682.1
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 17, 1991
GAGE HEIGHT at TW Dam 7: 631.30 ft
GAGE HEIGHT at Dam 8: 630.37 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 7.3×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Reno, Minn., and Genoa, Wis.
REMARKS:

Acadiana anchored on green buoy line, 185 m from LEW on line orthogonal to bank; 600 m from mouth of Spring Creek on left bank; 2,900 m from corner (marked '640' on map) of earth-dam part of Dam 8. Anchor dragged twice and *Acadiana* had to reanchor during collection of samples. Discharge through Dam 8 was 600 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 064° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
04	--	--	35	4.5	0.41	210	53	--	--
03	--	--	115	5.2	0.41	210	59	11.2	433
02	--	--	145	2.7	0.27	210	61	11.4	437
01	--	--	445	1.8	0.01	210	1	11.3	436
0831	43°36.625	091°13.785	620	2.1	0.27	120	143	11.3	436
0832	36.530	14.070	1,035	1.7	0.25	150	180	11.4	438
0833	36.425	14.365	1,455	3.1	0.24	150	299	11.4	442
0834	36.330	14.630	1,855	1.2	0.25	30	-62	11.8	439
0835	36.245	14.880	2,270	1.4	0.26	350	-142	12.1	438
0836	43°36.145	091°15.160	2,695	1.2	0.16	340	-81	11.7	450
REW			3,115	0.0					
Mean				1.8	0.09				
Total							511		

STATION: Mississippi River in Pool 8, Transect 1--UMR mile 684.7

PARTY: Moody, Meade, and Antweiler

DATE: April 16, 1992

GAGE HEIGHT at TW Dam 7: 634.20 ft

GAGE HEIGHT at Dam 8: 630.14 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 32.0 x 10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis., and Stoddard, Wis.

REMARKS:

Acadiana anchored shoreward of red buoy line at UMR mile 684.7; 510 m from south tip of Paramecium Island; 755 m from east end of section; 215 from Coon Middle Daymark (UMR mile 684.7); 3,125 m from west end of section at delta of small creek. Location of edges of chute are E01 and E02.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 067° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0				6.5	364
0811	43°38.840	091°13.795	195	1.0	0.27	200	59	6.3	368
0812	38.760	14.120	650	1.3	0.23	200	57	6.1	379
01	--	--	755	4.8	0.31	180	100	6.1	389
02	--	--	800	3.8	0.28	180	47	6.2	403
03	--	--	855	3.5	0.35	180	52	6.2	406
04	--	--	895	4.5	0.47	180	98	6.2	412
05	--	--	960	6.3	0.48	180	175	6.3	417
06	--	--	1,025	2.0	0.40	170	226	6.3	419
0813	38.615	14.745	1,550	1.4	0.33	170	208	6.4	435
0814	38.545	15.035	1,955	1.1	0.21	180	93	6.4	436
0815	38.465	15.395	2,455	1.0	0.24	200	74	6.3	442
E01	--	--	2,845	1.0	0.24	200	41	--	--
0816	38.380	15.745	2,955	3.7	0.35	180	287	6.3	453
E02	--	--	3,345	0.6	0.16	180	21	--	--
0817	43°38.300	091°16.100	3,445	0.6	0.16	180	23	6.3	463
REW			3,880	0.0					
Mean				1.5	0.27				
Total							1,561		

STATION: Mississippi River in Pool 8, Transect 2--UMR mile 683.3

PARTY: Moody, Meade, and Antweiler

DATE: April 16, 1992

GAGE HEIGHT at TW Dam 7: 634.20 ft

GAGE HEIGHT at Dam 8: 630.14 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 32.0×10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis., Stoddard, Wis., Genoa, Wis., and Reno, Minn.

REMARKS:

Acadiana anchored on green buoy line at UMR mile 683.3; 80 m from Warners Landing Light (UMR mile 683.3), 135 m (orthogonal distance) from left bank, 3,740 m from west shoreline at cluster of old buildings near Fairy Rock.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 078° magnetic

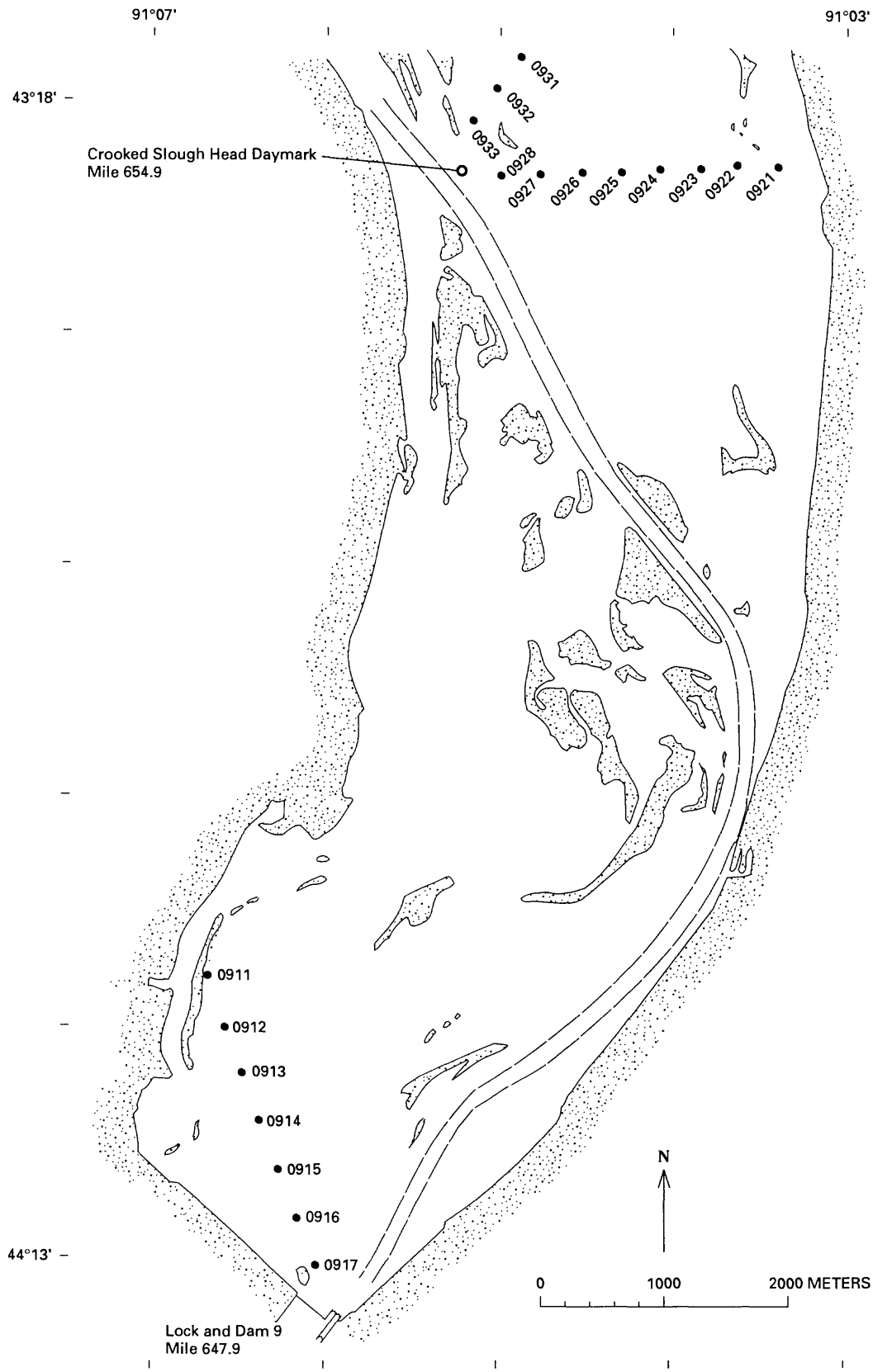
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
01	--	--	10	3.5	0.25	190	18	6.9	404
02	--	--	45	8.7	0.29	190	90	6.4	374
03	--	--	90	7.4	0.42	190	112	6.3	378
04	--	--	125	4.9	0.43	180	96	6.3	387
05	--	--	185	1.7	0.27	180	53	6.4	395
06	--	--	365	1.0	0.27	180	62	6.8	406
0821	43°37.555	091°13.795	655	1.0	0.20	180	67	6.8	414
0822	37.530	14.100	1,070	1.8	0.25	180	192	6.9	419
0823	37.500	14.445	1,545	1.1	0.20	180	101	7.0	424
0824	37.470	14.785	2,005	1.0	0.24	180	105	6.9	431
0825	37.435	15.125	2,470	2.0	0.27	180	239	7.0	439
0826	37.410	15.455	2,930	1.7	0.15	180	114	6.9	450
0827	43°37.380	091°15.795	3,390	0.7	0.17	180	61	6.8	452
REW			3,980	0.0					
Mean				1.4	0.23				
Total							1,310		

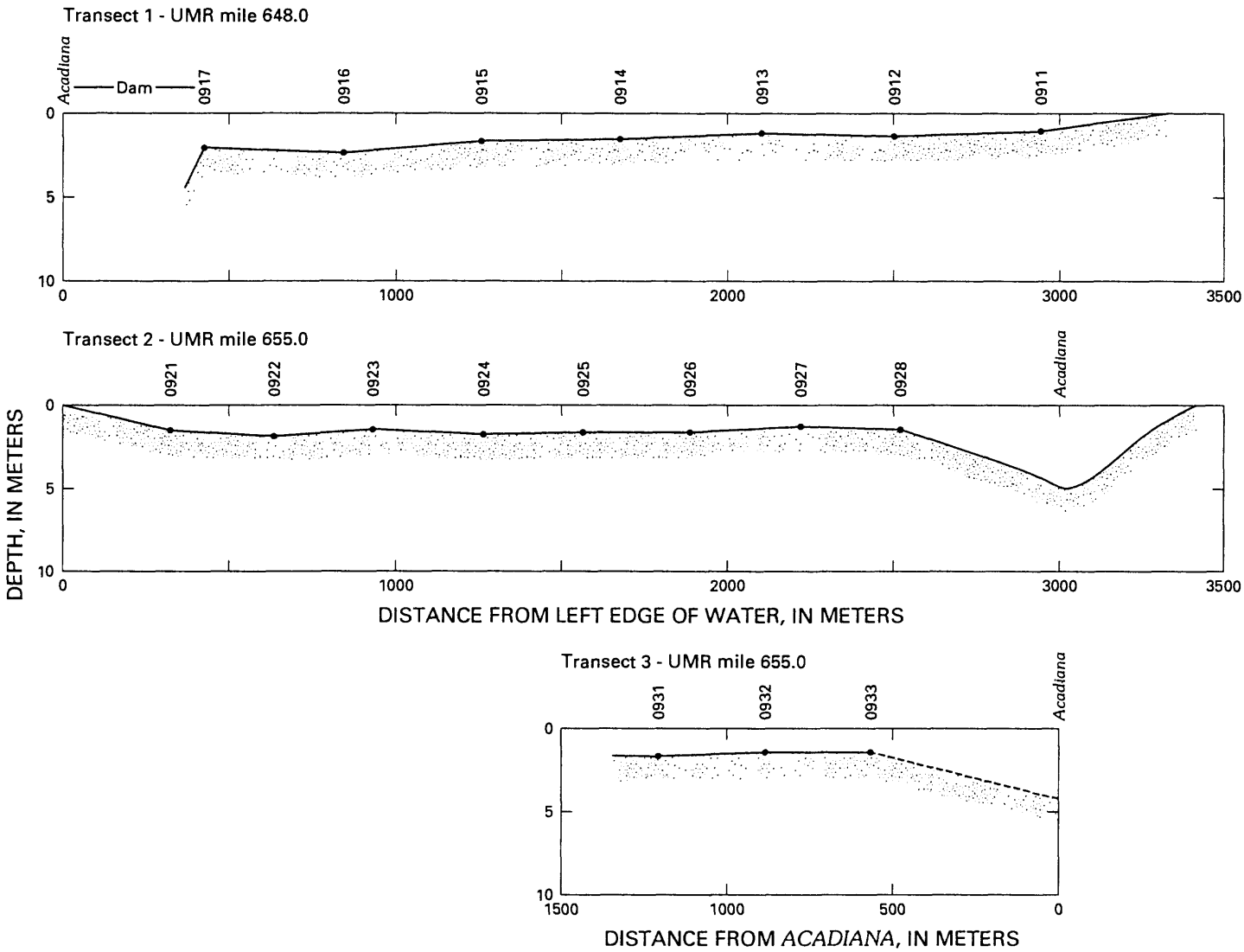
STATION: Mississippi River in Pool 8, Transect 3--UMR mile 682.1
PARTY: Moody, Meade, and Antweiler
DATE: April 16, 1992
GAGE HEIGHT at TW Dam 7: 634.20 ft
GAGE HEIGHT at Dam 8: 630.14 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 32.0 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Reno, Minn., and Genoa, Wis.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 682.1; 170 m from left bank; 590 m from mouth of Spring Creek; 2,920 m from corner (marked '640' on 7.5-minute quadrangle) of earth-dam part of Dam 8. Velocity at ship assumed to be zero so that discharge is just the off-channel flow.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 064° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
Acadiana			190	3.5	0.00	0	0		
0831	43°36.625	091°13.785	615	3.5	0.24	90	175	7.0	410
0832	36.530	14.070	1,025	1.6	0.22	120	127	7.1	421
0833	36.425	14.365	1,450	1.5	0.24	150	153	7.2	431
0834	36.330	14.630	1,860	1.3	0.21	150	108	7.3	441
0835	36.245	14.880	2,240	1.5	0.19	150	114	7.3	446
0836	43°36.145	091°15.160	2,660	0.9	0.24	180	81	7.3	445
REW			3,110	0.0					
Mean				1.7	0.14				
Total							758		


91°07'
91°03'
43°18'
44°13'
Crooked Slough Head Daymark
Mile 654.9
0931
0932
0933
0928
0927
0926
0925
0924
0923
0922
0921
0911
0912
0913
0914
0915
0916
0917
N
0
1000
2000 METERS
Lock and Dam 9
Mile 647.9


Transect 1 - UMR mile 648.0
Acadiana
Dam
0917
0916
0915
0914
0913
0912
0911
0
5
10
0
1000
2000
3000
3500
Transect 2 - UMR mile 655.0
0921
0922
0923
0924
0925
0926
0927
0928
Acadiana
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 3 - UMR mile 655.0
0931
0932
0933
Acadiana
1500
1000
500
DISTANCE FROM ACADIANA, IN METERS

STATION: Mississippi River in Pool 9, Transect 1--UMR mile 684.0
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 19, 1991
GAGE HEIGHT at TW Dam 8: 621.62 ft
GAGE HEIGHT at Dam 9: 619.65 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 12.0×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Eastman, Wis.-Iowa
REMARKS:

Acadiana moored to upstream end of east wall of auxiliary lock at Dam 9. Velocity was measured at 0.6 times the depth while anchored. No velocity measurements were made in front of dam between *Acadiana* at LEW (0 m) and station at 419 m. Discharge through Dam 9 was 650 m^3/s. Wind was from 240° magnetic at 0.5-1 m/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 159° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Dam			400	0.0					
0917	43°12.940	091°06.030	420	2.0	0.23	150	-9	7.1	463
0916	13.155	06.135	840	2.1	0.08	180	30	7.3	458
0915	13.370	06.240	1,260	1.7	0.03	270	19	6.7	460
0914	13.585	06.350	1,680	1.3	0.07	70	-36	6.7	460
0913	13.795	06.450	2,100	1.1	0.02	70	-10	6.5	468
0912	13.990	06.550	2,500	1.2	0.07	30	-27	6.8	466
0911	43°14.205	091°06.665	2,940	0.9	0.03	310	4	6.8	469
REW			3,365	0.0	0.00	--	0	7.5	466
Mean				1.3	-0.01				
Total							-29		

STATION: Mississippi River in Pool 9, Transect 2--UMR mile 655.0
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 19, 1991
GAGE HEIGHT at TW Dam 8: 621.62 ft
GAGE HEIGHT at Dam 9: 619.65 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 12.0×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Ferryville, Wis.-Iowa
REMARKS:

Acadiana anchored on green buoy line at UMR mile 655.0: 1,640 m from creek mouth on right bank near UMR mile 656.0; 1,310 m from a point upstream and riverward of railroad trestle over creek on right bank near UMR mile 654.0; 305 m off REW; 260 m from Crooked Slough Head Daymark.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 089° magnetic

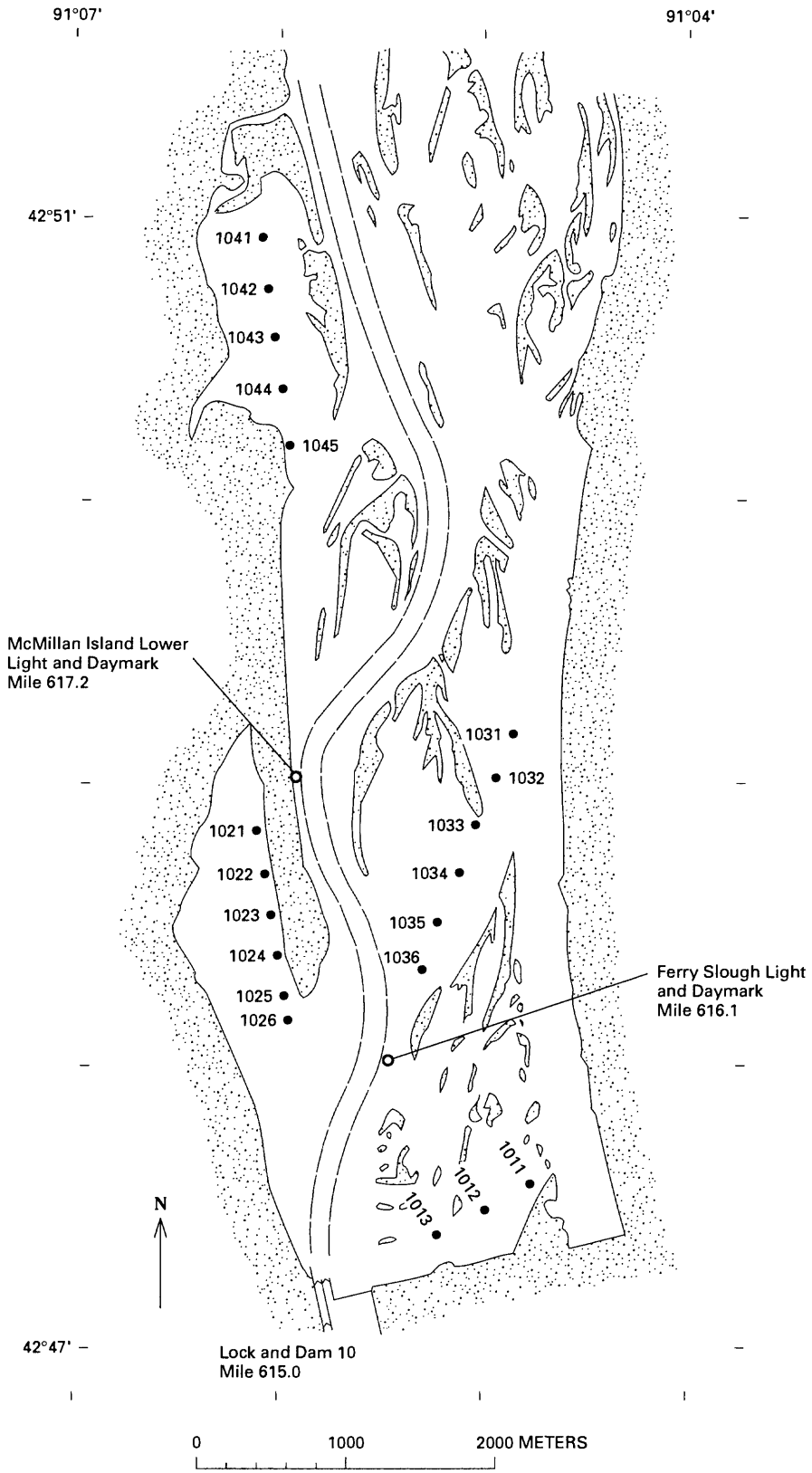
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
0921	43°17.760	091°03.325	325	1.4	0.08	350	-37	--	426
0922	17.755	03.570	640	1.8	0.07	180	37	--	426
0923	17.745	03.795	940	1.4	0.17	270	-7	--	426
0924	17.735	04.035	1,265	1.7	0.11	170	58	--	427
0925	17.730	04.250	1,570	1.6	0.08	180	37	--	427
0926	17.725	04.490	1,885	1.4	0.07	180	34	--	429
0927	17.175	04.730	2,215	1.2	0.10	190	36	--	430
0928	43°17.705	091°04.965	2,520	1.5	0.12	270	-6	--	430
04	--	--	2,900	3.8	0.27	130	177	changed instrument	
03	--	--	3,010	5.0	0.26	130	91	9.3	454
02	--	--	3,100	4.5	0.27	130	106	9.3	454
01	--	--	3,255	1.8	0.19	130	37	9.1	460
REW			3,405	0.0					
Mean				1.8	0.09				
Total							563		

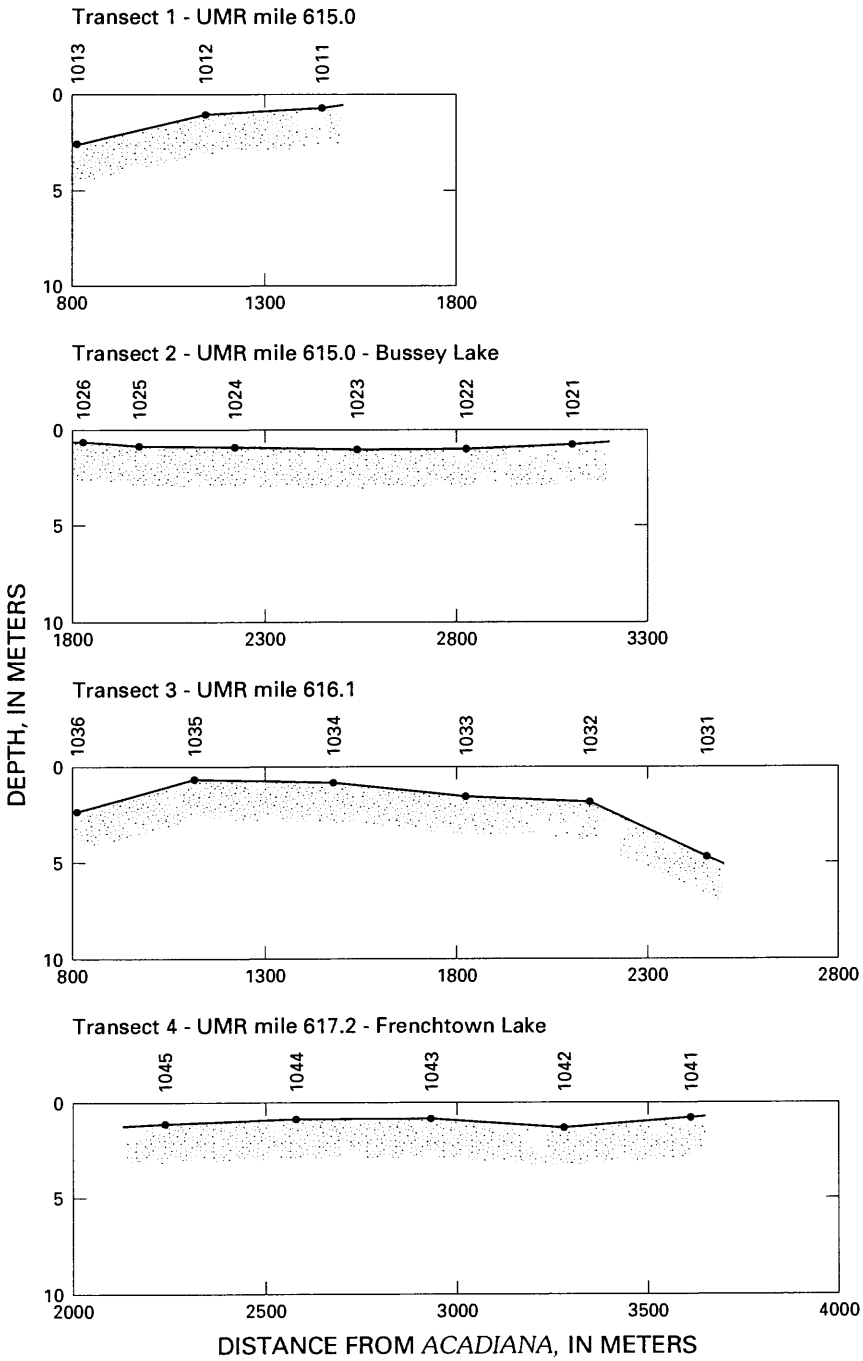
STATION: Mississippi River in Pool 9, Transect 3--UMR mile 655.0
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 19, 1991
GAGE HEIGHT at TW Dam 8: 621.62 ft
GAGE HEIGHT at Dam 9: 619.65 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 12.0×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Ferryville, Wis.-Iowa
REMARKS:

