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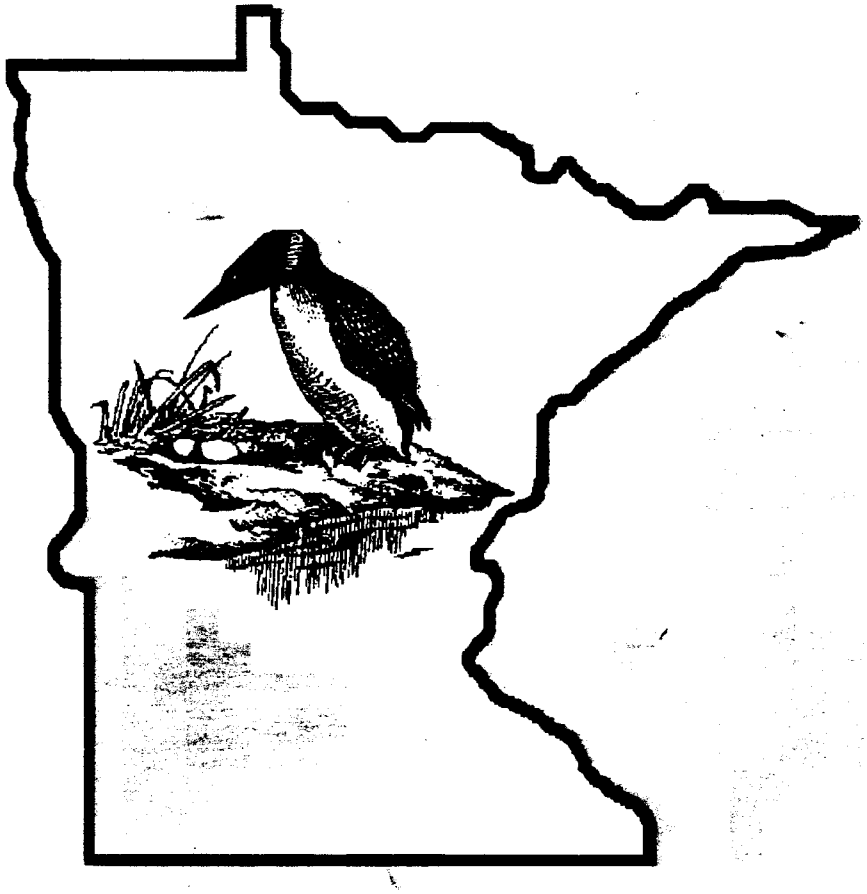
POTENTIAL TOXICITIES OF SEDIMENTS AT POINT SOURCE DISCHARGE SITES ALONG THE UPPER MISSISSIPPI NATIONAL WILDLIFE AND FISH REFUGE



TWIN CITIES

by

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March 1996

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POTENTIAL TOXICITIES OF SEDIMENTS AT POINT SOURCE DISCHARGE SITES ALONG THE UPPER MISSISSIPPI RIVER NATIONAL WILDLIFE AND FISH REFUGE

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ABSTRACT

Thirty-one sediment samples collected in the vicinity of twenty regulated discharge points within Pools 4 through 10 of the Upper Mississippi River National Wildlife and Fish Refuge (UMRNW&FR) were analyzed for certain metals, organochlorine pesticides (OCs), total polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). A sediment pore-water bioassay (Microtox) was also conducted to provide an integrated assessment of the potential toxicity of sediments. Point source discharge sites on the UMRNW&FR that may be of biological concern were ranked based on the results of these analyses and published sediment quality guidelines.

Bioassay results and quality guidance criteria indicated that concentrations of some metals and/or PAHs in sediments from several regulated discharge points on the Upper Mississippi River (UMR) were of biological concern. Sites of potential sediment toxicity to biota included wastewater treatment facilities (WTF) in Wabasha (MN), Winona (MN), Stoddard (WI), LaCrescent (MN), and Prairie du Chien (WI), an industrial complex in LaCrosse (WI), and a power utility in Genoa (WI). Concentrations of OCs and PCBs in samples were below levels of biological concern at these sites.

Recommended reductions of contaminant inputs to the UMR should improve environmental quality within certain portions of the UMRNW&FR.

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POTENTIAL TOXICITY OF SEDIMENTS AT POINT SOURCE DISCHARGE SITES ALONG THE UPPER MISSISSIPPI RIVER NATIONAL WILDLIFE AND FISH REFUGE

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INTRODUCTION

The Upper Mississippi River (UMR) is an intensively managed and regulated lotic ecosystem with a wide range of habitats that are utilized by many species of fish and wildlife. As immense and biologically rich as this river ecosystem is, however, continued human development-related activities threaten its ecological integrity. Despite the large-size of this biologically diverse river ecosystem, the ecological integrity of the UMR is continuously threatened by habitat degradation as anthropogenic developments encroach upon it. Among the major problems threatening its aquatic resources are upland erosion, sedimentation of backwater habitats, point and non-point source pollution, navigation-related activities, and channel maintenance practices.

Toxic organic and inorganic contaminants in this system are frequently associated with suspended particulates and fine-grained bed sediments. Since most chemicals of anthropogenic origin (e.g., pesticides, polycyclic aromatic hydrocarbons (PAHs), and chlorinated hydrocarbons) tend to sorb to silty sediments and organic particulates, they typically are most concentrated in this type of sediment. In addition, both naturally occurring and anthropogenic trace metals generally behave similarly, resulting in their deposition in riverine bottom sediments. Sediment contamination can have numerous detrimental effects on an ecosystem, some of which are more evident than others. For example, pollution-sensitive benthic invertebrates may be eliminated and benthic community structure altered in favor of pollution-tolerant species. This may in turn affect other ecosystem components. Moreover, the concentration of certain sediment-associated contaminants (e.g., polychlorinated biphenyls, pesticides) accumulated by bottom-feeding fish and benthic invertebrates can be biomagnified in predatory wildlife near the top of the river food chain (e.g., mink, eagles, osprey, falcons). The elevated chemical residue levels may in turn reduce or prohibit successful reproduction among these sensitive species.

The Upper Mississippi River National Wildlife and Fish Refuge (UMRNW&FR) was established in 1924 to provide a refuge and breeding place for migratory birds, resident

fishes, game animals, fur-bearing animals, wildflowers, aquatic plants and other aquatic life. More than 20 percent of the ducks in North America use the UMRNW&FR for feeding and resting during migration. In addition, the UMRNW&FR provides essential habitat for species such as the bald eagle, canvasback duck, and Higgins' eye pearly mussel. During the period since its inception, the UMRNW&FR and its resources have been exposed to chronic and acute contamination arising from releases of point-source industrial and municipal wastewater, non-point urban and agricultural runoff, contaminated groundwater, and spills of petroleum products and other hazardous material. Some of these contaminants have had overt adverse impacts on UMRNW&FR resources while others may have had similar but as of yet unrecognized consequences.

Results of a 1985 survey of contaminants in riverine backwater sediments, carp (*Cyprinus carpio*) and bluegill (*Lepomis macrochirus*) in Pools 4-14 (river miles 504-758) of the UMR indicated that surficial (recently deposited) sediments in off-shore areas and isolated backwaters generally contained low contaminant concentrations (Mahaffy et al. 1991). A few sediment samples collected nearby known or suspected point-source discharges did contain substantially elevated concentrations of certain metals, PCBs, or PAHs. However, this survey was not designed to evaluate contaminant concentrations of sediments near the many point-source discharges (e.g., urban stormwater, municipal wastewater, industrial effluents) entering the Refuge waters.

Several medium-sized cities and numerous smaller communities border Pools 4-10 of the UMR. Most of these municipalities discharge stormwater runoff, treated wastewater and National Pollution Discharge Elimination System (NPDES) permitted industrial effluents to the river where it is presumed the assimilative capacity of the river water will rapidly neutralize or dilute any residual toxicity associated with these discharges. Few industrial dischargers have been required to perform toxicity tests on their effluent and there has been essentially no toxicity testing of other discharges to the river. In addition to the potential acute toxicity of some of these effluents to sensitive organisms within the discharge mixing zone, there is the potentially chronic problem of toxic substances in these effluents adsorbing onto bottom sediments near the points of discharge to the river. Toxic responses of benthic invertebrates to contaminated sediments are mediated to a great extent by the cumulative solubility of the contaminants in porewater (water that occupies the interstitial spaces between sediment particles).