Acadiana anchored on green buoy line at UMR mile 655.0: 1,640 m from creek mouth on right bank near UMR mile 656.0; 1,310 m from a point upstream and riverward of railroad trestle over creek on right bank near UMR mile 654.0; 305 m off REW; 260 m from Crooked Slough Head Daymark.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 037° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana			0	0.0					
0933	43°17.940	091°05.135	575	1.2	0.09	210	2	--	430
0932	18.075	04.990	890	1.1	0.12	30	-2	--	430
0931	43°18.220	091°04.850	1,210	1.5	0.12	150	27	--	428
Mean				0.9	0.02				
Total							27		


91°07'
91°04'
42°51'
42°47'
1041
1042
1043
1044
1045
McMillan Island Lower
Light and Daymark
Mile 617.2
1031
1032
1033
1034
1035
1036
1021
1022
1023
1024
1025
1026
Ferry Slough Light
and Daymark
Mile 616.1
1011
1012
1013
N
Lock and Dam 10
Mile 615.0
0
1000
2000 METERS


Transect 1 - UMR mile 615.0
1013
1012
1011
0
5
10
800
1300
1800
Transect 2 - UMR mile 615.0 - Bussey Lake
1026
1025
1024
1023
1022
1021
0
5
10
1800
2300
2800
3300
Transect 3 - UMR mile 616.1
1036
1035
1034
1033
1032
1031
0
5
10
800
1300
1800
2300
2800
Transect 4 - UMR mile 617.2 - Frenchtown Lake
1045
1044
1043
1042
1041
0
5
10
2000
2500
3000
3500
4000
DEPTH, IN METERS
DISTANCE FROM ACADIANA, IN METERS

STATION: Mississippi River in Pool 10, Transect 1--UMR mile 615.0
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 16, 1991
GAGE HEIGHT at TW Dam 9: 617.3 ft
GAGE HEIGHT at Dam 10: 610.3 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 40 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa.-Wis.
REMARKS:

Acadiana moored to inside of river wall of auxiliary lock at Dam 10. Velocities were measured at 0.6 times the depth while anchored. No discharge was calculated because the transect was mostly parallel to the flow.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 057° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
1011	42°47.550	091°043.720	1,485	0.5	0.33	220	--	25.0	424
1012	47.460	04.940	1,145	0.8	0.10	220	--	25.4	426
1013	42°47.375	091°05.155	810	2.6	0.40	190	--	25.4	431

STATION: Mississippi River in Pool 10, Transect 2--UMR mile 615.0
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 16, 1991
GAGE HEIGHT at TW Dam 9: 617.3 ft
GAGE HEIGHT at Dam 10: 610.3 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 40 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa.-Wis.
REMARKS:

Acadiana moored to inside of river wall of auxiliary lock at Dam 10. Velocities were measured at the surface with a drifter (except at site 1026). No discharge was calculated because the transect was nearly parallel to the flow. Transect was mostly in Bussey Lake. Windspeed was 2-3 m/s from the south.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 164° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
1021	42°48.840	091°06.080	3,100	0.5	0.05	000	--	24.5	418
1022	48.675	06.040	2,825	0.8	0.04	020	--	24.4	488
1023	48.520	06.000	2,545	0.9	0.06	010	--	24.8	479
1024	48.375	05.965	2,220	0.8	0.06	000	--	25.0	477
1025	48.215	05.920	1,975	0.7	0.10	340	--	25.1	475
1026	42°48.140	091°05.900	1,825	0.5	0.16	230	--	25.2	475

STATION: Mississippi River in Pool 10, Transect 3--UMR mile 616.1
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 16, 1991
GAGE HEIGHT at TW Dam 9: 617.3 ft
GAGE HEIGHT at Dam 10: 610.3 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 40×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa.-Wis.
REMARKS:

Acadiana anchored 720 m from south tip of peninsula with airstrip; 150 m from channel marker at UMR mile 616.1 (Ferry Slough Light and Daymark); 3,530 m from tip of creek delta at Glen Haven, Wisconsin. No discharge was computed because the transect was mostly parallel to the flow.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 015° magnetic

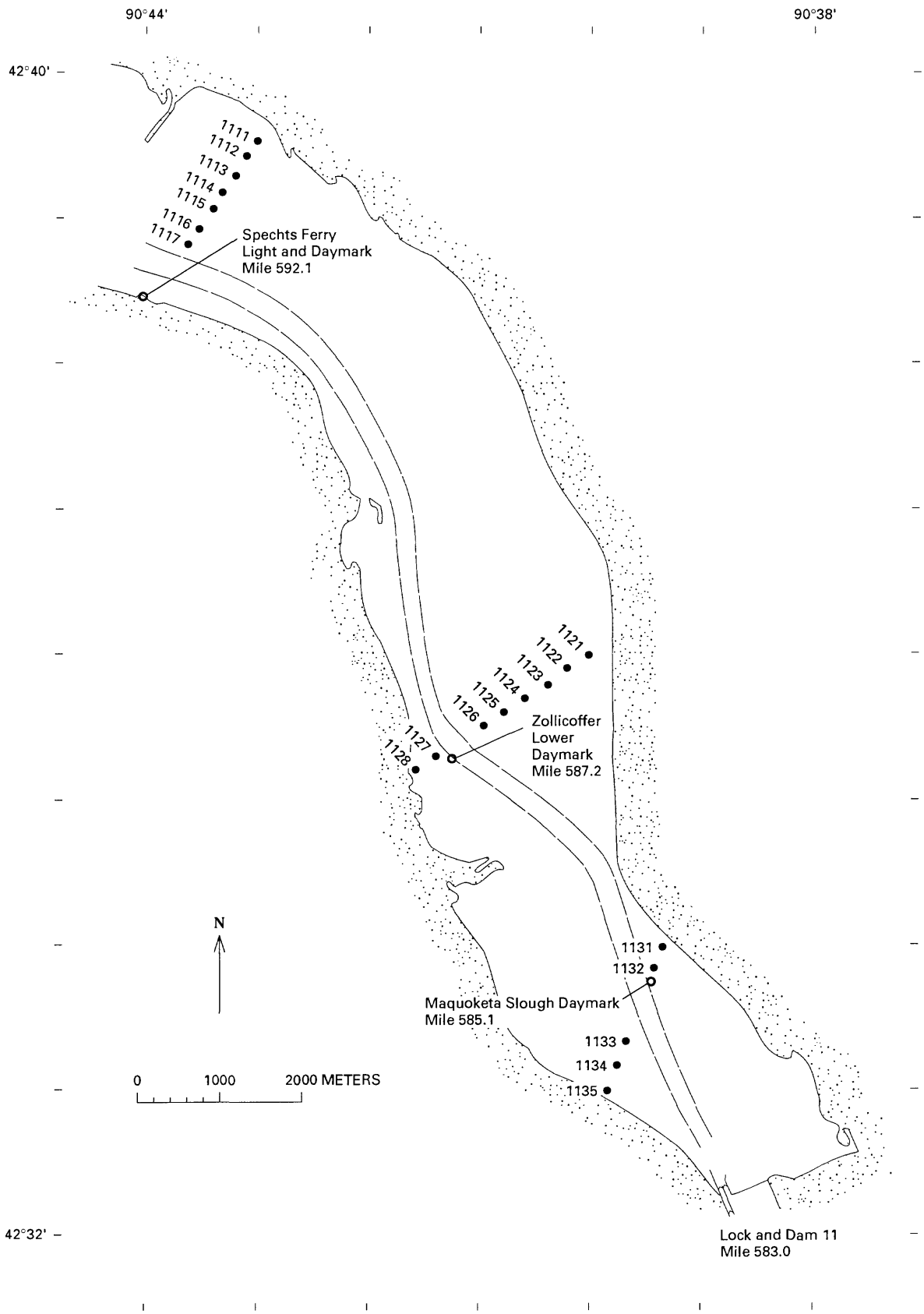
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
1031	42°49.160	091°04.855	2,460	4.6	0.47	210	--	25.8	448
1032	49.000	04.930	2,150	1.8	0.42	180	--	25.8	453
1033	48.790	05.030	1,820	1.6	0.45	240	--	25.9	454
1034	48.650	05.095	1,480	0.9	0.06	210	--	25.8	451
1035	48.470	05.175	1,115	0.5	0.16	220	--	26.2	451
1036	42°48.310	091°05.255	805	2.2	0.28	210	--	26.1	452

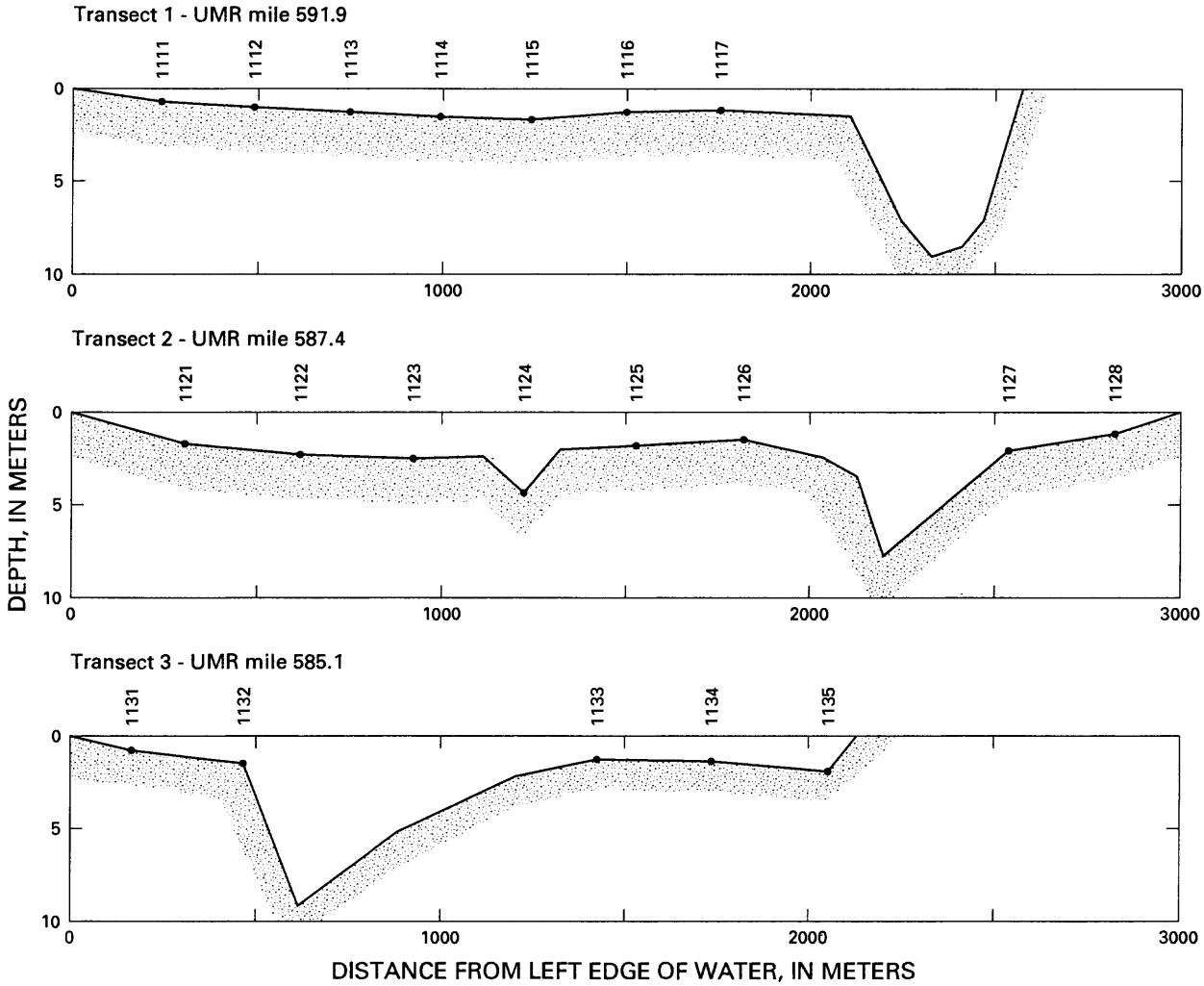
STATION: Mississippi River in Pool 10, Transect 4--UMR mile 617.2
PARTY: Moody, Meade, Bishop, and Roth
DATE: July 16, 1991
GAGE HEIGHT at TW Dam 9: 617.13 ft
GAGE HEIGHT at Dam 10: 610.3 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 40×10^{-06}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa.-Wis.
REMARKS:

Acadiana anchored 275 m from McMillan Island Lower Light and Daymark at UMR mile 617.2; 1,905 m from point near sandpit on north end of Abels Island. No discharge was computed because the transect was mostly in Frenchtown Lake and nearly parallel to the Mississippi River. The velocity at site 1041 was measured with a surface drifter.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 158° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
1041	42°50.940	091°06.100	3,610	0.7	0.04	000	--	28.1	471
1042	50.770	06.065	3,270	1.2	0.17	160	--	27.0	470
1043	50.580	06.020	2,935	0.6	0.11	100	--	27.3	470
1044	50.395	05.975	2,580	0.7	0.24	080	--	27.5	470
1045	42°50.210	091°05.960	2,235	1.0	0.14	180	--	28.7	468


90°44'
90°38'
42°40'
42°32'
1111
1112
1113
1114
1115
1116
1117
Spechts Ferry
Light and Daymark
Mile 592.1
1121
1122
1123
1124
1125
1126
1127
1128
Zollicoffer
Lower
Daymark
Mile 587.2
N
1131
1132
Maquoketa Slough Daymark
Mile 585.1
1133
1134
1135
0
1000
2000 METERS
Lock and Dam 11
Mile 583.0


Transect 1 - UMR mile 591.9
1111
1112
1113
1114
1115
1116
1117
0
5
10
0
1000
2000
3000
Transect 2 - UMR mile 587.4
1121
1122
1123
1124
1125
1126
1127
1128
DEPTH, IN METERS
Transect 3 - UMR mile 585.1
1131
1132
1133
1134
1135
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 11, Transect 1--UMR mile 591.9

PARTY: Moody, Meade, Brinton, and Writer

DATE: October 20, 1991

GAGE HEIGHT at TW Dam 10: 604.95 ft

GAGE HEIGHT at Dam 11: 603.12 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 10.8×10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangle is Potosi, Wis.-Iowa

REMARKS:

Acadiana anchored on green buoy line at UMR mile 591.9, 1,710 m from south corner of end of causeway out from left bank at Potosi; 337 m from tip of land at Spechts Ferry on right bank; 324 m from REW at abandoned daymark foundation just below Spechts Ferry. Edge of channel at E01 was estimated. Specific conductance at site 1111 was measured in a lily-pad patch near the left bank and was not double checked.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 034° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1111	42°39.520	090°43.005	235	0.6	0.07	30	0	6.7	615
1112	39.430	43.100	485	0.8	0.06	80	10	7.6	411
1113	39.300	43.200	740	1.2	0.08	80	19	8.2	400
1114	39.175	43.310	985	1.5	0.09	70	21	8.6	403
1115	39.065	43.405	1,230	1.6	0.11	120	43	8.8	403
1116	38.945	43.505	1,490	1.1	0.06	170	11	8.5	404
1117	42°38.835	090°43.600	1,740	1.0	0.08	150	17	8.7	406
05	--	--	1,980	1.6	0.10	140	28	9.0	407
E01	--	--	2,100	1.6	0.10	140	20	--	--
01	--	--	2,240	7.5	0.21	120	176	8.6	409
04	--	--	2,328	9.0	0.29	120	236	8.9	413
03	--	--	2,419	8.5	0.33	120	187	8.6	417
02	--	--	2,460	7.0	0.35	120	176	--	420
REW			2,564	0.0					
Mean				2.0	0.18				
Total							944		

STATION: Mississippi River in Pool 11, Transect 2--UMR mile 587.4
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 20, 1991
GAGE HEIGHT at TW Dam 10: 604.95 ft
GAGE HEIGHT at Dam 11: 603.12 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 10.8×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Dubuque North, Iowa-Wis.-Ill.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 587.4, 2,780 m from center of railroad trestle over Platte River mouth; 670 m from downstream corner of small delta on right bank; 860 m from REW and 2,120 m from LEW on line of sampling section. Discharge through Dam 10 was 835 m^3/s. Edges of channel at E01 and E02 were estimated.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 057° magnetic

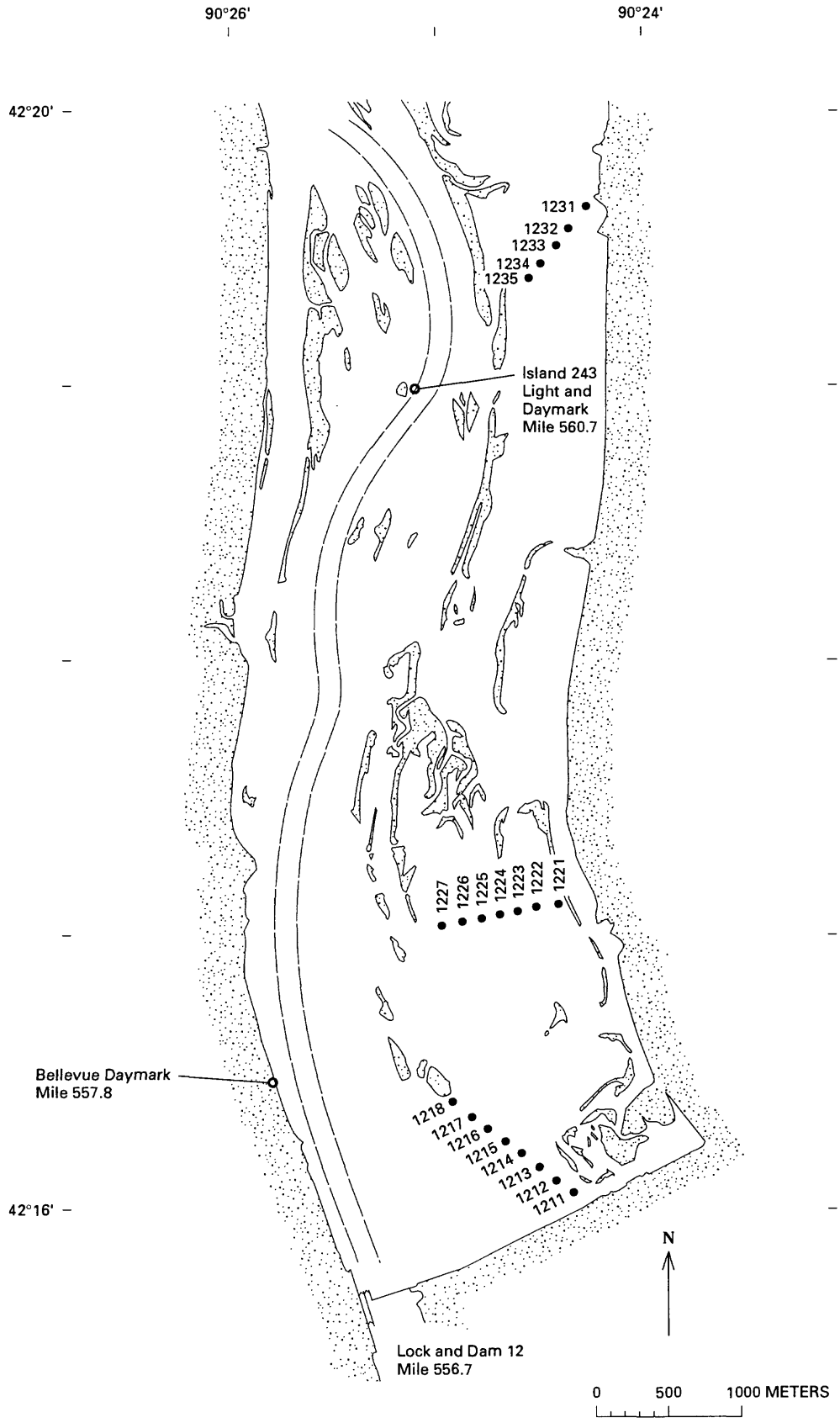
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1121	42°36.015	090°40.020	300	1.5	0.17	140	80	8.7	402
1122	35.920	40.205	610	2.0	0.20	140	121	8.8	405
1123	35.835	40.385	910	2.2	0.16	120	81	9.6	408
E01	--	--	1,110	2.2	0.16	120	49	--	--
1124	35.735	40.580	1,210	3.8	0.24	110	78	9.6	408
E02	--	--	1,310	1.7	0.14	50	-2	--	--
1125	35.640	40.770	1,520	1.7	0.14	50	-3	10.1	412
1126	35.560	40.930	1,815	1.2	0.14	60	5	9.9	412
01	--	--	2,015	2.1	0.25	140	80	9.7	415
05	--	--	2,120	3.0	0.17	150	44	9.7	416
02	--	--	2,190	7.5	0.36	150	161	9.5	417
03	--	--	2,240	7.0	0.34	150	159	9.5	419
04	--	--	2,325	5.2	0.17	100	93	9.7	420
1127	35.340	41.365	2,530	1.8	0.16	120	64	8.7	422
1128	42°35.255	090°41.535	2,820	0.9	0.11	140	21	9.8	421
REW			2,980	0.0					
Mean				2.1	0.17				
Total							1,031		

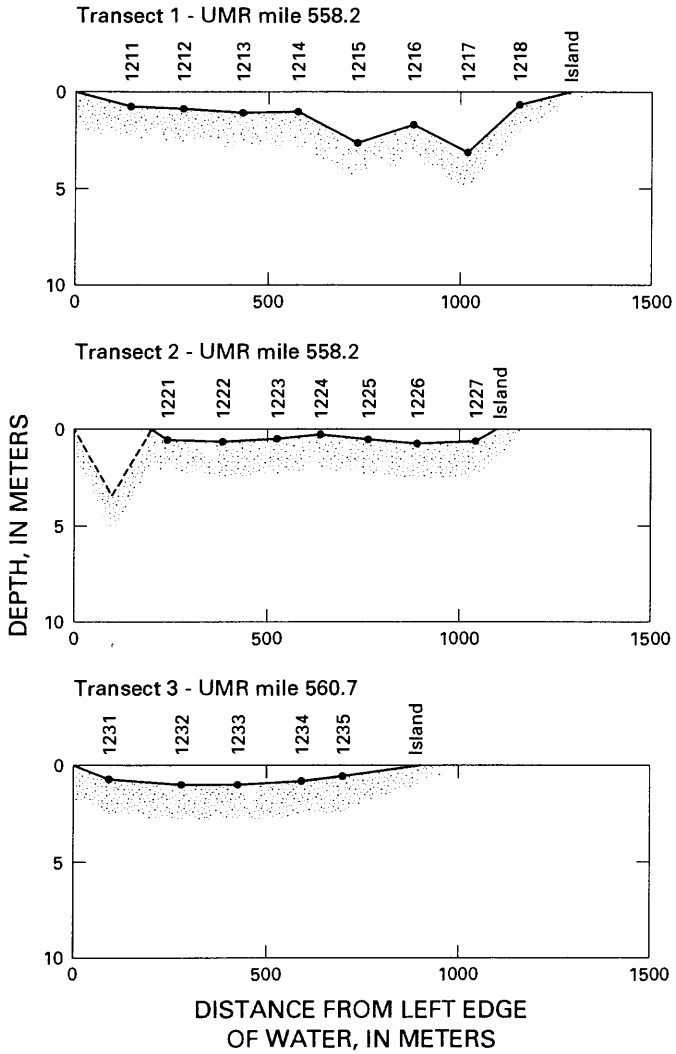
STATION: Mississippi River in Pool 11, Transect 3--UMR mile 585.1
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 20, 1991
GAGE HEIGHT at TW Dam 10: 604.95 ft
GAGE HEIGHT at Dam 11: 603.12 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 10.8×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Dubuque North, Iowa-Wis.-Ill.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 585.1, 1,655 m from LEW at house by BM 611; 970 m to centerline of railroad bridge over Sinipee Creek; 990 m from LEW and 1,140 m from REW on line of sampling section; and 380 m from Maquoketa Slough Daymark at UMR mile 585.1.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 021° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1131	42°34.060	090°39.345	160	0.9	0.14	120	28	9.7	410
1132	33.910	39.415	455	1.5	0.17	120	57	9.0	408
01	--	--	610	9.2	0.22	120	196	9.4	413
02	--	--	650	8.9	0.24	140	245	9.4	416
03	--	--	885	5.2	0.34	150	218	10.1	417
05	--	--	990	4.4	0.33	150	171	9.5	417
04	--	--	1,210	2.3	0.22	120	108	9.6	418
1133	33.425	39.660	1,420	1.2	0.22	120	67	9.6	419
1134	33.270	39.735	1,735	1.5	0.13	300	-61	9.7	419
1135	42°33.105	090°39.815	2,045	2.0	0.11	140	37	10.0	420
REW			2,130	0.0					
Mean				2.8	0.18				
Total							1,066		


90°26'
90°24'
42°20'
42°16'
1231
1232
1233
1234
1235
Island 243
Light and
Daymark
Mile 560.7
1227
1226
1225
1224
1223
1222
1221
Bellevue Daymark
Mile 557.8
1218
1217
1216
1215
1214
1213
1212
1211
N
Lock and Dam 12
Mile 556.7
0
500
1000 METERS


Transect 1 - UMR mile 558.2
1211
1212
1213
1214
1215
1216
1217
1218
Island
Transect 2 - UMR mile 558.2
1221
1222
1223
1224
1225
1226
1227
Island
Transect 3 - UMR mile 560.7
1231
1232
1233
1234
1235
Island
DEPTH, IN METERS
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE
OF WATER, IN METERS

STATION: Mississippi River in Pool 12, Transect 1--UMR mile 558.2
PARTY: Moody, Meade, and Antweiler
DATE: April 18, 1992
GAGE HEIGHT at TW Dam 11: 597.47 ft
GAGE HEIGHT at Dam 12: 591.74 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 41.7×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Bellevue, Iowa-Ill.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 558.2: 209 m from small creek mouth; 2,307 m from north end of middle wall of Lock 12; 2,718 m from east end of concrete low-sill dam in earth dam; 263 m from entrance to old quarry on west shore. Edge of island was estimated.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 126° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1211	42°16.050	090°24.325	148	0.8	0.09	180	9	9.3	430
1212	16.095	24.410	288	0.9	0.14	170	13	8.9	417
1213	16.140	24.490	428	1.1	0.20	180	28	8.7	414
1214	16.200	24.580	583	1.0	0.17	180	22	8.8	396
1215	16.240	24.665	728	2.5	0.23	180	71	8.9	385
1216	16.285	24.750	873	1.7	0.19	180	38	8.9	381
1217	16.330	24.825	1,013	3.0	0.24	190	94	8.9	378
1218	42°16.380	090°24.915	1,158	0.5	0.10	120	0	9.1	377
Island			1,300	0.0					
Mean				1.3	0.17				
Total							275		

STATION: Mississippi River in Pool 12, Transect 2--UMR mile 558.2
PARTY: Moody, Meade, and Antweiler
DATE: April 18, 1992
GAGE HEIGHT at TW Dam 11: 597.47 ft
GAGE HEIGHT at Dam 12: 591.74 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 41.7 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Bellevue, Iowa-Ill.
REMARKS:

Acadiana anchored near green buoy line at UMR mile 558.2: 209 m from small creek mouth; 2,307 m from north end of middle wall of Lock 12; 2,718 m from east end of concrete low-sill dam in earth dam; 263 m from entrance to old quarry on west shore. Edge of island was estimated.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 079° magnetic

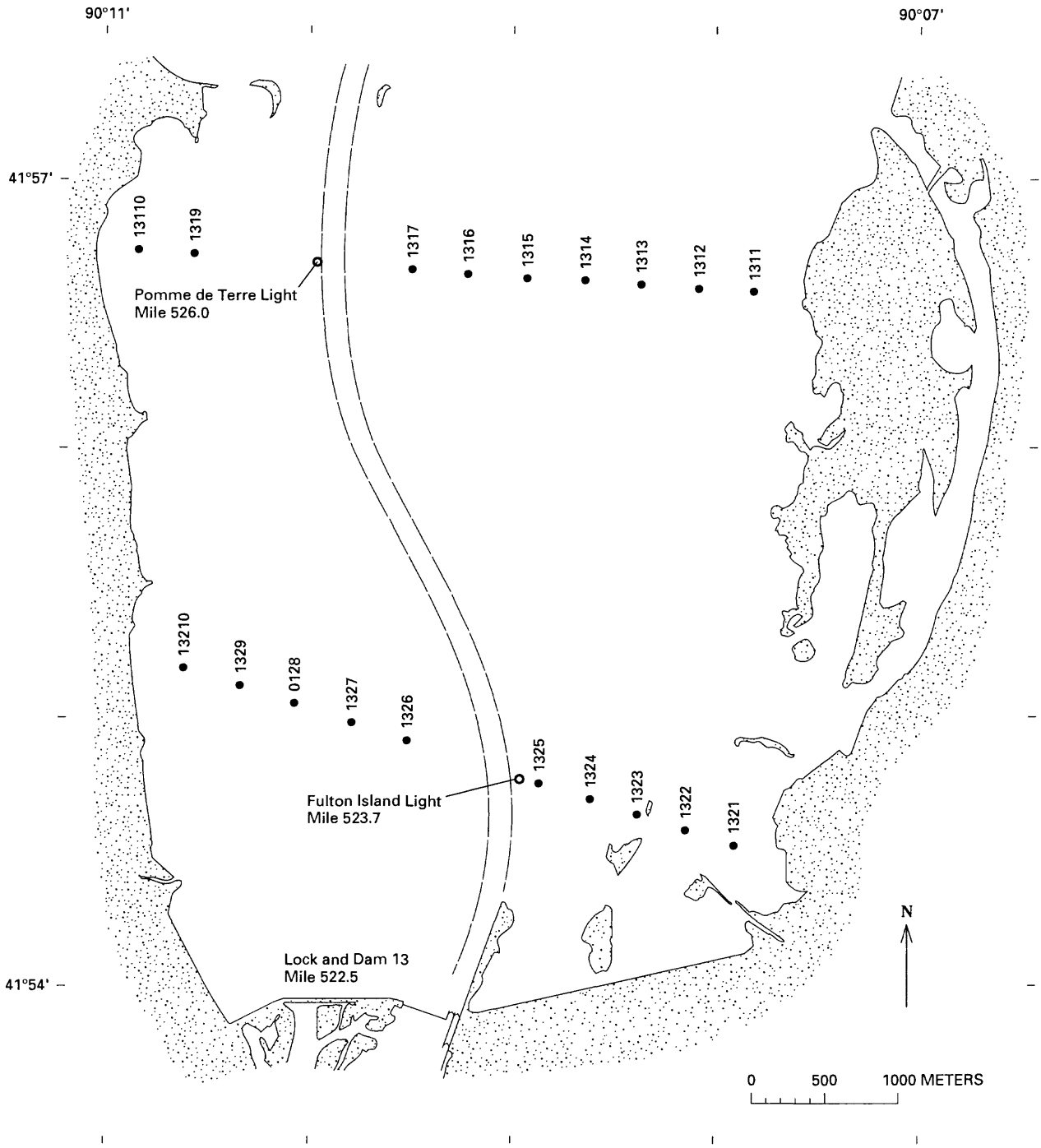
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
Island	--	--	200	0.0	0.01	0	0		
1221	42°17.110	090°24.400	240	0.6	0.10	160	5	10.0	374
1222	17.090	24.500	385	0.5	0.12	190	7	9.7	376
1223	17.080	24.590	515	0.5	0.19	200	10	9.9	369
1224	17.070	24.680	640	0.4	0.14	200	6	10.4	366
1225	17.055	24.770	765	0.5	0.16	190	9	10.4	366
1226	17.045	24.865	895	0.7	0.18	160	17	9.9	374
1227	42°17.030	090°24.965	1,030	0.5	0.16	160	8	10.5	368
Island			1,100	0.0					
Mean				0.4	0.14				
Total							62		

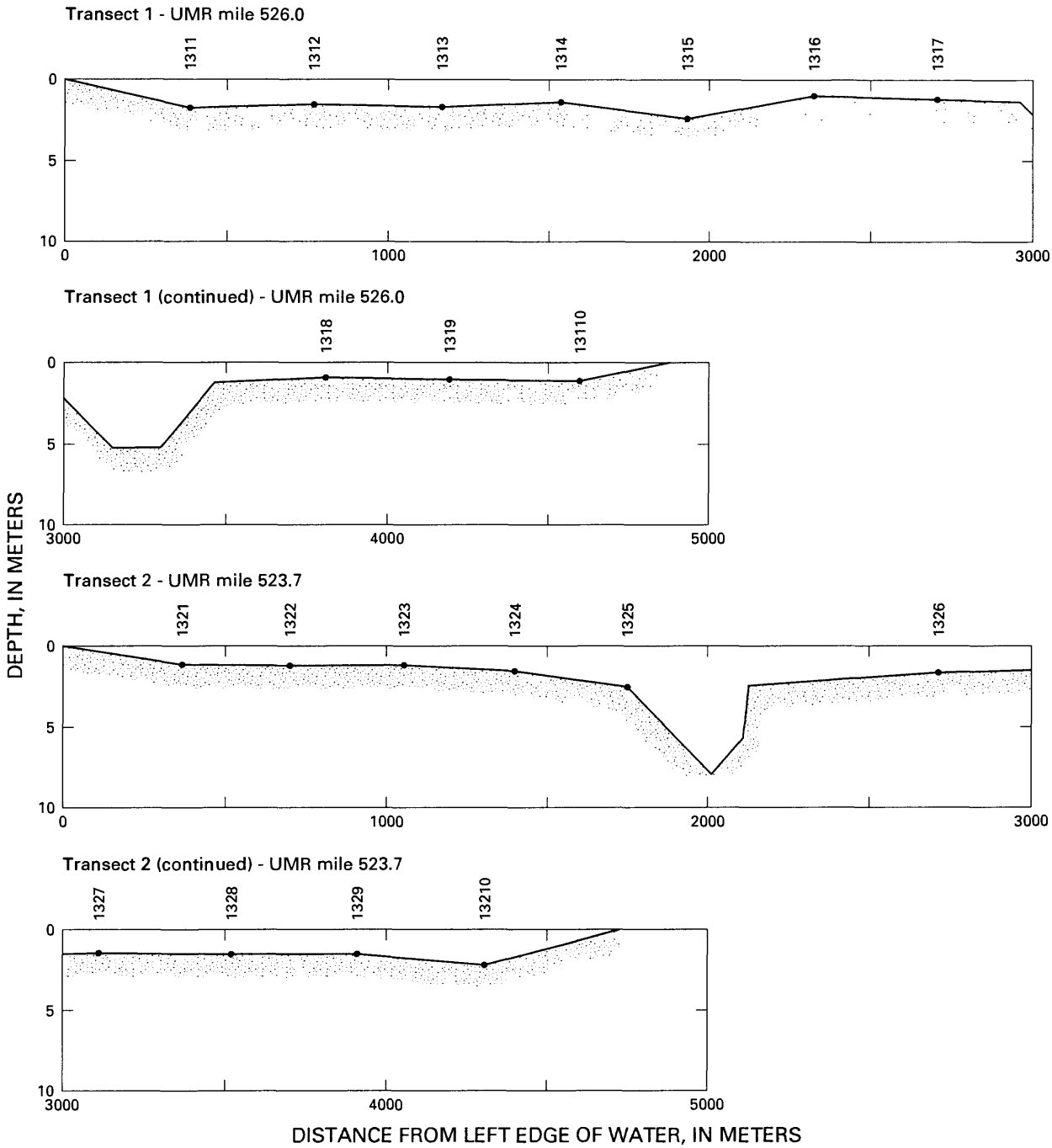
STATION: Mississippi River in Pool 12, Transect 3--UMR mile 560.7
PARTY: Moody, Meade, and Antweiler
DATE: April 18, 1992
GAGE HEIGHT at TW Dam 11: 597.47 ft
GAGE HEIGHT at Dam 12: 591.74 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 41.7 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Bellevue, Iowa-Ill.
REMARKS:

Acadiana anchored near green buoy line at UMR mile 560.7: 1,145 m from end of dock (52 m from centerline of railroad tracks) at end of road from bottom of ski lifts; 1,150 m from edge of water in front of old house near south edge of Section 21; 1,675 m from tip of small delta just north of line between Sections 16 and 21. Edge of island was estimated.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 039° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1231	42°19.655	090°24.270	95	0.7	0.17	170	12	11.5	527
1232	19.575	24.350	275	1.0	0.23	180	21	10.4	400
1233	19.515	24.410	420	0.9	0.28	180	22	10.2	392
1234	19.445	24.480	580	0.6	0.16	160	11	10.6	385
1235	42°19.400	090°24.545	700	0.3	0.01	0	0	10.5	366
Island			900	0.0					
Mean				0.6	0.12				
Total							66		


90°11'
90°07'
41°57'
41°54'
13110
1319
1317
1316
1315
1314
1313
1312
1311
Pomme de Terre Light
Mile 526.0
13210
1329
0128
1327
1326
1325
1324
1323
1322
1321
Fulton Island Light
Mile 523.7
Lock and Dam 13
Mile 522.5
N
0
500
1000 METERS


Transect 1 - UMR mile 526.0
1311
1312
1313
1314
1315
1316
1317
0
5
10
0
1000
2000
3000
Transect 1 (continued) - UMR mile 526.0
1318
1319
13110
0
5
10
3000
4000
5000
Transect 2 - UMR mile 523.7
1321
1322
1323
1324
1325
1326
0
5
10
0
1000
2000
3000
Transect 2 (continued) - UMR mile 523.7
1327
1328
1329
13210
0
5
10
3000
4000
5000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 13, Transect 1--UMR mile 526.0
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 21,1991
GAGE HEIGHT at TW Dam 12: 585.29 ft
GAGE HEIGHT at Dam 13: 583.30 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 11.1 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Clinton NW, Iowa-Ill.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 526.0: 1,745 m from boat ramp at Bulger's Hollow; 1,385 m from southwest protruding tip of Silver Creek/Helot Ditch delta; 1,170 m from midpoint of western shore of an island; 280 m from Pomme de Terre Light (UMR mile 526.0). Current direction in shallow water is questionable. Current direction is opposite to wind direction. Discharge through Dam 13 was 900 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 095° magnetic

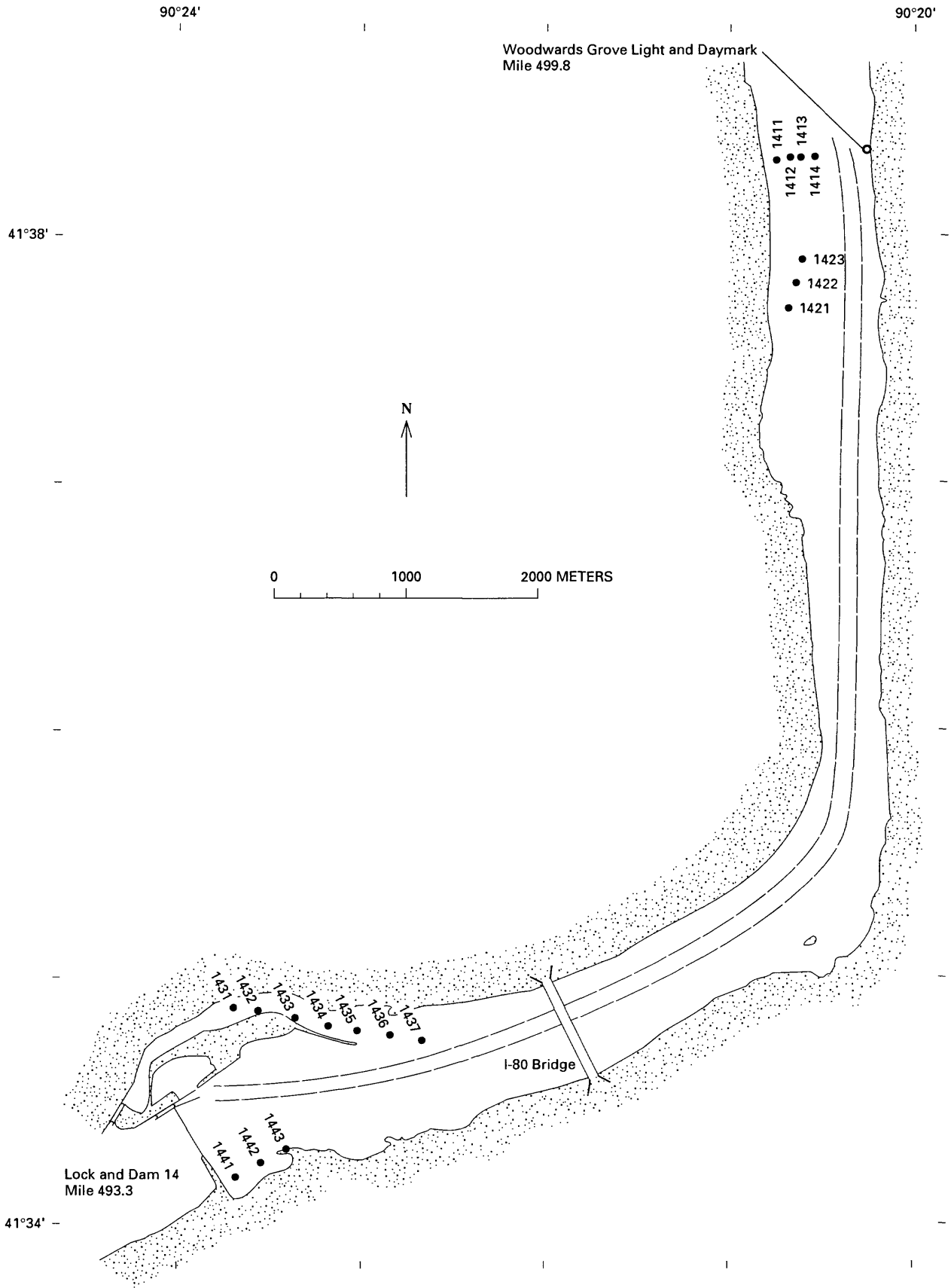
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1311	41°56.575	090°07.805	385	1.4	0.26	150	118		
1312	56.590	08.075	765	1.3	0.26	0	-129		
1313	56.600	08.365	1,160	1.5	0.26	150	129		
1314	56.615	08.645	1,545	1.2	0.20	150	81	No	
1315	56.625	08.930	1,930	2.3	0.19	120	83		
1316	56.640	09.220	2,320	0.9	0.21	170	73	temperature	
1317	56.655	09.505	2,705	1.0	0.23	150	62	or specific-	
01	--	--	2,960	1.2	0.30	150	69	conductance	
02	--	--	3,150	5.1	0.44	210	331	measurements	
03	--	--	3,295	5.1	0.34	210	241	were made	
04	--	--	3,465	1.1	0.20	100	9		
1318	56.705	10.290	3,805	0.8	0.17	120	23	on this	
1319	56.720	10.575	4,185	0.9	0.21	150	64	transect.	
13110	41°56.730	090°10.855	4,580	1.0	0.16	200	52		
REW			4,880	0.0					
Mean				1.4	0.18				
Total							1,206		

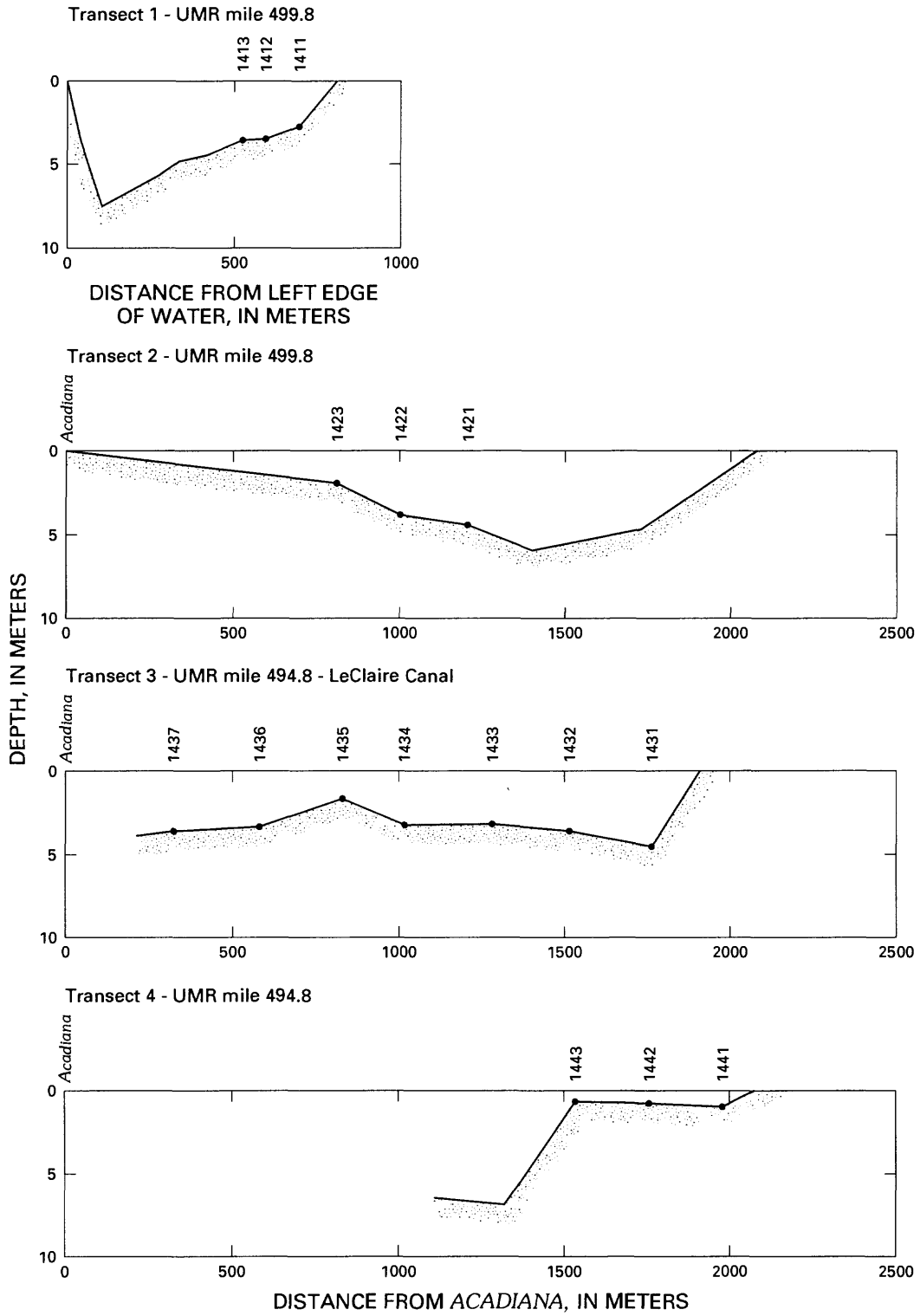
STATION: Mississippi River in Pool 13, Transect 2--UMR mile 523.7
PARTY: Moody, Meade, Brinton, and Writer
DATE: October 21,1991
GAGE HEIGHT at TW Dam 12: 585.29 ft
GAGE HEIGHT at Dam 13: 583.30 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 11.1×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Clinton NW, Iowa-Ill.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 523.7: 200 m from large mooring cell; 930 m from tip of jetty extension of Lock 13 guidewall; 2,400 m to centerline of railroad track on right bank near number '588' on the quadrangle; 2,600 m from REW and 2,110 m from LEW on sampling section.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 107° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
1321	41°54.515	090°07.895	360	1.0	0.07	130	11	10.7	402
1322	54.575	08.135	700	1.1	0.06	140	14	10.6	421
1323	54.635	08.375	1,050	1.0	0.13	160	38	10.9	427
1324	54.700	08.610	1,400	1.5	0.11	210	56	10.4	425
1325	54.760	08.860	1,750	2.3	0.11	210	64	10.0	423
01	--	--	1,950	6.5	0.18	150	112	10.9	420
02	--	--	2,015	7.9	0.24	210	147	10.7	422
03	--	--	2,110	5.8	0.38	210	116	10.7	423
04	--	--	2,125	2.3	0.20	190	135	10.3	424
1326	54.920	09.520	2,710	1.6	0.10	140	47	11.5	425
1327	54.990	09.800	3,110	1.4	0.10	150	40	11.6	426
1328	55.060	10.075	3,515	1.3	0.10	150	40	11.5	425
1329	55.130	10.350	3,910	1.3	0.08	120	13	11.4	425
13210	41°55.200	090°10.635	4,310	2.0	0.12	120	28	11.6	425
REW			4,710	0.0					
Mean				1.7	0.11				
Total							861		