Based on concerns expressed by the UMRNW&FR and Twin Cities Ecological Services Field Office (TCFO) staff, we conducted an investigation to determine the potential toxicities and contaminant concentrations of near-shore surficial sediments within and upstream of the mixing zone of selected point-source discharges to the UMR. Our objectives were to: (1) obtain baseline chemical and toxicological data on sediments within the mixing zone of point-source discharges to the UMR by instrumental analyses and bacterial bioassays; (2) identify potentially toxic contaminants that may adversely affect resident biota in the stretches of river studied; (3) assess the relationship between the point source contaminants we identified to findings of other studies; and (4) provide recommendations to eliminate contaminant inputs

where warranted.

This project was supported through the U.S. Fish and Wildlife Service's (USFWS) On-Refuge Environmental Contaminants Investigations process during fiscal years 1992 and 1994. We thank Dave Warburton (USFWS-TCFO), Carol Damberg (USFWS-UMRNW&FR, Winona District), John Sullivan (Wisconsin Department of Natural Resources), and Mark Steingraeber (USFWS-Fisheries) for their reviews of earlier drafts of this report. We also thank Lara Hill (USFWS-UMRNW&FR, LaCrosse District) who produced the maps for the report.

STUDY AREA DESCRIPTION

Extending over 260 river miles from Wabasha, Minnesota, to near Rock Island, Illinois, the UMRNW&FR encompasses approximately 200,000 acres of intricately networked wetlands, backwaters, side channels, and bottomland hardwoods providing essential habitat for a wide variety of plants, fish, migratory birds, and other animals. The study area encompassed the upper 125 river miles of the UMRNW&FR between Pools 4 and 10 (river mile 633-758; Figures 1-8). A more detailed description of the Upper Mississippi River is given by Fremling and Claflin (1984).

METHODS AND MATERIALS

Preparation and Field Collection

Copies of all current NPDES permits for discharges via pipe or ditch to the UMR or its backwaters within the reach encompassed by Pools 4 through 10 (inclusive, and to the lower one mile of tributaries to the UMR within that reach) were obtained from the appropriate state agencies (Iowa, Minnesota, Wisconsin) in early 1992. The states were also asked to supply the following additional information: (1) water quality monitoring reports or other water quality data used to establish effluent limits on those permits; (2) location information for the permitted outfalls in question; and (3) any available location and contaminant-related information the state might have concerning stormwater outfalls and other unregulated discharge outfalls to the river reach in question. We reviewed the histories of each regulated discharge to determine whether effluent characteristics or permit conditions had changed substantially in recent years. UMRNW&FR District Managers and other local river resource personnel were also queried regarding known toxic material spills or other non-regulated discharges. This information database was reviewed in its entirety to develop a ranking of discharge points with the greatest probability of discovering toxic impacts and loading to the UMR. Twenty regulated discharge points were finally chosen for sampling based on the above criteria.

In July, 1992, 31 sediment grab samples were obtained by Ekman dredge from near-shore

zones downstream and upstream (where possible) of 20 regulated discharge points and at all significant stormwater outfalls between Pools 4 and 10 of the UMR (river miles 633 to 758; Table 1, Figures 1-8). Sample site coordinates (latitude, longitude) were located with a LORAN-C receiver ($\pm$ 0.02-0.04 minutes). Methods of sediment collection, compositing, homogenation, and storage closely followed those of Chapman (1988).

Stemmer et al. (1990) showed that sediment-associated toxicity can vary greatly (e.g., cladoceran mortality ranging from 0-100%) in samples collected just centimeters apart, despite equivalent particle size distributions and water contents. One approach to minimize this spatial variation when evaluating sediment quality is to prepare a composite sample from several individual grab samples collected near one another. The sediment samples that we evaluated were a composite of five or more such grabs samples collected with an Eckman dredge from nearby locations at each site. In order to ensure that only recently deposited sediments were sampled, attempts were made to collect the uppermost 3-6 cm of sediment. Each composite sample was prepared in the field by homogenation in a stainless steel bowl and split among four 500-ml glass jars (chemically cleaned) that were filled completely (i.e., to exclude air). Samples were chilled on ice until returned to the Field Office laboratory. Two of the sample containers from each site were frozen for chemical analysis at a later time while the remaining samples were held at about 4° C prior to pore water extraction for Microtox testing.

Pore Water Preparation

Pore water was extracted from the bulk sediment samples within two weeks of the collection date and used to assess the potential toxicity at each discharge site. Pore water is believed to be a primary route of contaminant exposure for many benthic invertebrates that inhabit polluted sediments. The potential toxicity of this aqueous fraction is also easier to evaluate than that of bulk sediments of many toxicity assays since test organisms responses are readily observed. Pore water was extracted by centrifugation of 250-g bulk sediment subsamples at 10,000 RPM for up to two hours. This procedure eliminated the need to filter the supernatant (Mary Henry, pers. comm.), a step that may result in the loss of potentially toxic contaminants (Salomons et al. 1987, Winger and Lasier 1991). Centrifugation of bulk sediment at high speeds extracts pore water with a relatively greater proportion of bioavailable metals than that achieved at lower speeds (Ankley and Schubauer-Berigan 1994). Centrifugation of one 500-ml sediment sample provided an adequate volume of pore water for multiple Microtox bioassays.

Microtox Pore Water Bioassay

Bioassays are experiments designed to evaluate the response of a standard test organism to stress (e.g., chemical, physical) or combination of stress factors under controlled conditions. The Microtox bioassay can provide a rapid, direct assessment of the cumulative toxicity of sediment constituents that cannot be derived solely from chemical residue analyses (Long and Chapman 1985). This assay quantifies the light intensity that is metabolically produced by

the bioluminescent bacteria *Photobacterium phosphoreum*. Disruption of normal metabolic activities by exposure to toxicants will attenuate bacterial luminescence in proportion to the concentration of the toxic substance(s) present in the test medium. Changes in light intensity that occur under standard test conditions can be used to estimate lethal toxicant concentrations. A more thorough description of the assay and its application is described elsewhere (Luoma and Ho 1993; Giesy et al. 1988; Burton and MacPherson 1995).

We used the Microtox bioassay to evaluate the toxicity of the "biologically-active" chemical constituents present in the pore water of sediments at each discharge site. The tests were performed according to the 100% assay procedure (Microbics, Inc. 1992) with some recommended modifications (Coyle et al. 1989; Henry et al. 1993) that permit analysis of pore water extracts at nearly full strength (91%). Light intensity emitted from test vessels was quantified after 5 and 15 minute incubation in pore water extracts and was compared to that emitted from control vessels. Results were used to estimate the effective concentration of pore water extract from each site necessary to reduce normal bioluminescence intensity by 50% (EC_{50}). This information was subsequently used to rank the relative toxicity of sediments at all the discharge sites studied.

Analytical Chemistry

Analytical determinations for sediment samples were chosen based on the type of point source and its known effluent composition. Physicochemical analyses included metals scans (including mercury), organochlorine (OC)/total polychlorinated biphenyls (PCB) scans, polynuclear aromatic hydrocarbon (PAH) scans, grain size, total organic carbon (TOC) and percent moisture determinations (Table 2). All sediment analytical results are expressed in ug/g (ppm), dry weight.

Trace metals, OC/PCB, TOC, moisture, and grain size determinations of sediment samples were performed by the Geochemical and Environmental Research Group at Texas A&M University (College Station, TX). This laboratory is one of several that is contracted by the USFWS Patuxent Analytical Control Facility (PACF). Quality Assurance/Quality Control (QA/QC) at these laboratories is monitored by PACF through analyses of procedural blanks, duplicates, spike recoveries, standard reference materials, and GC/MS confirmation (available upon request). Results of this QA/QC program with our samples were acceptable.

Mercury was determined by cold vapor atomic absorption spectrometry (AAS) with Sn_{+2} used to reduce Hg^0. Trace amounts of arsenic, selenium, cadmium, and lead were determined by graphite furnace AAS. Cadmium (Cd) and lead (Pb) were also determined by atomic emission spectroscopy using an argon plasma when these metals were present at high concentrations.

Sediment samples for OC analysis were freeze-dried and extracted with a Soxhlet extraction apparatus. The freeze-dried samples were homogenized and a 10-g portion was placed into the extraction thimble. Surrogate standards and methylene chloride were added and the

samples extracted for 12 h. The extracts were treated with copper to remove sulfur and were further purified by silica/alumina column chromatography to isolate the aliphatic and aromatic/pesticide/PCB fractions.