90°24'
90°20'
Woodwards Grove Light and Daymark
Mile 499.8
1411
1413
1412
1414
41°38'
1423
1422
1421
N
0
1000
2000 METERS
1431
1432
1433
1434
1435
1436
1437
I-80 Bridge
1443
1442
1441
Lock and Dam 14
Mile 493.3
41°34'


Transect 1 - UMR mile 499.8
1413
1412
1411
0
5
10
0
500
1000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 499.8
Acadiana
1423
1422
1421
0
5
10
0
500
1000
1500
2000
2500
DEPTH, IN METERS
Transect 3 - UMR mile 494.8 - LeClaire Canal
Acadiana
1437
1436
1435
1434
1433
1432
1431
0
5
10
0
500
1000
1500
2000
2500
Transect 4 - UMR mile 494.8
Acadiana
1443
1442
1441
0
5
10
0
500
1000
1500
2000
2500
DISTANCE FROM ACADIANA, IN METERS

STATION: Mississippi River in Pool 14, Transect 1--UMR mile 499.8
PARTY: Moody, Meade, Roth, and Writer
DATE: July 19,1991
GAGE HEIGHT at TW Dam 13: ~576.66 ft
GAGE HEIGHT at Dam 14: 572.00 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: ~29 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Cordova, Ill.-Iowa
REMARKS:

Acadiana anchored 300 m off the left bank at Woodwards Grove Light, and 500 m off right bank at pile of old red bricks. Transect was a line between the light at UMR mile 499.8 and the pile of red bricks. Velocities were measured at 0.6 times the depth.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 088° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
01			30	2.8	0.39	180	59	26.8	470
02	--	--	110	7.5	0.68	180	382	27.0	465
03	--	--	180	6.7	0.62	180	339	27.3	464
04	--	--	275	5.8	0.57	180	269	27.6	461
05	--	--	345	4.7	0.58	180	196	27.8	465
06	--	--	420	4.5	0.48	180	176	28.1	463
1413	41°38.320	090°20.650	510	3.3	0.42	180	118	28.0	463
1412	38.315	20.705	590	3.6	0.40	180	130	28.0	463
1411	41°38.300	090°20.780	690	2.9	0.62	180	187	27.9	461
REW			800	0.0					
Mean				4.2	0.55				
Total							1,856		

STATION: Mississippi River in Pool 14, Transect 2--UMR mile 499.8
PARTY: Moody, Meade, Roth, and Writer
DATE: July 19,1991
GAGE HEIGHT at TW Dam 13: ~576.66 ft
GAGE HEIGHT at Dam 14: 572.00 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: ~29 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Cordova, Ill-Iowa
REMARKS:

Acadiana anchored 300 m off the left bank at Woodwards Grove Light, and 500 m off right bank at pile of old red bricks. Transect was a line running south southwest from *Acadiana's* anchorage. No discharge was calculated because the transect started in midriver.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 011° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana			0						
1423	41°37.910	090°20.640	805	1.8	0.47	180	--	28.3	464
1422	37.810	20.675	1,000	3.9	0.44	180	--	28.3	463
1421	41°37.710	090°20.710	1,200	4.2	0.42	180	--	28.2	463
02	--	--	1,395	6.0	0.45	180	--	28.3	462
01	--	--	1,730	4.7	0.47	200	--	28.3	460
REW			2,080	0.0					

STATION: Mississippi River in Pool 14, Transect 3--UMR mile 494.8
PARTY: Moody, Meade, Roth, and Writer
DATE: July 19,1991
GAGE HEIGHT at TW Dam 13: ~576.66 ft
GAGE HEIGHT at Dam 14: 572.00 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: ~29 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Silvis, Iowa-Ill.
REMARKS:

Acadiana anchored 1,000 m from downstream edge of I-80 bridge at the intersection with the Illinois shoreline, and 780 m from the edge of I-80 bridge at the intersection with the Iowa shoreline. Velocities were measured at 0.6 times the depth.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 096° magnetic

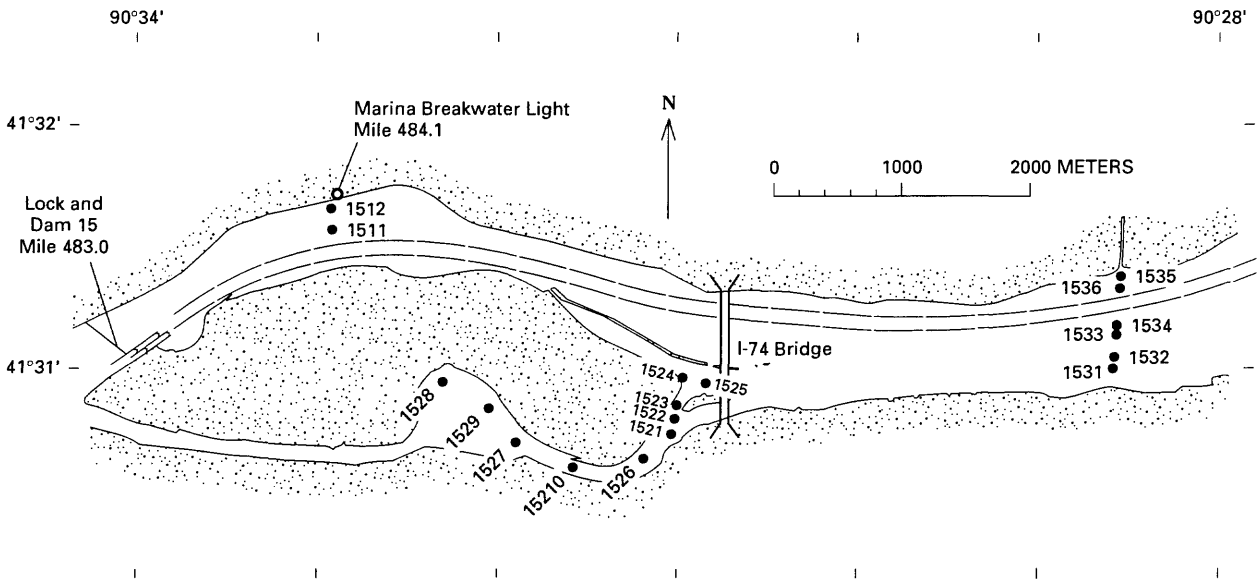
Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana			0						
1437	41°34.735	090°22.665	335	3.8	0.43	220	--	28.4	464
1436	34.755	22.840	575	3.2	0.34	230	--	28.9	466
1435	34.780	23.000	815	1.8	0.08	250	--	30.2	438
1434	34.800	23.150	1,010	3.1	0.06	215	--	30.4	438
1433	34.825	23.340	1,280	3.2	0.07	080	--	31.2	431
1432	34.850	23.535	1,515	3.6	0.07	210	--	29.9	435
1431	41°34.870	090°23.675	1,760	4.2	0.06	090	--	30.1	448
REW			1,900	0.0					

STATION: Mississippi River in Pool 14, Transect 4--UMR mile 494.8
PARTY: Moody, Meade, Roth, and Writer
DATE: July 19,1991
GAGE HEIGHT at TW Dam 13: ~576.66 ft
GAGE HEIGHT at Dam 14: 572.00 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: ~29 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Silvis, Iowa-Ill.
REMARKS:

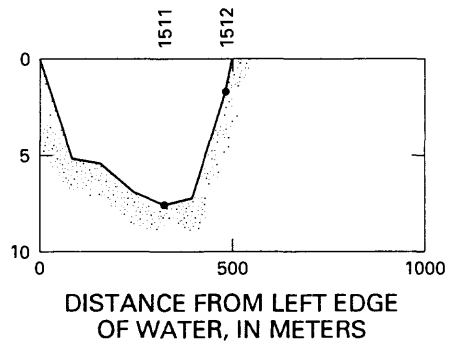
Acadiana anchored 1,000 m from downstream edge of I-80 bridge at the intersection with the Illinois shoreline, and 780 m from the edge of I-80 bridge at the intersection with the Iowa shoreline.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 056° magnetic

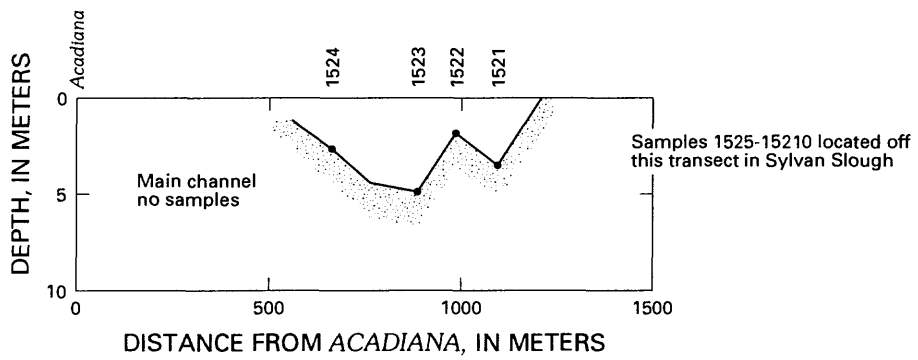
Site	NAD27 Latitude N	NAD27 Longitude W	Distance from *Acadiana* (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
Acadiana			0						
01	--	--	1,095	6.4	0.38	260	--	28.1	463
02	--	--	1,315	6.7	0.34	260	--	28.6	467
1443	41°34.295	090°23.395	1,525	0.5	0.14	290	--	29.9	459
1442	34.230	23.525	1,750	0.7	0.07	020	--	30.5	445
1441	41°34.180	090°23.665	1,970	0.8	0.05	020	--	30.1	445
REW			2,070	0.0					


90°34'
90°28'
41°32'
41°31'
N
0
1000
2000 METERS
Marina Breakwater Light
Mile 484.1
Lock and
Dam 15
Mile 483.0
1512
1511
1536
1535
1533
1534
1532
1531
I-74 Bridge
1524
1525
1523
1522
1521
1528
1529
1527
15210
1526

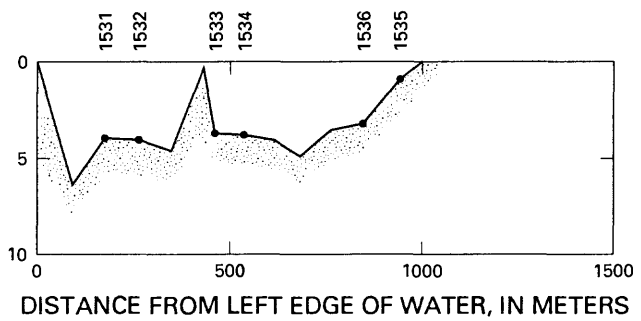
Transect 1 - UMR mile 484.0



Transect 2 - UMR mile 485.8



Transect 3 - UMR mile 487.8



STATION: Mississippi River in Pool 15, Transect 1--UMR mile 484.0

PARTY: Moody, Meade, Bishop, and Antweiler

DATE: April 20, 1992

GAGE HEIGHT at TW Dam 14: 564.42 ft

GAGE HEIGHT at Dam 15: 561.18 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 61.4 x 10^{-6}

CURRENT METER No: 90-JM-1

DATE RATED: 06-91

MAP: USGS 7.5-minute quadrangle is Davenport East, Iowa-Ill.

REMARKS:

Acadiana anchored at UMR mile 484.0 at southwest corner of low rock wall surrounding marina on the rightbank; 473 m from LEW at foot of Gillespe Avenue on Rock Island. Water discharge does not include flow in Sylvan Slough south of Rock Island.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006

BEARING OF TRANSECT: 174° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
02	--	--	79	5.0	0.68	260	267	11.1	393
03	--	--	156	5.3	0.88	260	360	11.6	384
04	--	--	233	7.0	0.64	260	340	11.1	387
1511	41°31.570	090°32.865	308	7.3	0.76	260	416	10.9	387
05	--	--	383	7.2	0.82	260	518	11.3	395
1512	41°31.660	090°32.870	483	1.8	0.01	260	in eddy	12.3	411
REW			490	0.0					
Mean				5.3	0.73				
Total							1,901		

STATION: Mississippi River in Pool 15, Transect 2--UMR mile 485.8
PARTY: Moody, Meade, Bishop, and Antweiler
DATE: April 20, 1992
GAGE HEIGHT at TW Dam 14: 564.42 ft
GAGE HEIGHT at Dam 15: 561.18 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 61.4 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Davenport East, Iowa-Ill.
REMARKS:

Acadiana secured to upstream corner of Lucky Seven barge where Diamond Lady moors; 60 m downstream from center line of Iowa-Illinois Memorial Bridge (U.S. Highway 6).

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 003° magnetic

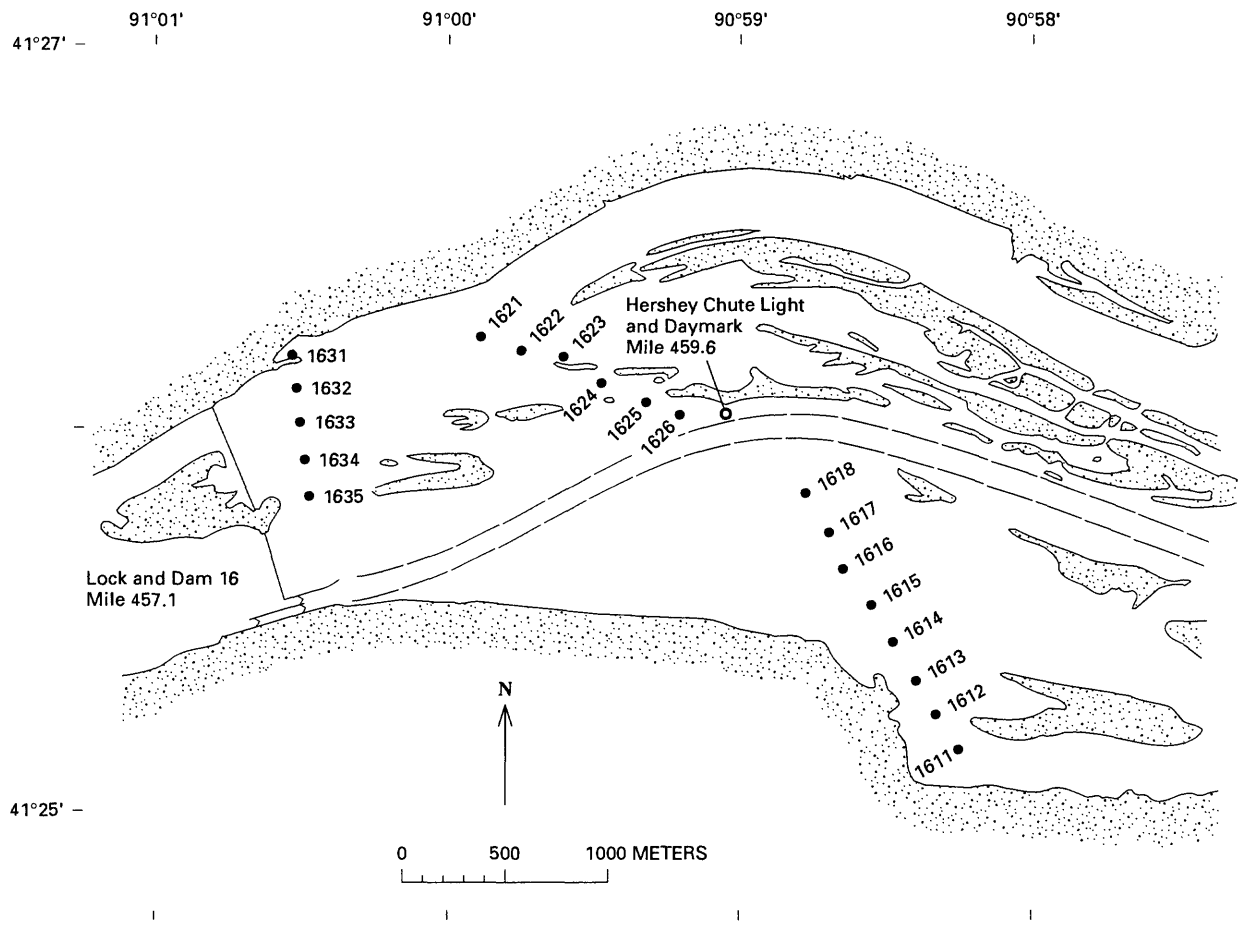
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana			0	0.0					
1524	41°30.975	090°30.920	660	2.3	0.22	250	--	12.0	384
01	--	--	775	4.4	0.32	170	--	12.1	387
1523	30.850	30.950	882	4.7	0.16	200	--	12.6	387
1522	30.800	30.960	986	1.7	0.41	200	--	12.2	389
1521	41°30.740	090°30.975	1,099	3.6	0.45	250	--	11.9	396
The following samples were not on the transect, but in the backwater area of Sylvan Slough upstream from Sylvan Island--see map for the location of sampling sites.									
1525	41°30.950	090°30.790	--	2.4	0.42	270	--	12.1	388
1526	30.632	31.112	--	4.4	0.36	230	--	12.3	394
1527	30.700	31.840	--	1.1	0.19	280	--	12.1	390
1528	30.945	32.250	--	0.9	no velocity measurement	--	--	13.0	388
1529	30.835	31.990	--	0.6		--	--	12.9	384
15210	41°30.595	090°31.525	--	4.5		--	--	12.9	385

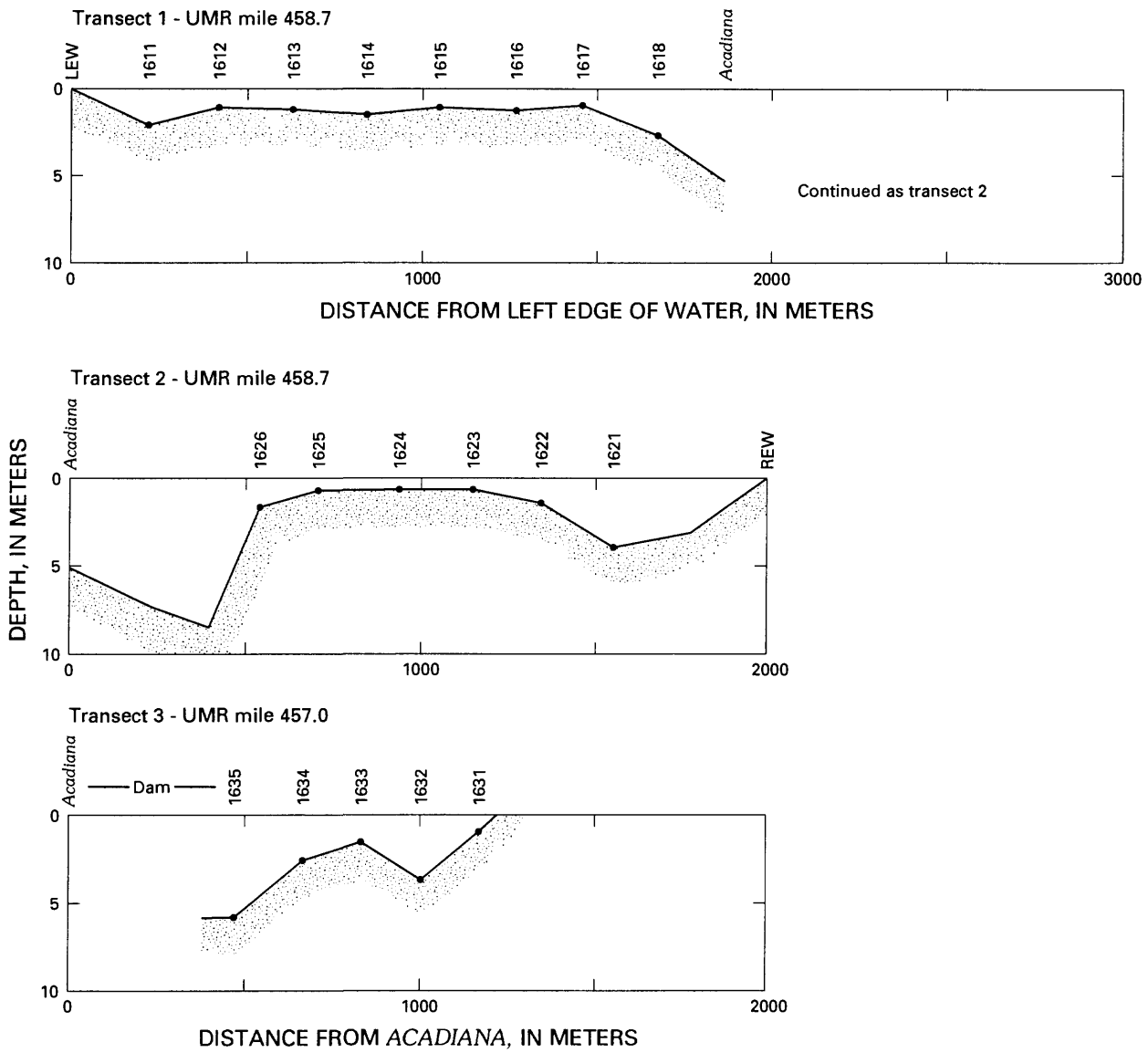
STATION: Mississippi River in Pool 15, Transect 3--UMR mile 487.8
PARTY: Moody, Meade, Bishop, and Antweiler
DATE: April 20, 1992
GAGE HEIGHT at TW Dam 14: 564.42 ft
GAGE HEIGHT at Dam 15: 561.18 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 61.4 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Silvis, Ill.-Iowa
REMARKS:

Acadiana anchored shoreward of green buoy line at UMR mile 487.8, directly off mouth of Duck Creek: 145 m from upstream mooring cell at Texaco Dock; 817 m from downstream tip of marina breakwater on left bank near BM 571 on quadrangle; 809 m from upstream corner of culvert on left bank downstream from breakwater; 746 m from tip of bulge near "P" in "ST. PAUL" on left bank (see 7.5-minute quadrangle); 250 m from upstream corner of mouth of Duck Creek.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 003° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
01	--	--	81	6.3	0.65	270	349	12.2	389
1531	41°31.010	090°28.535	171	3.8	0.82	260	277	11.9	390
1532	31.060	28.525	261	3.8	0.75	260	246	12.2	388
02	--	--	346	4.7	0.74	260	258	12.1	388
03	--	--	411	1.4	0.32	250	18	12.3	391
Shoal			429	0.5		no velocity measurement			
1533	31.155	28.515	451	3.7	0.78	260	138	12.2	388
1534	31.195	28.510	526	3.7	0.87	250	237	12.2	389
04	--	--	606	4.0	0.93	260	293	12.4	392
05	--	--	686	4.7	0.76	260	248	12.6	399
06	--	--	746	3.6	0.92	260	261	12.9	403
1536	31.340	28.495	846	3.2	0.61	250	175	13.2	406
1535	41°31.390	090°28.500	936	0.8	0.20	260	12	14.0	420
REW			996	0.0					
Mean				3.4	0.74				
Total							2,512		


91°01'
91°00'
90°59'
90°58'
41°27'
41°25'
1631
1632
1633
1634
1635
1621
1622
1623
1624
1625
1626
Hershey Chute Light
and Daymark
Mile 459.6
1618
1617
1616
1615
1614
1613
1612
1611
Lock and Dam 16
Mile 457.1
N
0
500
1000 METERS