Cautionary Note on Sediment Storage

Sediments primarily contaminated with nonpolar, nonvolatile organics storage due to a high resistance to biodegradation and strong sorption certain metals and metalloids (e.g., arsenic, selenium, mercury, lead, likely to be affected by changes in the sediment redox potential and m Metal-contaminated sediments, therefore, should be tested relatively s with as little manipulation as possible (Burton and MacPherson 1995, Studies indicate that most sediment toxicity stabilizes after about four storage at 4° C (Dillon et al. 1994). Therefore, subtle differences in the correlation between sediment metal concentrations (frozen samples analyzed in May and June 1993) and our reported Microtox toxicity values (refrigerated pore water samples analyzed in summer 1992) may have occurred.

Sediment Metal Enrichment

Manganese (Mn) concentrations are positively correlated with sediment surface area (Oliver 1973) and can be used to compensate for differences in grain size when comparing sediment metal contents (Wiener et al. 1984, Ackermann 1980). We used Mn as a reference element to compensate for differences in sediment grain size among the sample stations and permit nonbiased comparisons of sediment metal enrichment. The degree of metal enrichment among samples was compared to determine whether any significant sources of metal loading exist within the study area. The process of adjustment for particle size involved calculating the following ratio:

$$\frac{\text{concentration of metal "X" in sample "Y"}}{\text{concentration of manganese in sample "Y"}}$$

High ratio values (larger decimals) indicate the potential presence of a nearby source of a particular metal.

RESULTS AND DISCUSSION

Application of Study Results to Sediment Analytical Chemistry

Sediment Quality Guidelines

The Ontario Ministry of the Environment (OMOE) and the National Oceanic and Atmospheric Administration (NOAA) have independently attempted to define criteria

whereby acceptable and unacceptable levels of contaminants in sediments can be defined (Persaud et al. 1990; Long and Morgan 1990). These recently developed biological effects guidelines provide a quantitative basis for evaluating the effects of contaminated sediments on aquatic organisms (Table 3). The essence of these guidelines and their significance are briefly summarized below:

Ontario Ministry of the Environment (OMOE)

The Provincial Sediment Quality Guidelines (Persaud et al. 1990) ar based guidelines derived from three ecotoxicological endpoints desig organisms that may be directly impacted by contaminated sediments:

explanation of units

1. No-Effect Level - contaminant concentrations at or below t be protective for all biological resources. No toxic effects hav aquatic organisms.

2. Lowest Effect Level - the level of sediment contamination [illegible] the majority of benthic organisms.

3. Limit of Tolerance - contaminant concentrations at or above this level can be expected to cause pronounced disturbance of the sediment-dwelling community. This is the sediment concentration of a compound that would be detrimental to the majority of benthic species.

National Oceanic and Atmospheric Administration (NOAA)

The NOAA (Long and Morgan 1990) estimates of contaminant concentration effects were obtained by evaluating National Status and Trends Program data from three different approaches to establish effects-based criteria. Chemical concentrations associated with biological effects (observed or predicted by each method) were ranked the lower 10 percentile and median concentrations identified, and an overall apparent effects threshold concentration defined. The NOAA Effects Ranges are:

1. Effects Range - Low (ER-L) - the 10th percentile of concentrations at which adverse effects were observed in bioassays.

2. Effects Range - Median (ER-M) - the 50th percentile of concentrations at which adverse effects were observed in bioassays.

3. Apparent Effects Threshold (AET) - concentrations above which significant ($P \leq 0.05$) adverse effects occur and are expected to occur.

Both guidelines should be used cautiously. For example, most of the guidelines were developed using acute mortality as the endpoint. Thus, mutagenicity and other chronic

effects may occur at levels lower than those listed. Moreover, these into account potential chemical interactive effects (i.e., additivity, an nor do they provide information on the quantity of the chemical that or its effect.

Application of Guidelines to Analytical Chemistry Results

Trace Element Concentrations

Trace element concentrations, particle size distributions, and total organic carbon content (Tables 4, 5) of surficial sediments from the UMR were highly variable among sampling sites. The textural composition of sediment samples analyzed for particle size ranged from predominantly sand to predominantly silt and clay. Sediments that have smaller grain sizes (i.e., silt and clay sized sediments < 62 um) and higher organic carbon content are predisposed to enrichment with metals and organic compounds (Knezovich et al. 1987).

The greatest concentrations of cadmium (2 ppm), arsenic (10 ppm), chromium (40 ppm), mercury (0.8 ppm) nickel (33 ppm) and lead (44 ppm) occurred in sediments near the Wabasha (MN) Wastewater Treatment Facility (WTF). Highest sediment concentrations of copper (123 ppm) and zinc (327 ppm) occurred near the Stoddard (WI) WTF (Bullhead Slough) while the peak manganese concentration (5.9 ppm) occurred near the Trempealeau (WI) WTF. Greatest concentrations of aluminum (0.8%) and iron (2.9%) occurred in sediments near the Prairie du Chien (WI) WTF and Winona (MN) WTF (north end), respectively.

Sediments at several sample sites had metal concentrations that could cause adverse biological effects based on NOAA and OMOE sediment quality guidelines. For example, sediments collected near the Stoddard (WI) WTF had zinc concentrations exceeding both NOAA effects range-medium (ER-M) and apparent effects threshold (AET) concentrations indicating zinc-related negative impacts to aquatic organisms are likely. In addition, sediment copper concentrations at the Stoddard (WI) WTF exceeded the OMOE limit of tolerance level indicating a pronounced disturbance of the benthic community may be expected. Zinc and copper are essential trace elements but large concentration imbalances can cause death and marginal imbalances contribute to retarded growth and poor health (Leland and Kawabara 1985). Furthermore, increased toxicity of copper when in solution with zinc make synergistic effects of these two metals of biological concern (Parrott and Sprague 1993).

Concentrations of arsenic, cadmium, chromium, copper, mercury, manganese, nickel, lead, and zinc in UMR sediments were above the OMOE lowest effect level (LEL), the NOAA effects range-low level (ER-L), or both levels at several sites (Table 6). These locations included the Prairie du Chien (WI) WTF, Interstate Power Company (Lansing, IA), Lansing WTF, Brownsville (MN) WTF, Isle La Plume (LaCrosse, WI) WTF, LaCrescent (MN) WTF, Dairyland Power Plant (Genoa, WI), Stoddard (WI) WTF, Trempeleau (WI) WTF,

Winona (MN) (north-end) WTF, Wabasha (MN) WTF, and Dairyland Power (Alma, WI). Moreover, Interstate Power at Lansing, Brownsville WTF, Trempeleau WTF, and Winona WTF (north end) all had sediments with manganese concentrations exceeding the OMOE limit of tolerance level.

PAH Concentrations

PAHs that exhibit toxicity and carcinogenicity to invertebrates, fish, and mammals have low aqueous solubility, degrade very slowly, and are readily absorbed to organic matter near their discharge source. Concentrations of PAHs in UMRNW&FR sediments (Table 7) ranged widely relative to the NOAA and OMOE levels of biological concern (Table 6). Acenaphthene, 1,6,7-trimethylnaphthalene, and naphthalene were present at levels near the detection limit in all samples.

Sediment PAH levels at the Heileman-Norplex-stormwater combined outfall (LaCrosse, WI) are a cause for concern. Sediments obtained here had a significantly greater total PAH concentration than at any other UMRNW&FR sample station. The highest concentration for 17 of the 20 PAH compounds analyzed also occurred here. This sample had concentrations of total PAHs (35 ppm), benzo(a)pyrene (2.8 ppm), pyrene (5.1 ppm), chrysene (2.1 ppm), fluoranthene (6.6 ppm), and phenanthrene (3.0 ppm) that each exceeded the NOAA AET level. Moreover, the concentrations of flouranthrene, phenanthrene, and pyrene were more than twice that of the AET. Anthracene (0.5 ppm) and chrysene (2.1 ppm) concentrations at the site also exceeded the AET levels while flourene (0.3 ppm) exceeded the ER-L level.

Several PAH compounds were also detected at elevated levels in sediment at the Prairie du Chien (WI) WTF (WI) site. Concentrations of total PAHs (5.1 ppm), anthracene (0.1 ppm), fluoranthene (0.7 ppm), and pyrene (0.7 ppm) were above the LEL and phenanthrene (0.3 ppm) exceeded the AET at this site. Concentrations of certain PAHs were slightly elevated above the ER-L and AET at the following sites: flourene (0.04 ppm) and phenanthrene (0.3 ppm) at Barron Island (LaCrosse, WI); phenanthrene (0.3 ppm) and pyrene (0.4 ppm) at Metallics Inc. (LaCrosse, WI).