Transect 1 - UMR mile 458.7
LEW
1611
1612
1613
1614
1615
1616
1617
1618
Acadiana
0
5
10
Continued as transect 2
0
1000
2000
3000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 458.7
Acadiana
1626
1625
1624
1623
1622
1621
REW
0
5
10
0
1000
2000
DEPTH, IN METERS
Transect 3 - UMR mile 457.0
Acadiana
Dam
1635
1634
1633
1632
1631
0
5
10
0
1000
2000
DISTANCE FROM ACADIANA, IN METERS

STATION: Mississippi River in Pool 16, Transect 1--UMR mile 458.7
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: October 24, 1991
GAGE HEIGHT at TW Dam 15: 547.46 ft
GAGE HEIGHT at Dam 16: 545.59 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 13.6 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Illinois City, Iowa-Ill.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 458.7; 295-300 m from Hershey Chute Lower Light and Daymark (UMR mile 458.6); 1,255 from Hershey Chute Light and Daymark (UMR mile 459.6); 2,410 m from upstream tip of wall between locks at Lock 16; 0.466 nautical miles (radar distance) from LEW. Transect 1 and 2 make a complete transect from LEW to REW with a dogleg at *Acadiana*. Discharge through Dam 16 was about 1,030 m^3/s. Velocity at site 1613 was estimated to be equal to the velocity at site 1612. Rock River had a specific conductance of 635 µS/cm and discharged into the pool about 34 kilometers upstream from this transect.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 149° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1611	41°25.165	090°58.255	215	2.0	0.19	270	65	14.4	576
1612	25.255	58.330	420	1.0	0.11	290	13	14.9	574
1613	25.350	58.400	630	1.2	0.11	290	15	--	572
1614	25.450	58.430	830	1.4	0.22	270	52	14.6	539
1615	25.545	58.550	1,045	1.0	0.14	270	25	13.8	528
1616	25.635	58.650	1,260	1.2	0.18	270	37	14.0	486
1617	25.730	58.705	1,450	0.8	0.07	270	10	14.6	477
1618	41°25.830	090°58.785	1,660	2.5	0.20	260	78	14.1	453
01	--	--	1,795	1.0	0.13	280	9	13.7	448
02	--	--	1,865	5.1	0.20	240	36	13.7	443
Acadiana			1,867	5.1					
Mean				1.3	0.14				
Total							340		

STATION: Mississippi River in Pool 16, Transect 2--UMR mile 458.7
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: October 24, 1991
GAGE HEIGHT at TW Dam 15: 547.46 ft
GAGE HEIGHT at Dam 16: 545.59 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 13.6 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Illinois City, Iowa-Ill.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 458.7; 295-300 m from Hershey Chute Lower Light and Daymark (UMR mile 458.6); 1,255 m from Hershey Chute Light and Daymark (UMR mile 459.6); 2,410 m from upstream tip of wall between locks at Dam 16; 0.466 nautical miles (radar distance) from LEW. Transect 1 and 2 make a complete transect from LEW to REW with a dogleg at *Acadiana*. Discharge through Dam 16 was about 1,030 m^3/s. Rock River had a specific conductance of 635 µS/cm and discharged into the pool about 34 kilometers upstream from this transect. Site 05 is the same as site 02 on transect 1.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 112° magnetic

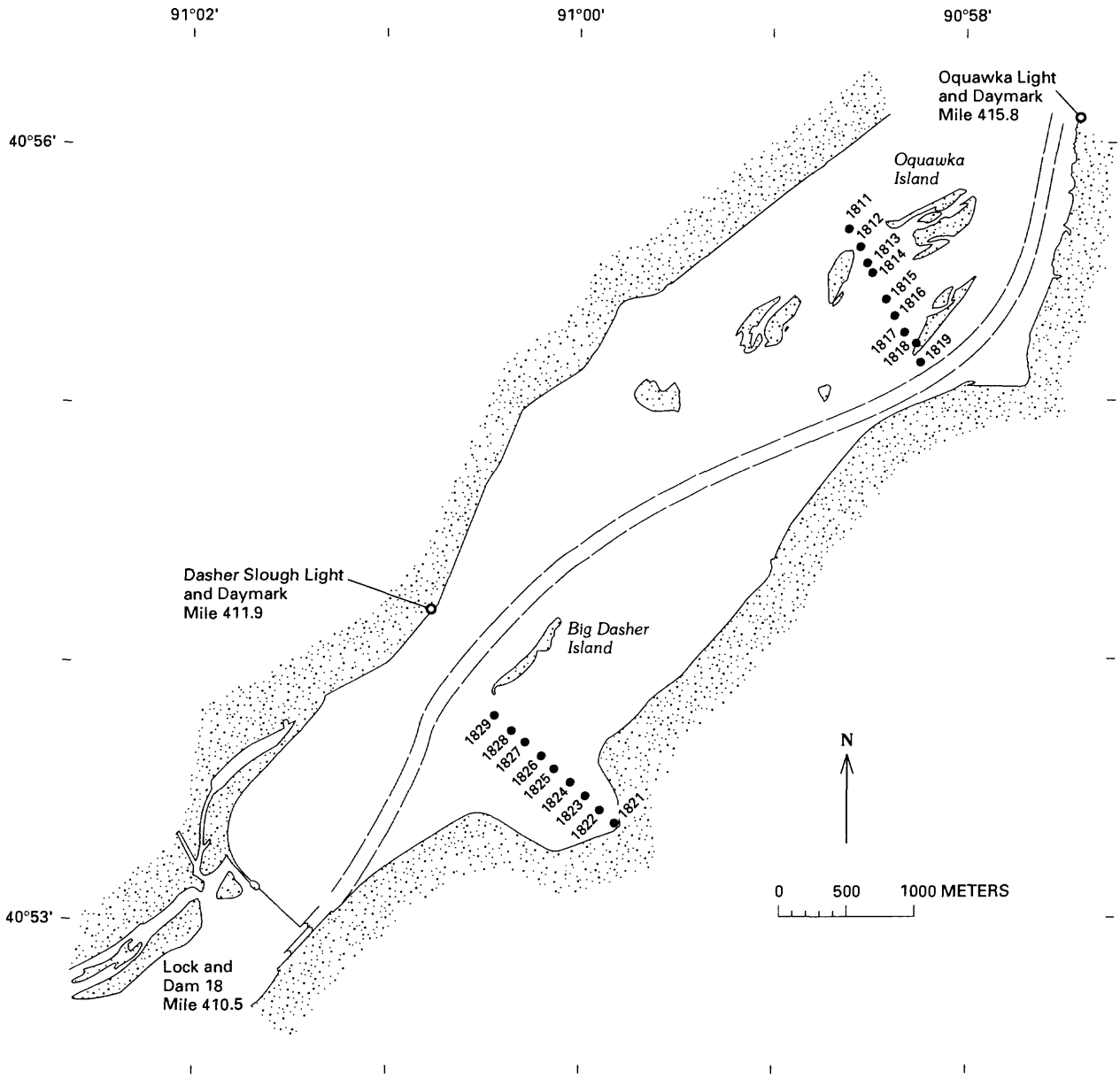
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana			0	0.0					
05	--	--	2	5.1	0.20	240	57	13.7	443
04	--	--	155	6.4	0.31	240	200	14.4	434
03	--	--	270	7.4	0.39	270	106	13.4	431
02	--	--	395	8.2	0.40	270	132	14.5	429
1626	41°26.035	090°59.215	530	1.5	0.15	240	27	14.2	429
1625	26.065	59.330	705	0.5	0.12	270	4	14.6	429
1624	26.115	59.490	930	0.5	0.11	350	-11	15.9	424
1623	26.155	59.625	1,145	0.4	0.18	270	5	15.9	423
1622	26.195	59.770	1,345	1.2	0.06	250	9	15.3	425
1621	41°26.235	090°59.900	1,550	3.8	0.22	200	175	13.6	431
01			1,770	3.0	0.25	220	151	14.1	435
REW			1,985	0.0					
Mean				2.7	0.16				
Total							855		

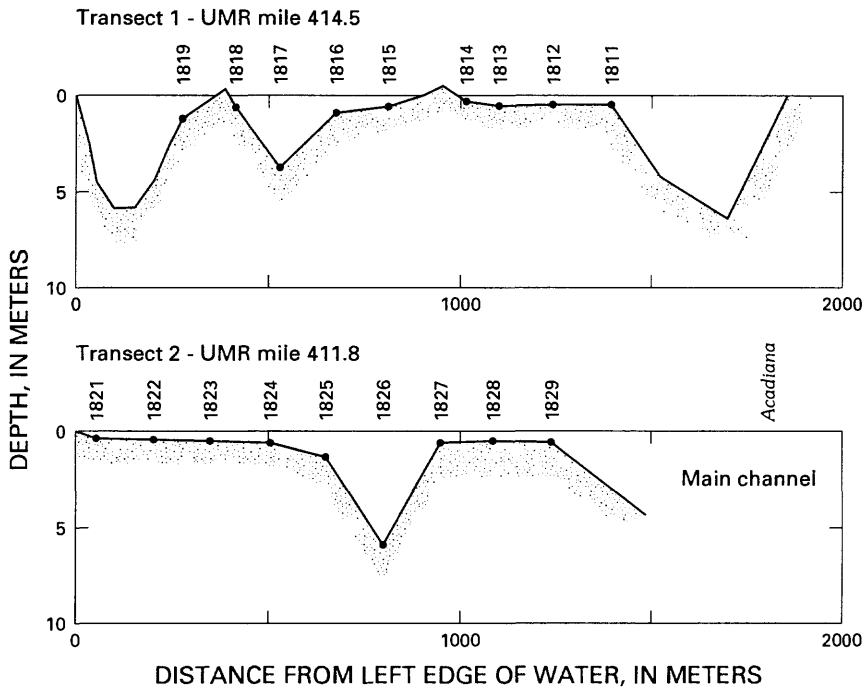
STATION: Mississippi River in Pool 16, Transect 3--UMR mile 457.0
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: October 24, 1991
GAGE HEIGHT at TW Dam 15: 547.46 ft
GAGE HEIGHT at Dam 16: 545.59 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 13.6×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Davenport East, Iowa-Ill.
REMARKS:

Acadiana moored to south side of upper riverside wall of Lock 16, about 30 m from eastern tip of wall. No velocity measurements were made upstream from the dam between 0 and 467 m from *Acadiana*. Discharge through Dam 16 was about 1,030 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 173° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
Acadiana			0	0.0					
1635	41°25.820	091°00.510	467	5.8	0.22	240	394	13.3	428
1634	25.910	00.525	655	2.5	0.16	190	25	13.3	432
1633	26.005	00.535	828	1.1	0.13	200	12	13.5	430
1632	26.100	00.550	995	3.6	0.15	180	17	13.5	431
1631	41°26.185	091°00.570	1,165	0.5	0.01	0	0	13.7	431
REW			1,215	0.0					
Mean				2.6	0.14				
Total							448		


91°02'
91°00'
90°58'
40°56'
40°53'
Oquawka Light
and Daymark
Mile 415.8
Oquawka
Island
1811
1812
1813
1814
1815
1816
1817
1818
1819
Dasher Slough Light
and Daymark
Mile 411.9
Big Dasher
Island
1829
1828
1827
1826
1825
1824
1823
1822
1821
N
0
500
1000 METERS
Lock and
Dam 18
Mile 410.5


Transect 1 - UMR mile 414.5
1819
1818
1817
1816
1815
1814
1813
1812
1811
0
5
10
0
1000
2000
Transect 2 - UMR mile 411.8
1821
1822
1823
1824
1825
1826
1827
1828
1829
Acadiana
Main channel
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 18, Transect 1--UMR mile 414.5
PARTY: Moody, Meade, and Antweiler
DATE: April 22, 1992
GAGE HEIGHT at TW Dam 17: 538.05 ft
GAGE HEIGHT at Dam 18: 528.09 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 72.6 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Oquawka, Ill.-Iowa
REMARKS:

Acadiana anchored along green buoy line at UMR mile 414.5; 1,405 m from tip of small "peninsula" at small marina 780 m downstream from Oquawka Light and Daymark (UMR mile 415.8) at Public Access ramp; 940 m from LEW at white building; 1,390 m downstream from Oquawka Light; 386 m from tip of small peninsula near center of Section 28 (on 7.5-minute quadrangle map). Wind was 3-8 m/s from 200° magnetic.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 149° magnetic

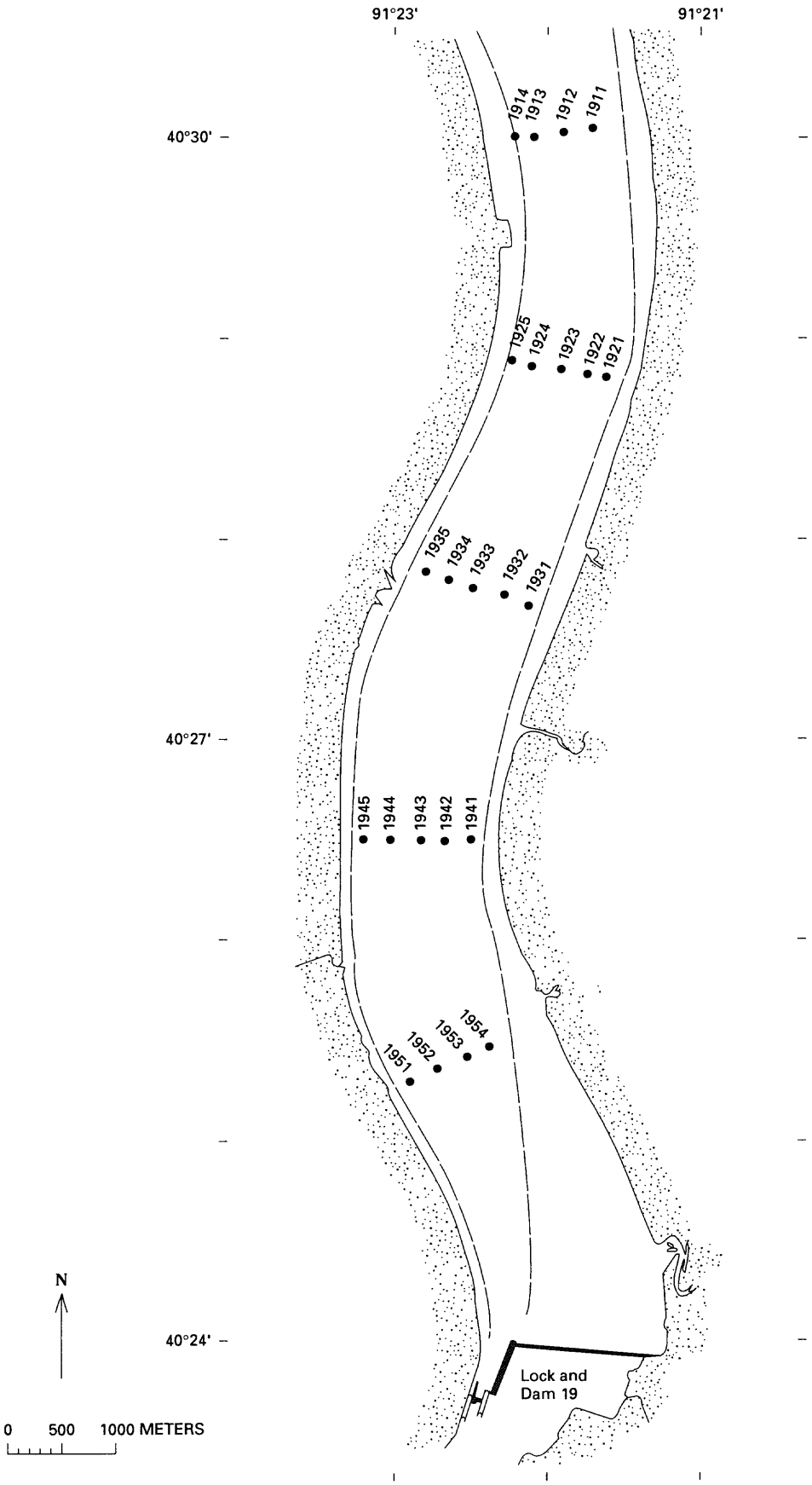
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
06	--	--	50	4.5	0.79	230	168	9.9	473
05	--	--	95	6.0	1.16	240	347	9.9	466
04	--	--	150	6.0	0.96	230	331	9.9	457
03	--	--	210	4.6	0.65	240	185	9.9	443
1819	40°55.150	090°58.240	275	1.2	0.18	200	15	9.7	435
Island	--	--	375	0.0	0.01	260	0	--	--
1818	55.205	58.280	400	0.6	0.19	200	7	10.0	434
1817	55.270	58.330	525	3.8	0.88	220	446	9.6	428
1816	55.335	58.375	675	0.9	0.50	210	58	10.0	410
1815	55.400	58.420	810	0.6	0.26	220	21	9.6	414
Island	--	--	950	0.0	0.01	220	0	--	--
1814	55.500	58.495	1,015	0.3	0.06	220	1	8.8	419
1813	55.540	58.520	1,100	0.4	0.24	240	11	9.6	414
1812	55.605	58.575	1,245	0.4	0.17	300	4	9.5	415
1811	40°55.665	090°58.615	1,385	0.6	0.42	220	32	9.6	419
02	--	--	1,510	4.2	0.97	230	642	9.7	414
01	--	--	1,700	6.3	1.03	230	1,097	9.3	475
REW			1,850	0.0				10.0	493
Mean				2.1	0.85				
Total							3,365		

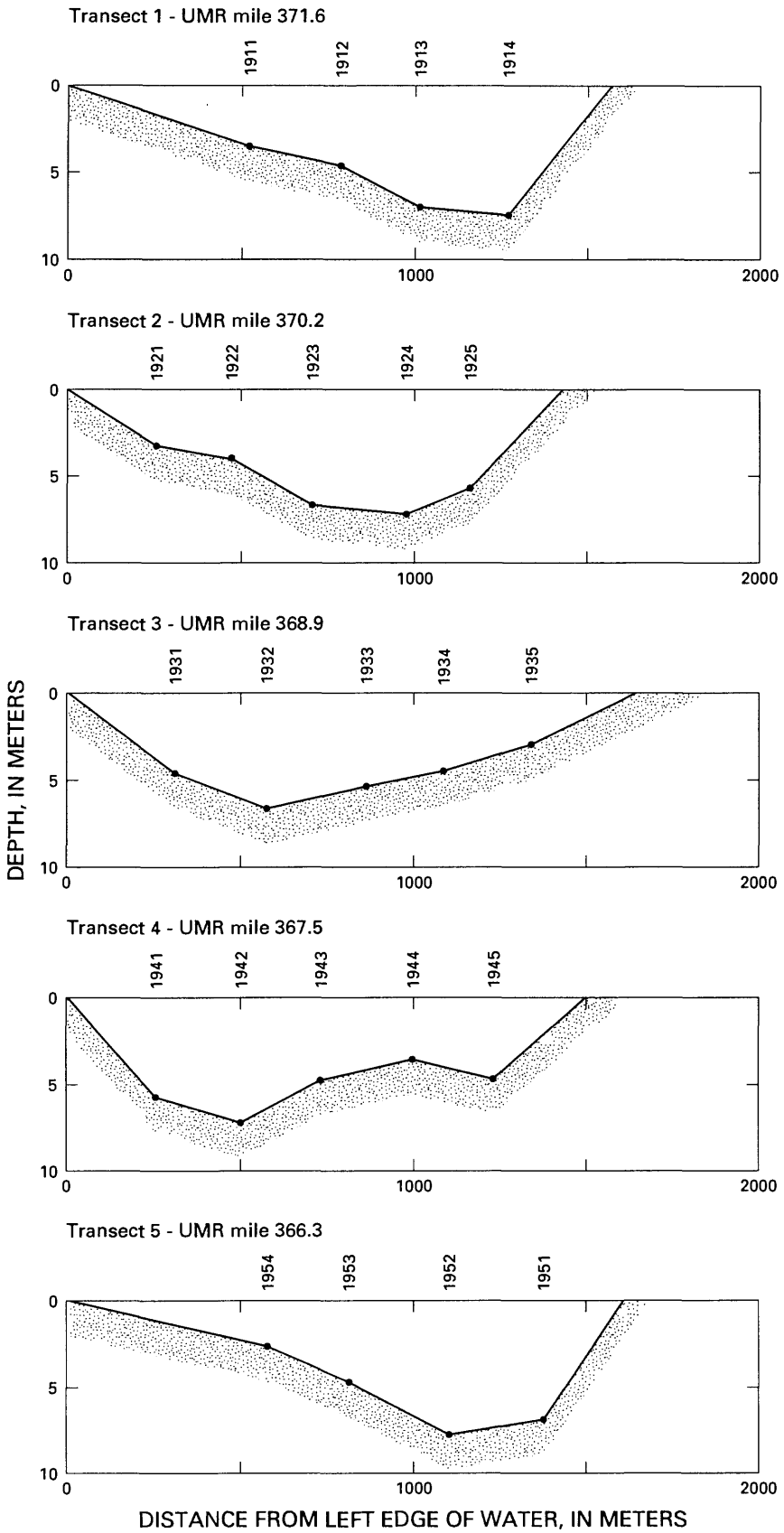
STATION: Mississippi River in Pool 18, Transect 2--UMR mile 411.8
PARTY: Moody, Meade, and Antweiler
DATE: April 22, 1992
GAGE HEIGHT at TW Dam 17: 538.05 ft
GAGE HEIGHT at Dam 18: 528.09 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 72.6×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Oquawka, Ill.-Iowa, and Kingston, Iowa-Ill.
REMARKS:

Acadiana anchored on green buoy line at UMR mile 411.8; 860 m from water's edge in corner where Rag Island meets the southwest end of levee in northwest corner of Section 6; 1,810 m from pumping station by Pogue Lake on Illinois side of the river. No velocity measurements were made.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 129° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
1821	40°53.350	090°59.820	60	0.3				11.3	454
1822	53.405	59.900	205	0.3				11.3	470
1823	53.455	59.970	350	0.3	Currents were too slow to measure with current meter.			10.9	476
1824	53.505	091°00.060	505	0.5				10.9	473
1825	53.565	00.150	650	1.3				10.7	475
1826	53.610	00.220	795	6.0				10.7	470
1827	53.665	00.300	945	0.5	No velocity measurements were made.			11.3	454
1828	53.715	00.375	1,080	0.5				--	--
1829	40°53.770	091°00.460	1,235	0.5				11.0	456
Acadiana			1,810						


91°23'
91°21'
40°30'
40°27'
40°24'
1914
1913
1912
1911
1925
1924
1923
1922
1921
1935
1934
1933
1932
1931
1945
1944
1943
1942
1941
1954
1953
1952
1951
Lock and
Dam 19
N
0
500
1000 METERS


Transect 1 - UMR mile 371.6
1911
1912
1913
1914
Transect 2 - UMR mile 370.2
1921
1922
1923
1924
1925
Transect 3 - UMR mile 368.9
1931
1932
1933
1934
1935
Transect 4 - UMR mile 367.5
1941
1942
1943
1944
1945
Transect 5 - UMR mile 366.3
1954
1953
1952
1951
0
5
10
0
1000
2000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 19, Transect 1--UMR mile 371.6
PARTY: Moody, LeBoeuf, Rostad, Garbarino, and Noyes
DATE: October 26, 1991
GAGE HEIGHT at Burlington: 519.35 ft
GAGE HEIGHT at Dam 19: 518.03 ft
MAP: USGS 7.5-minute quadrangle is Niota, Ill.-Iowa
RIVER SLOPE: 6.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore on the northeastern corner of the rectangular earth-filled dock at UMR mile 371.1 (Y-remote), and on the tip of the southern lobe of a creek delta (X-remote) directly east of the earth-filled dock. The distances north of the line between the X and Y-remotes to *Acadiana* are listed below. Latitude and longitude correspond to the location of the grab sample. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured. The fifth site could not be collected because of shallow water near the left bank.

BEARING OF TRANSECT: 079° magnetic

Site	NAD27		Distance		Distance from LEW (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
	Latitude N	Longitude W	X remote	Y remote				
LEW					0			
1911c	40°30.075	091°21.720	954	1,146	520	3.4	13.5	458
1911g			953	1,145				
1912c	30.055	21.910	1,135	960	770	4.6	13.5	458
1912g			1,134	963				
1913c	30.035	22.100	1,311	805	1,020	7.0	13.5	457
1913g			1,311	805				
1914c	40°30.035	091°22.220	1,457	773	1,290	7.5	13.7	459
1914g			1,426	742		7.0		
REW					1,560			

STATION: Mississippi River in Pool 19, Transect 2--UMR mile 370.2
PARTY: Moody, LeBoeuf, Rostad, Garbarino, and Noyes
DATE: October 26, 1991
GAGE HEIGHT at Burlington: 519.35 ft
GAGE HEIGHT at Dam 19: 518.03 ft
MAP: USGS 7.5-minute quadrangle is Hamilton, Ill.-Iowa
RIVER SLOPE: 6.5×10^{-6}
REMARKS:

Microwave trisponders were located ashore on the northeastern corner of the rectangular earth-filled dock at UMR mile 371.1 (Y-remote), and on the tip of the southern lobe of a creek delta (X-remote) directly east of the earth-filled dock. The distances south of the line between the X- and Y-remotes to *Acadiana* are listed below. Latitude and longitude correspond to the location of the grab sample. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured.

BEARING OF TRANSECT: 094° magnetic

Site	NAD27		Distance		Distance from LEW (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
	Latitude N	Longitude W	X remote	Y remote				
LEW					0			
1921c	40°28.825	091°21.615	1,564	1,727	230	3.0	13.5	460
1921g			1,578	1,712				
1922c	28.835	21.750	1,606	1,586	460	3.8	13.4	458
1922g			1,606	1,586				
1923c	28.860	21.915	1,675	1,460	700	6.7	13.6	457
1923g			1,675	1,460				
1924c	28.875	22.150	1,806	1,362	970	7.1	13.7	459
1924g			1,823	1,366				
1925c	40°28.900	091°22.230	1,883	1,313	1,150	5.4	13.8	460
1925g			1,883	1,313				
REW					1,400			

STATION: Mississippi River in Pool 19, Transect 3--UMR mile 368.9

PARTY: Moody, LeBoeuf, Rostad, Garbarino, and Noyes

DATE: October 26, 1991

GAGE HEIGHT at Burlington: 519.35 ft

GAGE HEIGHT at Dam 19: 518.03 ft

MAP: USGS 7.5-minute quadrangles are Keokuk, Iowa-Mo.-Ill. and Hamilton, Ill.-Iowa

RIVER SLOPE: 6.7×10^{-6}

REMARKS:

Microwave trisponders were located ashore on the northern lobe of the delta at Waggoner Creek on the left bank (X-remote), and 2 m north of a culvert opposite the mouth of Waggoner Creek on the right bank at about UMR mile 368.0. The distances north of the line between the X- and Y-remotes to *Acadiana* are listed below. Latitude and longitude correspond to the location of the grab sample. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured.

BEARING OF TRANSECT: 102° magnetic

Site	NAD27		Distance		Distance from LEW (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
	Latitude N	Longitude W	X remote	Y remote				
LEW					0			
1931c	40°27.710	091°22.120	1,152	2,212	320	4.5	13.9	462
1931g			1,149	2,185		4.9		
1932c	27.755	22.285	1,227	2,077	560	6.4	13.8	458
1932g			1,227	2,077				
1933c	27.780	22.490	1,351	1,910	850	5.3	14.1	463
1933g			1,351	1,910				
1934c	27.830	22.650	1,510	1,830	1,090	4.5	14.1	462
1934g			1,510	1,830				
1935c	40°27.870	091°22.810	1,700	1,791	1,350	2.9	14.5	465
1935g			1,700	1,791				
REW					1,630			

STATION: Mississippi River in Pool 19, Transect 4--UMR mile 367.5
PARTY: Moody, LeBoeuf, Rostad, Garbarino, and Noyes
DATE: October 26, 1991
GAGE HEIGHT at Burlington: 519.35 ft
GAGE HEIGHT at Dam 19: 518.03 ft
MAP: USGS 7.5-minute quadrangles are Keokuk, Iowa-Mo.-Ill., and Hamilton, Ill.-Iowa
RIVER SLOPE: 6.7×10^{-6}

REMARKS:

Microwave trisponders were located ashore on the northern lobe of the delta at Waggoner Creek on the left bank (X-remote), and 2 m north of a culvert opposite the mouth of Waggoner Creek on the right bank at about UMR mile 368.0. The distances south of the line between the X- and Y-remotes to *Acadiana* are listed below. Latitude and longitude correspond to the location of the grab sample. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured.

BEARING OF TRANSECT: 086° magnetic

Site	NAD27		Distance		Distance from LEW (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
	Latitude N	Longitude W	X remote	remote				
LEW					0			
1941c	40°26.530	091°22.500	1,110	1,470	260	5.7	13.8	461
1941g			1,144	1,455				
1942c	26.520	22.670	1,230	1,273	500	7.1	14.3	463
1942g			1,247	1,269		7.2		
1943c	26.520	22.825	1,356	1,101	720	4.7	14.2	463
1943g			1,358	1,108		4.8		
1944c	26.520	23.015	1,555	962	980	3.5	14.0	460
1944g			1,555	962				
1945c	40°26.535	091°23.180	1,723	840	1,220	4.8	14.0	461
1945g			1,724	841				
REW					1,460			

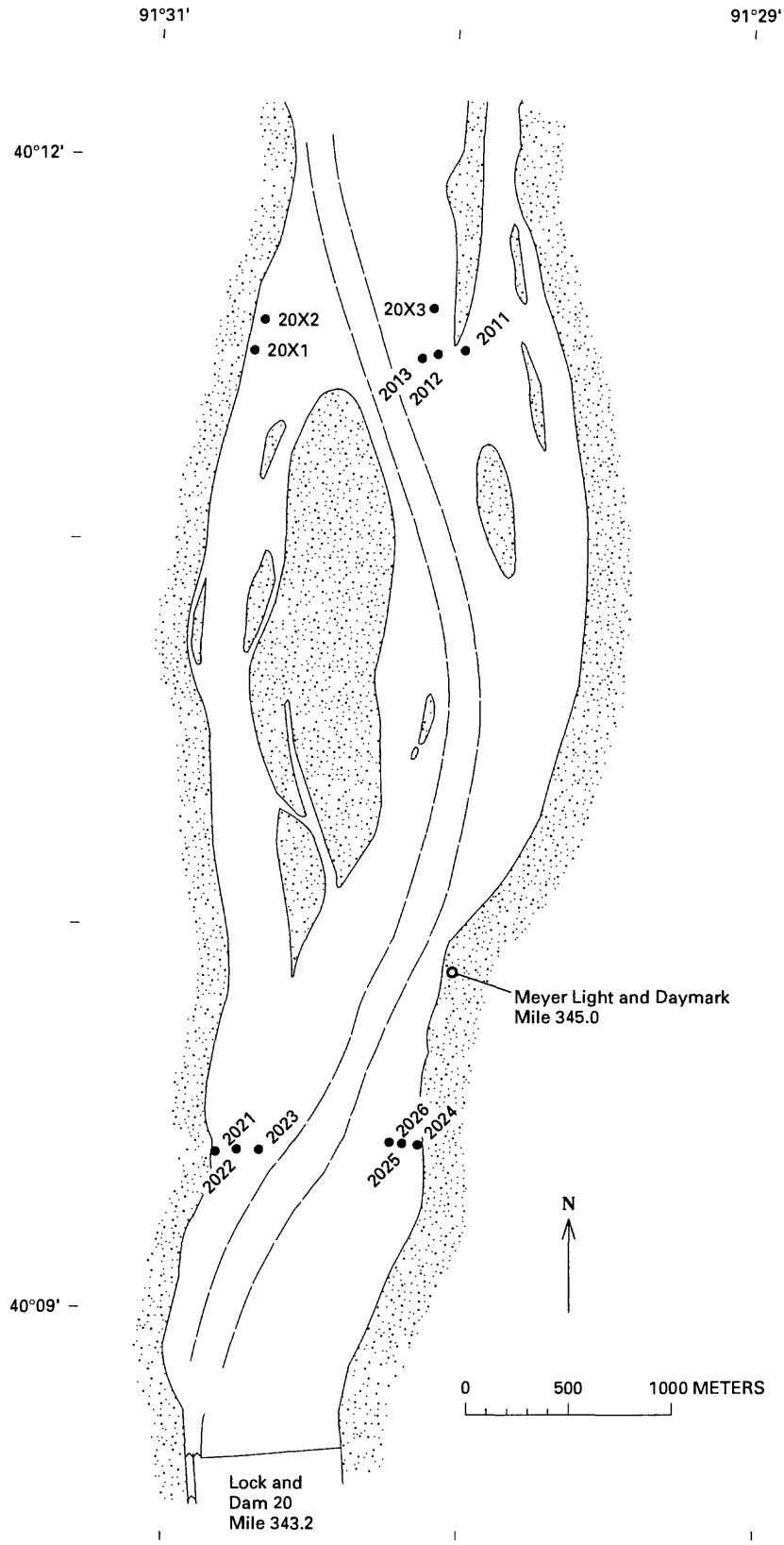
STATION: Mississippi River in Pool 19, Transect 5--UMR mile 366.3
PARTY: Moody, LeBoeuf, Rostad, Garbarino, and Noyes
DATE: October 26, 1991
GAGE HEIGHT at Burlington: 519.35 ft
GAGE HEIGHT at Dam 19: 518.03 ft
MAP: USGS 7.5-minute quadrangles are Keokuk, Iowa-Mo.-Ill., and Hamilton, Ill.-Iowa
RIVER SLOPE: 7.2×10^{-6}

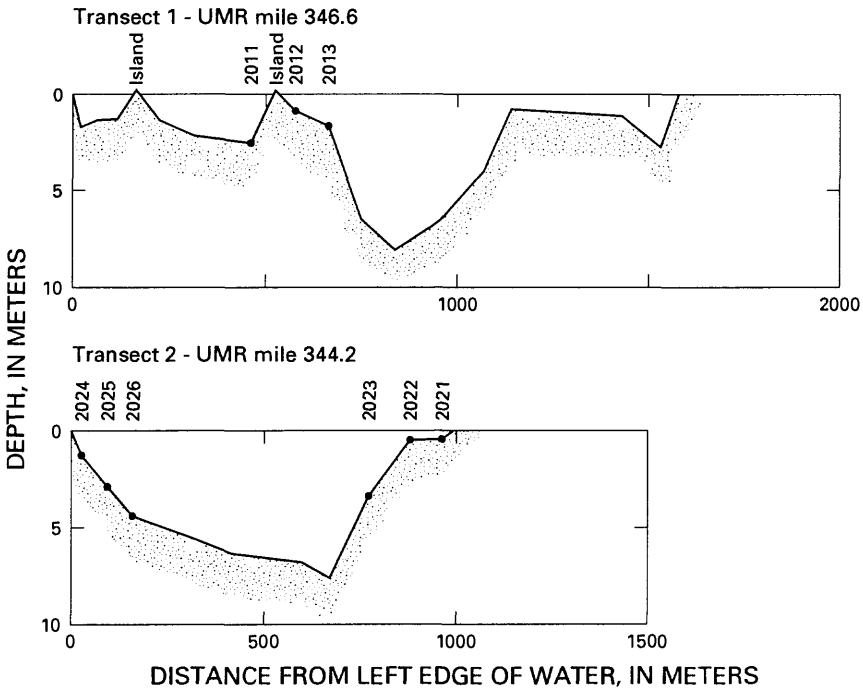
REMARKS:

Microwave trisponders were located 2 m south of the small northern inlet to the Keokuk Marina at UMR mile 366.3 (X-remote), and 2 m north of a culvert opposite the mouth of Waggoner Creek on the right bank at about UMR mile 368.0. The X-remote was at the REW of the transect. Distances from the remotes to *Acadiana* are listed below. Latitude and longitude correspond to the location of the grab sample. The "g" denotes van Veen grab and the "c" denotes gravity core samples. Water depth, temperature, and specific conductance are the same for the grab and core samples. No water velocities were measured. The fifth site could not be collected because of shallow water near the left bank.

BEARING OF TRANSECT: 063° magnetic

Site	NAD27		Distance		Distance from LEW (m)	Depth (m)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
	Latitude N	Longitude W	X remote	Y remote				
LEW			0					
1954c	40°25.470	091°22.365	1,044	3,055	580	2.4	14.1	462
1954g			1,044	3,055				
1953c	25.420	22.515	801	3,045	810	4.8	14.5	464
1953g			802	3,048				
1952c	25.365	22.715	521	3,044	1,100	7.7	13.9	459
1952g			518	3,048				
1951c	40°25.305	091°22.885	248	3,082	1,370	6.8	14.2	465
1951g			244	3,089		7.0		
REW					1,600			


91°31'
91°29'
40°12'
40°09'
20X2
20X1
20X3
2011
2013
2012
Meyer Light and Daymark
Mile 345.0
2021
2023
2022
2026
2024
2025
N
0
500
1000 METERS
Lock and
Dam 20
Mile 343.2


Transect 1 - UMR mile 346.6
Island
2011
Island
2012
2013
0
5
10
0
1000
2000
Transect 2 - UMR mile 344.2
2024
2025
2026
2023
2022
2021
0
5
10
0
500
1000
1500
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 20, Transect 1--UMR mile 346.6
PARTY: Moody, Meade, Roth, and Writer
DATE: July 22, 1991
GAGE HEIGHT at TW Dam 19: 483.64 ft
GAGE HEIGHT at Dam 20: 478.79 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 44 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangles are Canton, Mo.-Ill. and Lima, Ill.-Mo.
REMARKS:

Acadiana anchored 1,690 m downstream from the end of an unimproved road that intersects the right bank at the line between T.62N. and T.63N.; 1,005 m from left bank where road crosses levee. Velocities were measured while anchored.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 077° magnetic

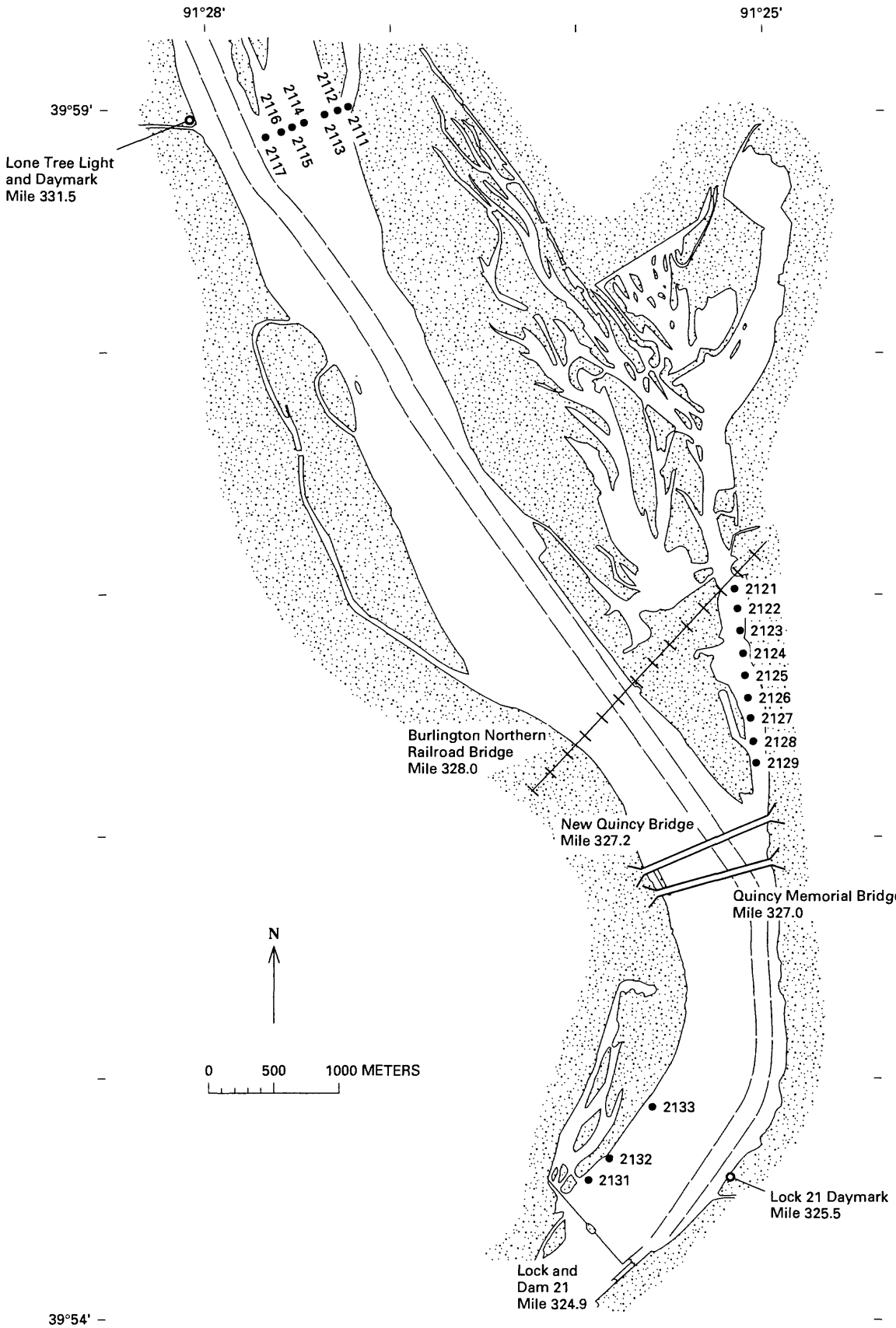
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
01	--	--	18	1.8	0.46	165	24	28.7	474
02	--	--	58	1.2	0.41	170	24	28.7	471
03	--	--	117	1.2	0.46	170	26	28.7	473
Island	--	--	152	0.0	0.01	170	0	--	--
04	--	--	212	1.4	0.60	190	60	28.8	474
05	--	--	312	2.2	0.67	200	150	28.7	474
2011	40°11.495	091°29.980	467	2.4	0.69	210	127	28.7	474
Island	--	--	537	0.0	0.01	170	0	--	--
2012	11.485	30.070	587	0.8	0.14	150	7	29.0	470
2013	40°11.470	091°30.120	667	1.4	0.23	150	24	29.0	472
06	--	--	742	6.3	0.50	165	270	29.0	471
07	--	--	837	8.0	0.74	170	680	28.8	477
08	--	--	972	6.2	0.92	170	664	28.5	504
09	--	--	1,072	3.9	0.66	175	215	28.4	521
10	--	--	1,142	0.8	0.48	180	28	28.4	522
11	--	--	1,222	0.8	0.59	190	41	28.4	522
12	--	--	1,337	0.9	0.52	210	34	28.4	522
13	--	--	1,432	1.1	0.54	210	38	28.5	522
14	--	--	1,527	2.8	0.64	210	80	28.5	523
REW			1,562	0.0					
Mean				2.6	0.62				
Total							2,492		
			These sites below are not on transect 4, but they are nearby.						
20X1	40°11.510	091°30.665	--	3.2	0.50	205	--	28.7	523
20X2	11.590	30.640	--	2.1	0.30	210	--	28.7	525
20X3	40°11.610	091°30.060	--	0.8	0.21	070	--	32.1	463

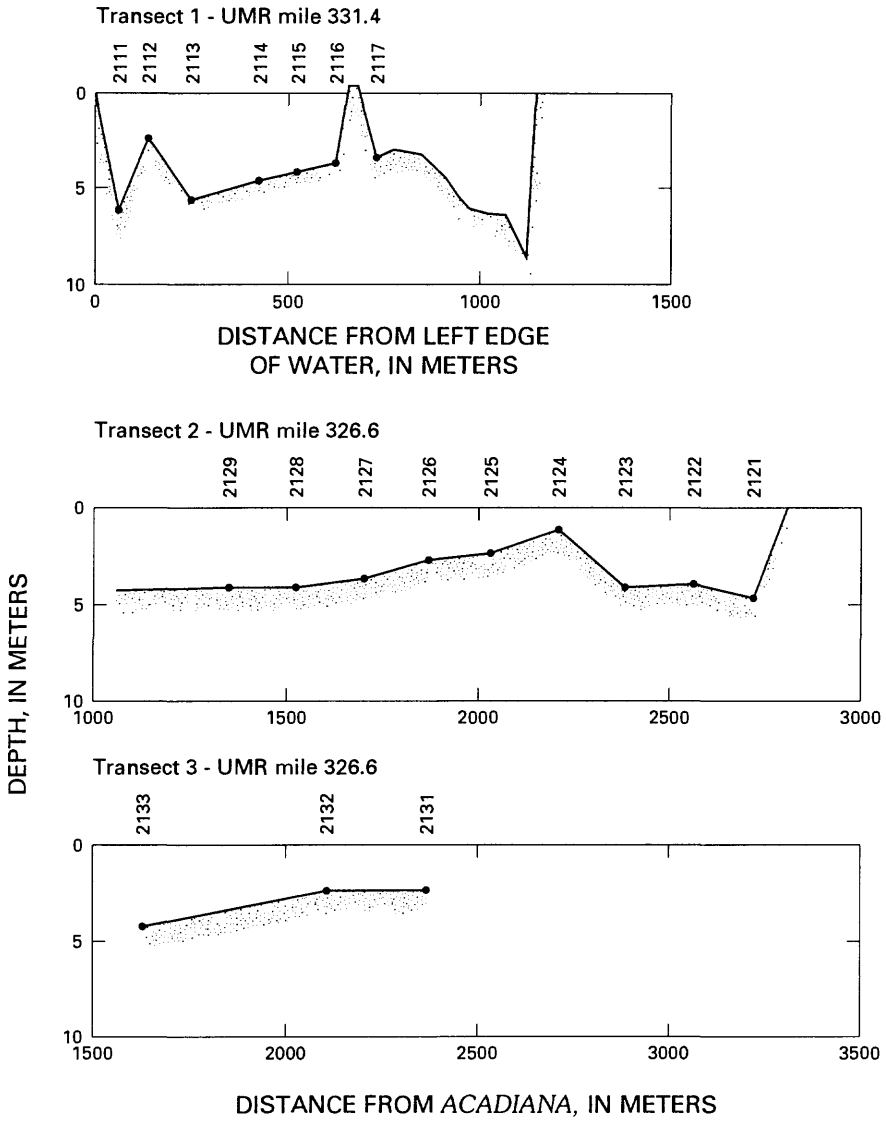
STATION: Mississippi River in Pool 20, Transect 2--UMR mile 344.2
PARTY: Moody, Meade, Roth, and Writer
DATE: July 22, 1991
GAGE HEIGHT at TW Dam 19: 483.64 ft
GAGE HEIGHT at Dam 20: 478.79 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 44 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Canton, Mo.-Ill.
REMARKS:

Acadiana anchored at UMR mile 344.7; 2,260 m from end of long guidewall of Lock 20; 1,995 m from projection of southern-most east-west street in Meyer, Illinois; 490 m from Meyer Light and Daymark at UMR mile 345.0. Velocities were measured while anchored.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 086° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
2024	40°09.435	091°30.130	20	1.2	0.18	185	11	30.0	466
2025	09.445	30.185	100	3.0	0.40	175	84	29.8	469
2026	09.445	30.220	160	4.3	0.51	205	166	29.6	471
05	--	--	280	5.4	0.76	200	291	29.5	472
04	--	--	320	5.8	0.75	200	290	29.4	473
03	--	--	430	6.3	0.78	200	609	29.2	485
02	--	--	600	6.7	0.58	190	465	29.4	516
01	--	--	680	7.5	0.45	195	281	29.3	518
2023	09.435	30.660	780	3.2	0.17	170	53	29.6	522
2022	09.430	30.725	870	0.4	0.22	180	8	29.7	526
2021	40°09.430	091°30.800	970	0.5	0.29	180	9	31.7	525
REW			1,000	0.0					
Mean				4.3	0.53				
Total							2,267		


91°28'
91°25'
39°59'
39°54'
Lone Tree Light
and Daymark
Mile 331.5
2117
2116
2115
2114
2113
2112
2111
2121
2122
2123
2124
2125
2126
2127
2128
2129
Burlington Northern
Railroad Bridge
Mile 328.0
New Quincy Bridge
Mile 327.2
Quincy Memorial Bridge
Mile 327.0
N
0
500
1000 METERS
2133
2132
2131
Lock 21 Daymark
Mile 325.5
Lock and
Dam 21
Mile 324.9