Organochlorine Concentrations

Concentrations of total PCBs and organochlorine (OC) pesticides were at or below the detection limits for all samples and were below established levels of concern (Table 8). Therefore, no adverse impacts to benthic organisms are expected from OCs and PCBs at the UMR sites sampled.

Application of Study Results to Relative Metal Enrichment

We normalized the metal content (arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn)) of each sediment sample relative to its manganese (Mn) content to compensate for grain size differences that alter the ability of

what ratio was

sediments to bind metals (Figures 9-16). This procedure allowed the direct compari: metal enrichment at our UMRNW&FR sites with that reported at other nearby UMR (Wiener et al. 1984) (Table 9).

Most of the 20 UMRNW&FR sites we examined had relatively low metal/Mn ratios. Sample sites with the greatest metal ratios were the Wabasha WTF, LaCrescent WTF, and Dairyland Power Plant (Genoa). Wabasha (MN) WTF had the highest metal/Mn ratio for all eight metals suggesting the presence of a nearby source. The Dairyland Power Plant in Genoa had ratios similar to that at Wabasha for arsenic, cadmium and chromium. The LaCrescent WTF sample indicated elevated copper and zinc ratios as well. The Stoddard WTF, Prairie du Chien WTF, Winona WTF, and Heilemann-Norplex-stormwater combined discharge sites followed with elevated ratios but had less than that of the three sites previously noted.

Navigation pools (i.e., the stretch of river between two adjacent locks and dams) varied in metal enrichment ratios as well (Table 10). The metal enrichment of surficial sediments generally diminished with increasing distance downstream from Pool 4-10, supporting earlier findings (Bailey and Rada 1984; Wiener et al. 1984) primarily of a pollution gradient. Pools 2 through 10 span a pollution gradient caused primarily by domestic and industrial wastes from the Twin Cities (Minneapolis and St. Paul, MN) metropolitan area (Wiener et al. 1984, Steingraeber et al. 1994). The Metropolitan WTF at river mile 834.5 treats more than 80% of the wastewater from this metropolitan area (Maschewitz 1984). Despite recent improvement in wastewater treatment at this facility, a recent survey of the fingernail clams (*Musculium transversum*) in the UMR indicated significantly greater densities in pools far downstream of the Twin Cities (Wilson et al. 1995). This distribution may be related to the sediment pollution gradient. Likewise, the cadmium and mercury content of UMR burrowing mayflies (*Hexagenia bilineata*) reflects a similar pattern of spatial contamination in Pools 2-4 (Beauvais et al. 1995, Dukerschein et al. 1992).

Wiener et al. (1984) sampled sediments along 5 cross-sectional transects at each of 19 main channel and backwater locations. Comparisons (where possible) to our study indicate metal enrichment ratios among sediment samples collected at point source outfalls in 1992 were equal to or greater (as much as 15-fold) than that reported in this earlier survey. Enrichment of sediment with As, Cd, Hg, and Pb was greatest in samples collected at point source discharge sites in Pool 4 for both studies. This closely follows our findings that the Wabasha ATF site (Pool 4) had the highest ratio for seven (Cd, Cr, Cu, Hg, Ni, Pb, Zn) of the eight metals analyzed (enrichment ratio for As at Wabasha ranked second highest). Lake Pepin, a large natural riverine lake in Pool 4, serves as a settling basin for sediment and associated contaminants (Rada et al. 1990). These findings are also in agreement with Bailey and Rada (1984) who suggested that Pool 4 sediments were enriched with heavy metals and that effects of grain size (absorptive capacity) on sediment metal concentrations were greater in Pools 4 than in Weaver Bottoms or Pool 9.

Application of Study Results to Toxicity Bioassay (Microtox)

The Microtox porewater bioassay was used to identify and rank the most toxic sediments we collected. Five samples demonstrated impairment of bacterial luminescence due to toxicants present in sediment porewater extracts during the 15-minute bioassays (Table 11). The toxicity ranking for these locations was: LaCrescent WTF (EC_{50}=13.9) > Wabasha WTF (EC_{50}=29.5) > Winona (North end) (EC_{50}=83.9) > Lansing WTF (EC_{50}=99.6) > and Stoddard WTF (EC50$\geq$100). The LaCrescent, Wabasha, and Stoddard sediment samples had elevated concentrations of several metals, corresponding high metal/Mn ratios, and low OC concentrations. These results suggested metal interactions were responsible for the toxicity observed in these samples during the Microtox bioassay although PAH-related toxicity could not be ruled out (PAH analysis was not performed on these samples).