Transect 1 - UMR mile 331.4
2111
2112
2113
2114
2115
2116
2117
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE
OF WATER, IN METERS
Transect 2 - UMR mile 326.6
2129
2128
2127
2126
2125
2124
2123
2122
2121
0
5
10
1000
1500
2000
2500
3000
Transect 3 - UMR mile 326.6
2133
2132
2131
0
5
10
1500
2000
2500
3000
3500
DISTANCE FROM ACADIANA, IN METERS
DEPTH, IN METERS

STATION: Mississippi River in Pool 21, Transect 1--UMR mile 331.4
PARTY: Moody, Meade, Bishop, and Peart
DATE: April 24, 1992
GAGE HEIGHT at TW Dam 20: 480.61 ft
GAGE HEIGHT at Dam 21: 472.32 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 87.2 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Quincy West, Ill.-Mo.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 331.4; 394 m from upstream corner of mouth of Durgens Creek; 374 m from shoreline at downstream side of house about 700 m downstream from mouth of Durgens Creek.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 068° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0				--	450
2111	39°59.015	091°27.225	53	6.0	0.99	190	327	11.1	444
2112	59.005	27.285	138	2.4	0.42	200	64	11.3	444
2113	58.980	27.350	238	5.6	0.96	180	466	11.1	445
09	--	--	333	3.6	1.49	180	430	11.2	442
2114	58.950	27.465	418	4.6	1.04	190	344	11.1	442
2115	58.930	27.530	513	4.2	1.01	190	332	11.2	445
2116	58.910	27.590	613	3.7	0.87	190	180	11.2	441
Island	--	--	654	0.0	0.01	190	0	--	--
Island	--	--	687	0.0	0.01	190	0	--	--
2117	39°58.885	091°27.670	728	3.2	0.79	190	71	11.2	444
08	--	--	757	3.0	0.83	170	131	11.0	445
07	--	--	838	3.6	0.89	170	234	11.1	446
06	--	--	910	4.5	1.04	180	204	11.1	450
03	--	--	936	5.5	1.26	180	211	11.1	451
04	--	--	978	6.2	1.12	180	248	11.1	453
05	--	--	1,016	6.4	0.92	180	239	11.1	454
02	--	--	1,069	6.5	1.08	180	320	11.3	454
01	--	--	1,118	8.5	1.20	180	390	11.3	444
REW			1,155	0.0				10.9	444
Mean				4.1	0.87				
Total							4,191		

STATION: Mississippi River in Pool 21, Transect 2--UMR mile 326.6
PARTY: Moody, Meade, Bishop, and Peart
DATE: April 24, 1992
GAGE HEIGHT at TW Dam 20: 480.61 ft
GAGE HEIGHT at Dam 21: 472.32 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 87.2 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Quincy West, Ill.-Mo.
REMARKS:

Acadiana moored to wall at Quincy Soybean Co. on left bank at UMR mile 326.6; 613 m downstream from downstream side of pier of Quincy Memorial Bridge at left shoreline; 2,320 m from centerline of road bridge to Quinsippi Island; 2,798 m from Quincy shoreline at railroad bridge. Transect did not cross channel from bank to bank so no water discharge is listed below.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 168° magnetic

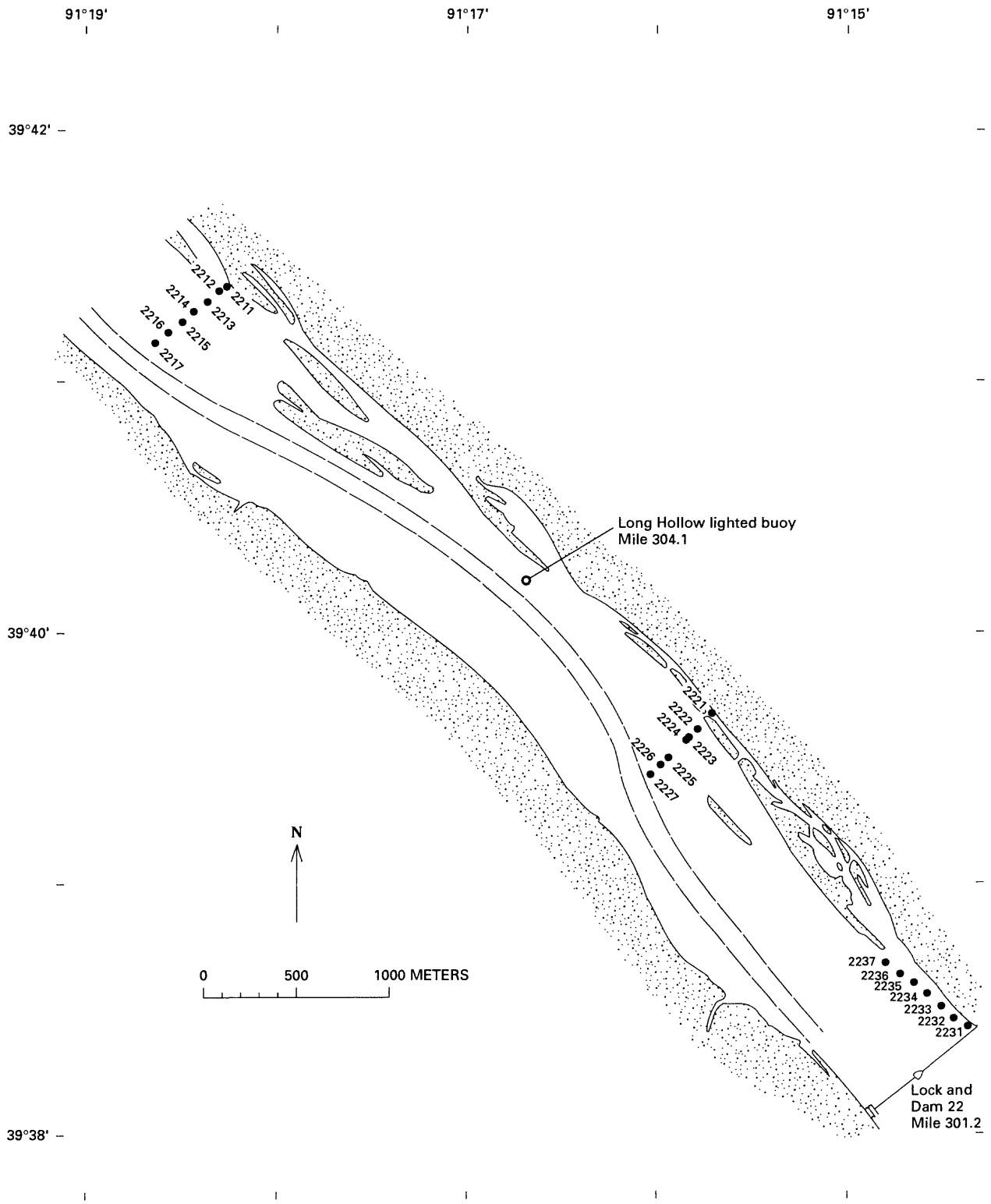
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
Acadiana			0					
2121	39°57.020	091°25.125	2,710	4.5	0.65	170	11.9	448
2122	56.935	25.120	2,550	3.7	0.69	190	11.6	448
2123	58.845	25.100	2,375	4.0	0.64	190	11.7	446
2124	56.750	25.085	2,205	1.0	0.07	170	11.8	446
2125	56.660	25.070	2,035	2.2	0.46	180	11.7	447
2126	56.575	25.055	1,865	2.6	0.56	170	11.7	447
2127	56.490	25.045	1,700	3.5	0.47	170	11.6	447
2128	56.385	25.030	1,525	3.9	0.59	180	11.6	446
2129	39°56.300	091°25.025	1,355	3.8	0.55	180	11.6	447

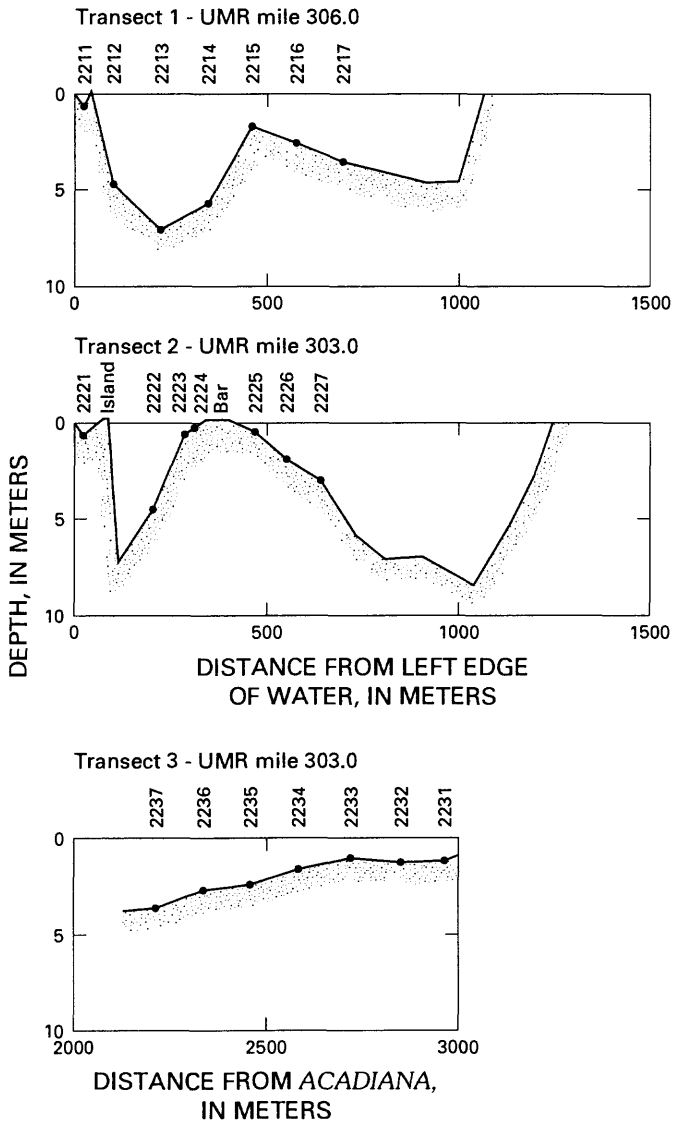
STATION: Mississippi River in Pool 21, Transect 3--UMR mile 326.6
PARTY: Moody, Meade, Bishop, and Peart
DATE: April 24, 1992
GAGE HEIGHT at TW Dam 20: 480.61 ft
GAGE HEIGHT at Dam 21: 472.32 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 87.2 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
REMARKS:

Acadiana moored to wall at Quincy Soybean Co. on left bank at UMR mile 326.6; 613 m downstream from downstream side of pier of Quincy Memorial Bridge at left shoreline; 2,320 m from centerline of road bridge to Quinsippi Island; 2,798 m from Quincy shoreline at railroad bridge. This was only a short transect parallel to shore crossing, the only off-channel area near Dam 21--no water discharge is listed below.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 034° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
Acadiana			0	0.0				
2131	39°54.585	091°25.925	2,360	2.3	0.69	220	11.7	452
2132	54.675	25.820	2,110	2.1	0.50	230	11.7	448
2133	39°54.885	091°25.575	1,620	4.2	1.12	220	11.5	457


91°19'
91°17'
91°15'
39°42'
39°40'
39°38'
2212
2211
2214
2213
2216
2215
2217
Long Hollow lighted buoy
Mile 304.1
2221
2222
2224
2223
2226
2225
2227
N
0
500
1000 METERS
2237
2236
2235
2234
2233
2232
2231
Lock and
Dam 22
Mile 301.2


Transect 1 - UMR mile 306.0
2211
2212
2213
2214
2215
2216
2217
0
5
10
0
500
1000
1500
Transect 2 - UMR mile 303.0
2221
Island
2222
2223
2224
Bar
2225
2226
2227
0
5
10
0
500
1000
1500
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE
OF WATER, IN METERS
Transect 3 - UMR mile 303.0
2237
2236
2235
2234
2233
2232
2231
0
5
10
2000
2500
3000
DISTANCE FROM *ACADIANA*,
IN METERS

STATION: Mississippi River in Pool 22, Transect 1--UMR mile 306.0
PARTY: Moody, Meade, Roth, and Writer
DATE: July 23, 1991
GAGE HEIGHT at TW Dam 21: 465.15 ft
GAGE HEIGHT at Dam 22: 459.56 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 44×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Hannibal East, Mo.-Ill.
REMARKS:

Acadiana anchored 380 m from Continental Cement silo; 380 m from mouth of creek that drains gully with LeBaume Cave. Velocities were measured while anchored.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 048° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
2211	39°41.350	091°18.200	15	0.4	0.04	150	0	26.9	455
Land	--	--	35	0.0	0.01	150	0	--	--
2212	41.330	18.235	95	4.7	0.35	130	150	28.0	474
2213	41.290	18.300	215	7.0	0.56	150	465	28.7	479
2214	41.255	18.365	340	5.5	0.54	150	350	28.7	486
2215	41.215	18.425	460	1.4	0.49	150	77	28.8	489
2216	41.170	18.490	575	2.4	0.56	150	151	28.7	491
2217	39°41.130	091°18.560	695	3.5	0.61	150	212	28.8	493
01	--	--	780	3.7	0.74	150	204	28.7	497
02	--	--	850	4.3	0.72	150	209	28.7	503
03	--	--	920	4.7	0.79	150	277	28.7	505
04	--	--	1,005	4.5	0.81	150	264	28.7	505
REW			1,070	0.0					
Mean				3.8	0.58				
Total							2,359		

STATION: Mississippi River in Pool 22, Transect 2--UMR mile 303.0
PARTY: Moody, Meade, Roth, and Writer
DATE: July 23, 1991
GAGE HEIGHT at TW Dam 21: 465.15 ft
GAGE HEIGHT at Dam 22: 459.56 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 44 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Hannibal East, Mo.-Ill.
REMARKS:

Acadiana anchored 2,835 m upstream from northwest tip of wall between main and auxiliary locks at Dam 22; 390 m off tip of land on upstream side of mouth of creek at north end of Saverton, Missouri. Velocities were measured while anchored.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 041° magnetic

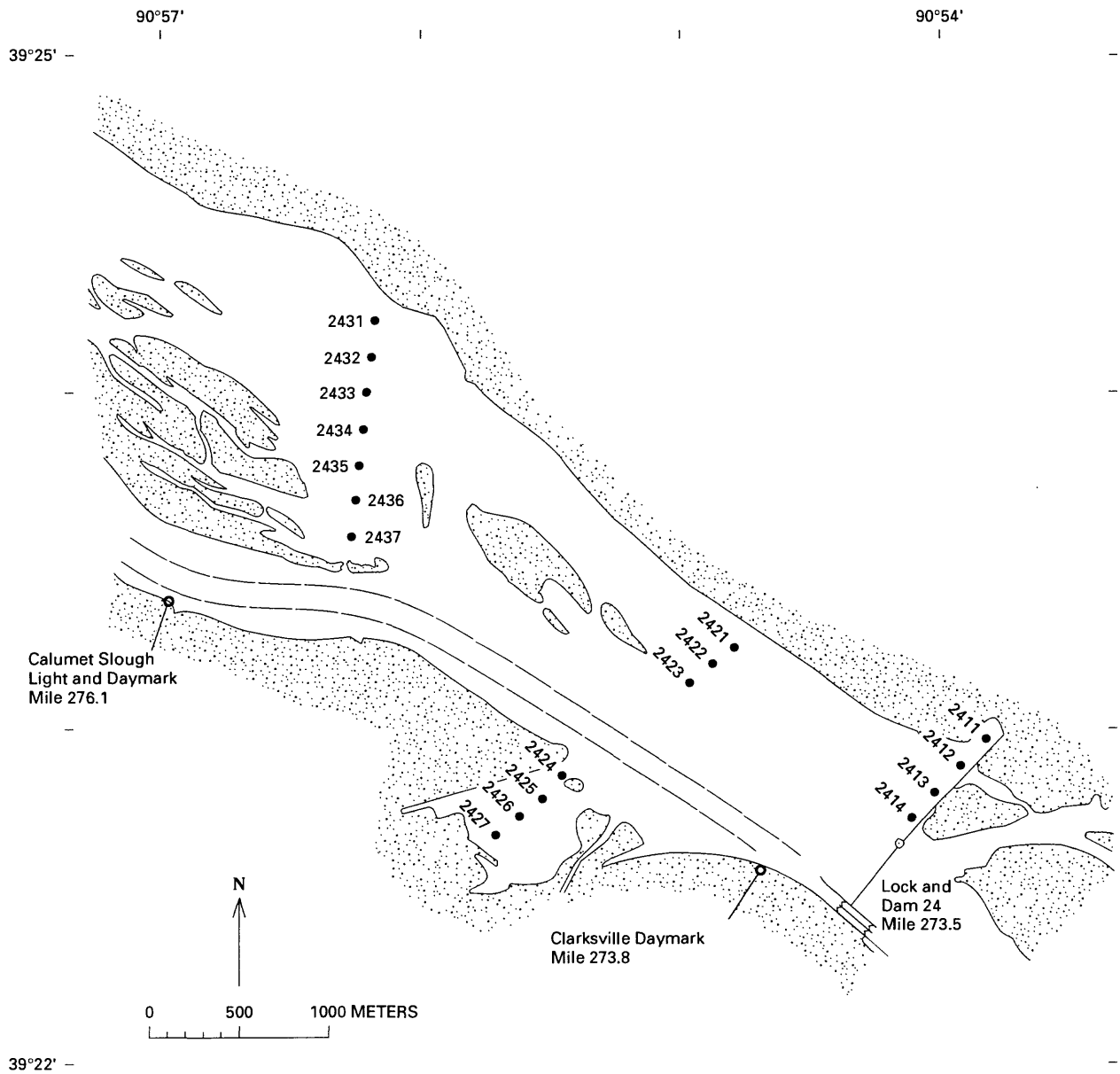
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
2221	39°39.710	091°15.740	15	0.5	0.18	150	3	30.7	471
Island	--	--	80	0.0	0.01	150	0	--	--
01	--	--	120	7.3	0.64	150	258	29.5	474
2222	39.640	15.830	200	4.5	0.47	150	154	29.5	476
2223	39.605	15.870	280	0.4	0.05	150	1	30.3	470
2224	39.590	15.885	300	0.2	0.01	150	0	30.7	468
Bar	--	--	360	0.0	0.01	150	0	--	--
2225	39.530	15.965	470	0.2	0.04	150	1	31.2	471
2226	39.510	16.010	550	1.7	0.14	60	8	30.5	470
2227	39°39.470	091°16.050	640	3.7	0.44	100	129	29.8	479
02	--	--	730	5.6	0.60	140	264	29.7	481
03	--	--	800	6.8	0.69	140	436	29.5	487
04	--	--	920	6.7	0.86	150	667	29.3	493
05	--	--	1,050	8.1	0.83	150	526	29.2	505
06	--	--	1,090	2.6	0.78	150	75	29.2	505
REW			1,130	0.0					
Mean				3.6	0.62				
Total							2,522		

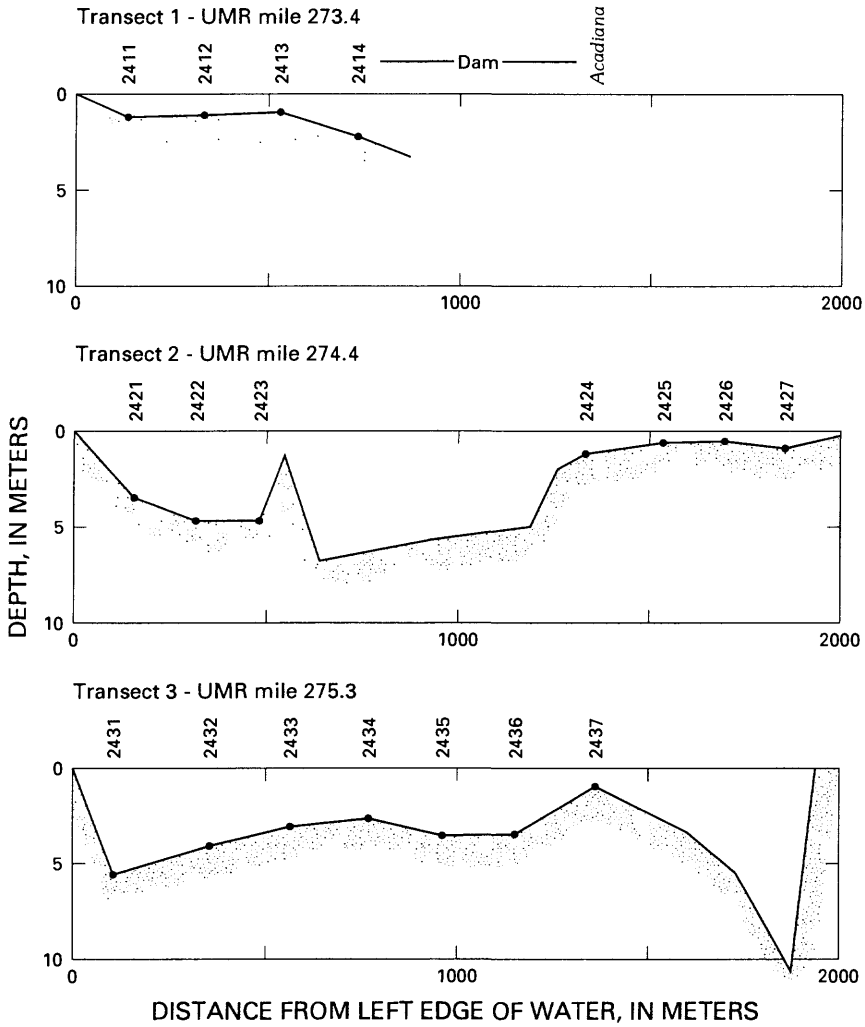
STATION: Mississippi River in Pool 22, Transect 3--UMR mile 303.0
PARTY: Moody, Meade, Roth, and Writer
DATE: July 23, 1991
GAGE HEIGHT at TW Dam 21: 465.15 ft
GAGE HEIGHT at Dam 22: 459.56 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 44×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Hull, Ill.-Mo.
REMARKS:

Acadiana anchored 2,835 m upstream from northwest tip of wall between main and auxiliary locks at Dam 22; 390 m off tip of land on upstream side of mouth of creek at north end of Saverton, Missouri. Velocities were measured while anchored. Transect was from *Acadiana's* anchorage to northeast corner of earth-filled section of Dam 22. Discharge was not calculated because the transect ended in midriver.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 126° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
2231	39°38.500	091°14.455	2,965	1.1	0.00	--	30.6	467
2232	38.530	14.515	2,850	1.3	0.06	060	31.4	465
2233	38.570	14.585	2,720	1.2	0.12	140	30.6	464
2234	38.615	14.655	2,585	1.5	0.13	110	30.3	468
2235	38.660	14.725	2,465	2.2	0.30	110	30.4	469
2236	38.700	14.795	2,340	2.6	0.49	110	29.9	474
2237	39°38.740	091°14.865	2,215	3.2	0.53	130	29.9	473


90°57'
90°54'
39°25'
39°22'
2431
2432
2433
2434
2435
2436
2437
2421
2422
2423
2424
2425
2426
2427
2411
2412
2413
2414
Calumet Slough
Light and Daymark
Mile 276.1
Clarksville Daymark
Mile 273.8
Lock and
Dam 24
Mile 273.5
N
0
500
1000 METERS


Transect 1 - UMR mile 273.4
2411
2412
2413
2414
Dam
Acadiana
0
5
10
0
1000
2000
Transect 2 - UMR mile 274.4
2421
2422
2423
2424
2425
2426
2427
0
5
10
0
1000
2000
Transect 3 - UMR mile 275.3
2431
2432
2433
2434
2435
2436
2437
0
5
10
0
1000
2000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 24, Transect 1--UMR mile 273.4
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: October 29, 1991
GAGE HEIGHT at TW Dam 22: 451.54 ft
GAGE HEIGHT at Dam 24: 449.04 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 16.9×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Pleasant Hill, Ill.-Mo.
REMARKS:

Acadiana moored to inside of river wall of auxiliary Lock 24; 50 m upstream from top of rock dam across auxiliary lock.

Estimated discharge through Dam 24 was 1,630 m^3/s. No velocity measurements were made across the gates in the dam.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 045° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
2411	39°22.965	090 53.825	129	1.2	0.05	360	-6	16.2	446
2412	22.890	53.920	329	1.0	0.04	310	-8	15.8	449
2413	22.805	54.025	524	0.9	0.05	90	7	15.9	448
2414	39 22.735	090 54.110	729	2.2	0.04	240	-11	15.8	449
Acadiana			1,329	0.0					
Mean				1.1	-0.01				
Total							-18		

STATION: Mississippi River in Pool 24, Transect 2--UMR mile 274.4
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: October 29, 1991
GAGE HEIGHT at TW Dam 22: 451.54 ft
GAGE HEIGHT at Dam 24: 449.04 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 16.9 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Pleasant Hill West, Ill.-Mo.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 274.4; 2,710 m from Calumet Slough Light (UMR mile 276.1); 2,270 m from Pharrs Island Lower Light (UMR mile 275.5); 1,310 m from upstream tip of river wall at Lock 24; 630 m from tip of land at upstream side of entrance to Roblee Harbor. Estimated discharge through Dam 24 was 1,630 m^3/s. Site 2425 and 2426 were in a lily-pad field.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 053° magnetic

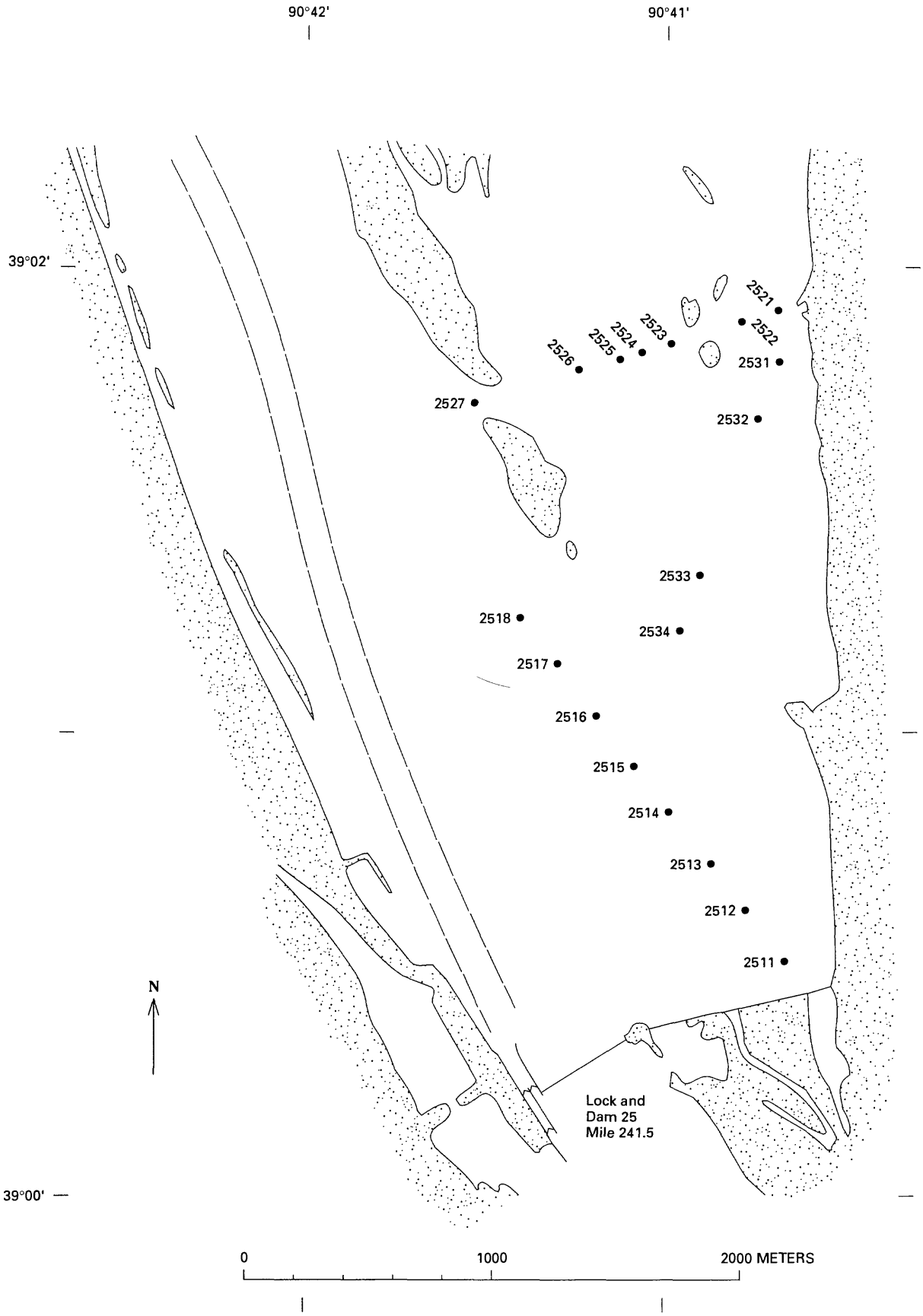
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
2421	39°23.240	090°54.795	159	3.5	0.25	150	134	15.3	457
2422	23.185	54.880	314	4.6	0.27	110	170	15.0	457
2423	23.130	54.970	474	4.5	0.24	120	123	15.5	458
01	--	--	554	1.3	0.08	160	7	15.2	458
02	--	--	629	6.5	0.12	120	66	15.7	457
03	--	--	734	6.5	0.32	120	297	15.3	459
04	--	--	934	5.7	0.37	140	480	15.2	461
05	--	--	1,184	5.0	0.27	130	213	15.2	460
06	--	--	1,254	2.0	0.07	150	9	16.0	458
2424	22.845	55.445	1,324	1.1	0.04	60	1	16.1	450
2425	22.790	55.540	1,519	0.6	0.01	0	-1	16.9	448
2426	22.735	55.630	1,689	0.6	0.01	0	-1	17.0	444
2427	39°22.680	090°55.720	1,849	0.8	0.03	30	-1	17.4	453
REW			2,029	0.0					
Mean				3.1	0.24				
Total							1,497		

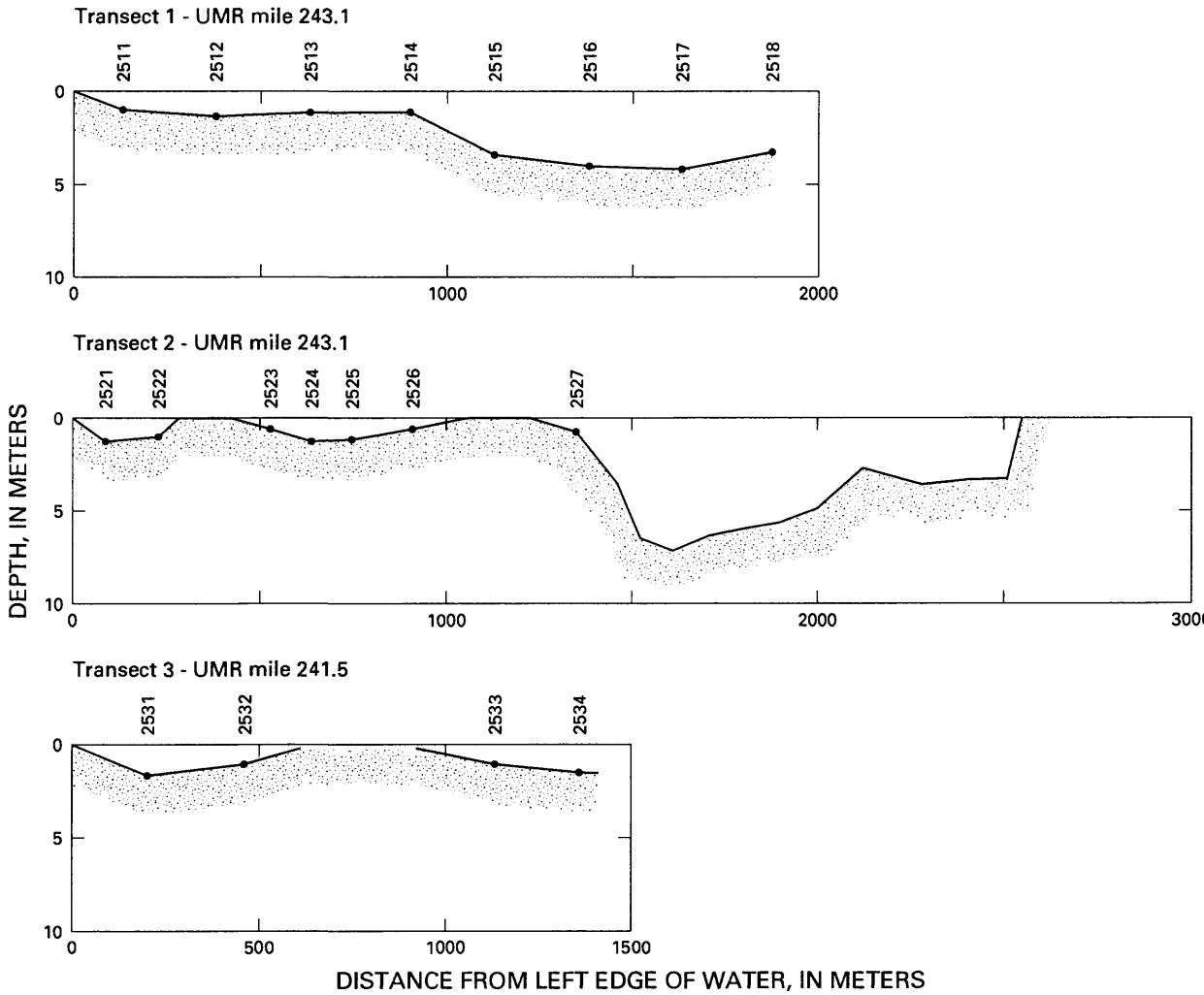
STATION: Mississippi River in Pool 24, Transect 3--UMR mile 275.3
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: October 29, 1991
GAGE HEIGHT at TW Dam 22: 451.54 ft
GAGE HEIGHT at Dam 24: 449.04 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 16.9×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Pleasant Hill West, Ill.-Mo.
REMARKS:

Acadiana anchored on red buoy line at UMR mile 275.3; 975 m from center of mouth of O'Neil Creek on right bank; 1,545 m from tip of land at upstream side of entrance to Roblee Harbor. Estimated discharge through Dam 24 was 1,630 m^3/s.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 007° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temperature (°C)	Specific conductance (µS/cm)
LEW			0	0.0					
2431	39°24.210	090°56.180	100	5.8	0.23	140	160	15.9	456
2432	24.100	56.195	355	4.0	0.26	160	92	15.0	458
2433	24.000	56.210	560	3.0	0.24	130	117	15.9	459
2434	23.890	56.230	760	2.8	0.27	150	81	15.6	460
2435	23.780	56.250	960	3.5	0.23	160	61	15.4	460
2436	23.680	56.260	1,150	3.5	0.24	160	66	15.7	460
2437	39°23.570	090°56.280	1,355	0.8	0.09	140	11	16.1	460
01	--	--	1,600	3.3	0.25	110	147	16.1	463
02	--	--	1,725	5.6	0.28	110	200	16.0	460
03	--	--	1,865	10.5	0.38	120	367	16.0	461
REW			1,930	0.0					
Mean				3.7	0.18				
Total							1,302		


90°42'
90°41'
39°02'
39°00'
2521
2522
2523
2524
2525
2526
2531
2527
2532
2533
2518
2534
2517
2516
2515
2514
2513
2512
2511
N
Lock and
Dam 25
Mile 241.5
0
1000
2000 METERS


Transect 1 - UMR mile 243.1
2511
2512
2513
2514
2515
2516
2517
2518
0
5
10
0
1000
2000
Transect 2 - UMR mile 243.1
2521
2522
2523
2524
2525
2526
2527
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
Transect 3 - UMR mile 241.5
2531
2532
2533
2534
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 25, Transect 1--UMR mile 243.1
PARTY: Moody, Meade, Bishop, and Peart
DATE: April 25, 1992
GAGE HEIGHT at Pool Dam 24: 446.27 ft
GAGE HEIGHT at Dam 25: 432.24 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 83.0 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Foley, Mo.-Ill.
REMARKS:

Acadiana anchored near red buoy line at UMR mile 243.1; 1,823 m from downstream tip of prominent stone breakwater on left bank at UMR mile 242.05; 2,802 m from point (92 m from intersection of dam and Illinois shoreline) on low sill part of Dam 25; 1,720 m from tip of peninsula on Illinois shoreline 500 m downstream from Wilson Cemetery. This transect did not cross from bank to bank, so no discharges are listed below.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 139° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0				
2511	39°00.510	090°40.660	132	0.7	0.13	190	11.3	438
2512	00.620	40.770	382	1.1	0.48	200	11.2	433
2513	00.720	40.870	627	1.0	0.46	190	11.4	438
2514	00.840	40.990	897	0.9	0.76	180	11.4	441
2515	00.930	41.090	1,122	3.3	0.88	180	11.5	440
2516	01.040	41.200	1,372	3.9	1.00	170	11.2	448
2517	01.155	41.305	1,627	4.0	0.85	170	11.3	441
2518	39°01.255	090°41.405	1,872	3.2	0.94	170	11.3	441

STATION: Mississippi River in Pool 25, Transect 2--UMR mile 243.1
PARTY: Moody, Meade, Bishop, and Peart
DATE: April 25, 1992
GAGE HEIGHT at TW Dam 24: 446.27 ft
GAGE HEIGHT at Dam 25: 432.24 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 83.0 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Foley, Mo.-Ill.
REMARKS:

Acadiana anchored near red buoy line at UMR mile 243.1; 1,823 m from downstream tip of prominent stone breakwater on left bank at UMR mile 242.05; 2,802 m from point (92 m from intersection of dam and Illinois shoreline) on low sill part of Dam 25; 1,720 m from tip of peninsula on Illinois shoreline 500 m downstream from Wilson Cemetery.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 071° magnetic

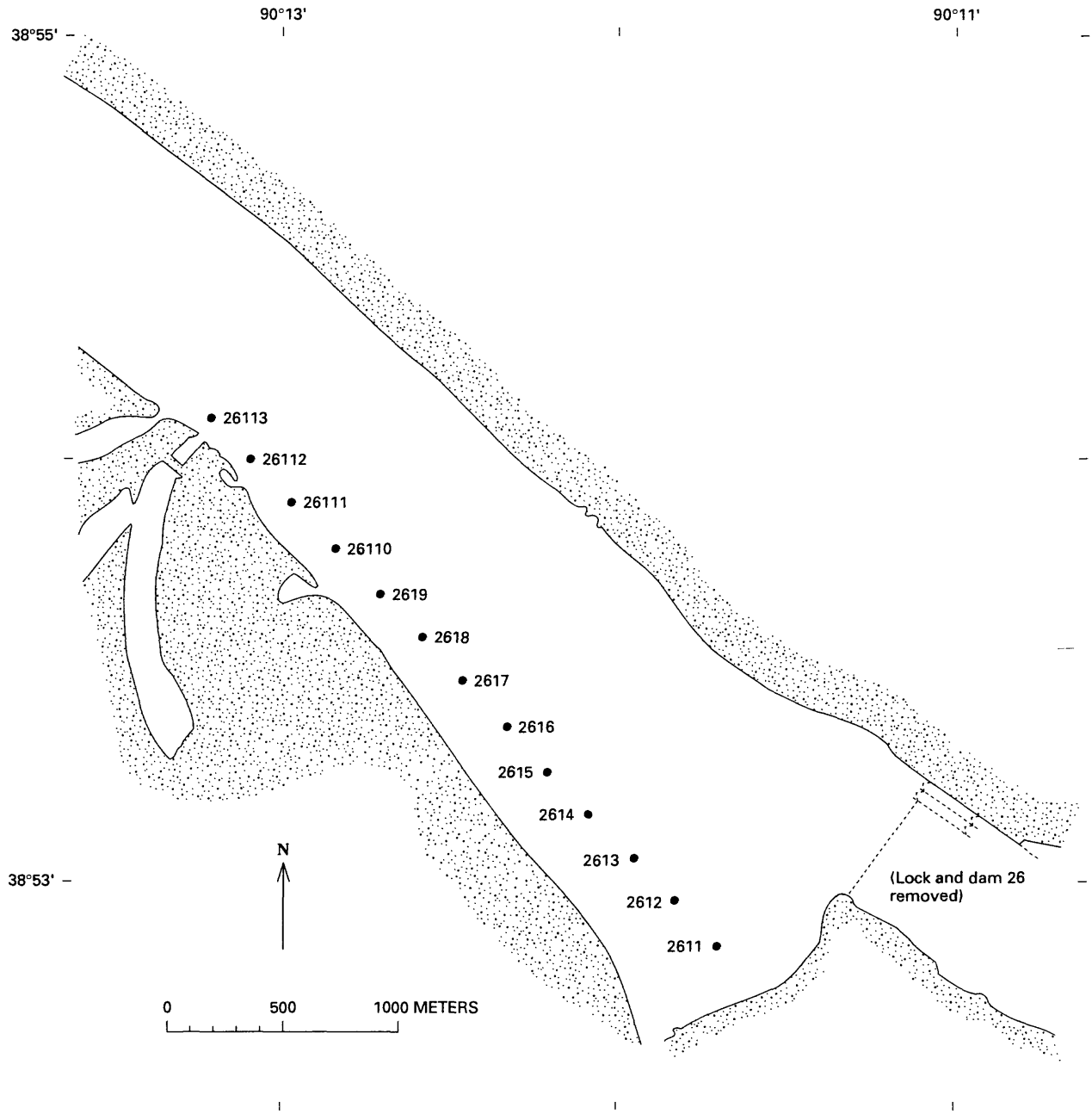
Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0					
2521	39°01.915	090°40.705	75	1.2	0.44	180	54	11.7	443
2522	01.890	40.805	220	0.8	0.37	170	28	11.7	400
Island	--	--	270	0.0	0.01	0	0	--	--
Island	--	--	420	0.0	0.01	0	0	--	--
2523	01.845	41.000	515	0.4	0.20	170	8	12.0	435
2524	01.830	41.080	630	1.0	0.09	90	4	11.3	439
2525	01.815	41.145	735	1.0	0.07	90	4	11.0	443
2526	01.785	41.225	900	0.4	0.20	120	10	10.8	440
Island	--	--	1,050	0.0	0.01	0	0	--	--
Island	--	--	1,220	0.0	0.01	0	0	--	--
2527	39°01.715	090°41.545	1,355	0.4	0.29	150	13	10.7	441
01	--	--	1,455	3.5	0.62	150	178	11.4	439
02	--	--	1,520	6.6	1.14	170	552	11.3	441
03	--	--	1,605	7.1	1.09	170	744	11.3	441
04	--	--	1,717	6.1	1.12	170	683	11.2	438
05	--	--	1,810	6.0	1.15	170	569	11.1	435
06	--	--	1,885	5.8	1.10	160	637	11.0	435
07	--	--	2,010	4.6	1.02	170	530	11.1	432
08	--	--	2,115	2.6	0.99	170	335	11.1	430
09	--	--	2,275	3.4	0.83	170	540	11.0	425
10	--	--	2,505	3.3	0.79	170	344	11.0	423
REW			2,545	0.0					
Mean				2.3	0.90				
Total							5,233		

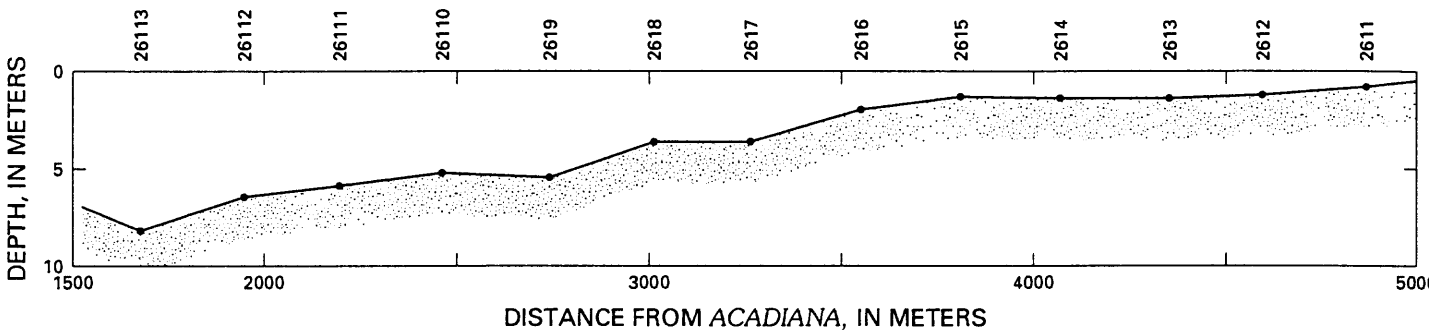
STATION: Mississippi River in Pool 25, Transect 3--UMR mile 241.5
PARTY: Moody, Meade, Bishop, and Peart
DATE: April 25, 1992
GAGE HEIGHT at TW Dam 24: 446.27 ft
GAGE HEIGHT at Dam 25: 432.24 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 83.0 x 10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
REMARKS:

Acadiana moored to inner side of wingwall on upper end of Lock 25, 20 m downstream from prominent bend in wall; 3,198 m from tip of peninsula on Illinois shoreline, 500 m downriver from Wilson Cemetery. This transect did not cross from bank to bank, so no discharges are listed below.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 139° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
LEW			0	0.0				
2531	39°01.810	090°40.705	205	1.4	0.40	180	10.5	433
2532	01.680	40.760	458	0.9	0.38	170	11.4	440
2533	01.340	40.915	1,124	0.9	0.12	180	11.7	436
2534	39°01.220	090°40.965	1,366	1.2	0.10	140	11.2	443


90°13'
90°11'
38°55'
38°53'
26113
26112
26111
26110
2619
2618
2617
2616
2615
2614
2613
2612
2611
N
0
500
1000 METERS
(Lock and dam 26
removed)


26113
26112
26111
26110
2619
2618
2617
2616
2615
2614
2613
2612
2611
DEPTH, IN METERS
0
5
10
1500
2000
3000
4000
5000
DISTANCE FROM *ACADIANA*, IN METERS

STATION: Mississippi River in Pool 26, Transect 1--UMR mile 206.1
PARTY: Moody, Meade, Garbarino, and Noyes
DATE: November 1, 1991
GAGE HEIGHT at TW Dam 25: 422.39 ft
GAGE HEIGHT at Mel Price Dam: 419.1 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 15.6×10^{-6}
CURRENT METER No: 90-JM-1
DATE RATED: 06-91
MAP: USGS 7.5-minute quadrangle is Alton, Ill.-Mo.
REMARKS:

Acadiana anchored to right of green buoy line at UMR mile 206.1; 2,310 m from end of downriver-pointing dike enclosing boat harbor at Clifton Terrace; 540 m from culvert below bluff where Oblate Fathers Novitiate sits: 530 m from culvert on left bank about 400 m downstream from first culvert. All 13 sites were along the right bank and may represent a bias sample that excludes Illinois River sediment.

Collection of samples was stopped due to high winds and cold temperatures. A separate Illinois River bed-sediment sample was collected 40 m from LEW at Illinois River mile 21.8 on October 31, 1991.

CURRENT METER EQUATION: V(m/s) = 0.667*rev/s + 0.006
BEARING OF TRANSECT: 137° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Distance (m)	Depth (m)	Mean velocity (m/s)	Direction (°magnetic)	Discharge (m^3/s)	Temp-erature (°C)	Specific conduc-tance (µS/cm)
Acadiana			0						
2611	38°52.850	090°11.695	4,865	0.7				12.4	436
2612	52.950	11.820	4,590	1.2				12.3	452
2613	53.050	11.940	4,340	1.4				12.5	450
2614	53.160	12.080	4,060	1.3				12.3	449
2615	53.265	12.200	3,800	1.2				12.4	454
2616	53.365	12.325	3,540	1.9				12.3	451
2617	53.475	12.460	3,260	3.5				11.6	450
2618	53.585	12.580	3,010	3.4				12.1	456
2619	53.680	12.710	2,730	5.2				12.0	457
26110	53.785	12.840	2,460	5.0				12.2	456
26111	53.900	12.975	2,180	5.8				11.6	452
26112	53.995	13.085	1,940	6.5				11.7	452
26113	38°54.095	090°13.215	1,665	8.1				no reading	448

No velocity measurements were made because this transect was parallel to the main channel.

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