The Winona WTF (north end) sediments contained metals of low concentrations (except for Mn and As), had low metal/Mn ratios, low PAH and OC concentrations. Likewise, the Lansing WTF sediment sample had relatively low metal concentrations (except for Hg and Mn) and low metal/Mn ratios (neither PAHs or OCs were quantified). Therefore, the cause of toxicity for these sediment porewater bioassays is unknown.

EC_{50} estimates indicated no inhibition of bioluminescence would be caused by sediment porewater from the 15 remaining locations. This does not mean there was no reduction in bioluminescence with porewater extracts from these locations, but rather that it would take concentrated extract (i.e., >100%) to cause a 50% reduction in bioluminescence. Our reported ranking of sediment toxicity, therefore, is conservative and sediments classified as non-toxic by our Microtox bioassay may cause chronic toxicity to some other sensitive organism.

Several porewater extracts from sediments with elevated contaminant concentrations did not elicit a toxic response during our Microtox bioassay. For example, sediment metal concentrations and metal/Mn ratios in the Dairyland Power Plant sample from Genoa indicated elevated concentrations of As, Cd, and Cr (Figures 2, 3, and 5). As stated previously, however, the Microtox bacterium *P. phosphoreum* is insensitive to cadmium. Also, some sediments can accumulate relatively high concentrations of contaminants that may not be biologically available. A concentrated pore water extract may be required from such a sample to cause a 50% reduction in bioluminescence under these circumstances.

The Heileman-Norplex-stormwater discharge outfall had elevated sediment PAH concentrations relative to all other samples analyzed, but its porewater extract did not elicit a toxic bioassay response. Metal concentrations and enrichment ratios in this sample were generally low while concentrations were at the detection limits. Organochlorine concentrations were also at the detection limits. Bacteria are generally regarded as tolerant of refined petroleum hydrocarbon products (Adams 1985) but intolerant to crude oils (Hodson et al. 1977). Results of a Microtox test using porewater extract may not elicit a toxic response due to PAHs and OCs in the sediment while a test using an organic solvent

extract of the sediment may elicit such a response (Schiewe et al. 1985). The potential difference in apparent toxicity is due to the inherent differences in the solubility (i.e., Kow partition coefficient) of these compounds and Microtox test design.

Use of the photoluminescent marine bacteria *P. phosphoreum* as a surrogate assay organism for fish or invertebrate toxicity bioassays is predicated on the assumption that toxicant-elicited effects are similar. Comparisons of the Microtox assay to sediment, fish, and invertebrate assays have generally been favorable (Greene et al. 1985, Giesy et al. 1988). However, *P. phosphoreum* is regarded as insensitive to ammonia (Ankley et al. 1990), insecticides and herbicides (Beckmann et al. 1984), and some petroleum hydrocarbons (Adams 1985). This marine bacteria is also insensitive to mercury and cadmium (DeZwart and Sloof 1983), but is relatively sensitive to copper (Giesy et al. 1988). Therefore, not all chemicals of toxicological concern are accounted for by results of the Microtox bioassay.

Toxic Point Source Discharge Sites on the UMRNW&FR of Ecological Concern

Persistent toxic substances that accumulate in surficial sediments from industrial, municipal, and nonpoint sources may threaten the local benthic community structure, benthic predators, and water quality in certain portions of the UMR. River managers need meaningful criteria to evaluate the potential risk of contaminated sediments to the local fauna. While our sediment bulk chemistry data indicated the relative degree of contamination among sample sites, it could not predict contaminant bioavailability or the potential for adverse biological effects. We therefore used the Microtox bioassay as a screening tool to assess the potential toxicity of sediment-associated contaminants. Moreover, we incorporated biologically-derived sediment toxicity guidelines into our environmental risk assessment. This three-tiered strategy was used to identify and rank point source discharge sites on the UMRNW&FR that may be of ecological concern.

A summary of point source discharges on the UMRNW&FR and toxic results of the Microtox bioassay, sediment guidelines, and metal enrichment ratios in this study are provided in Table 12. Sediments in the vicinity of several wastewater treatment facilities and industrial sites appear to be toxic to benthic biota. These sediments may be contaminated by current or historic discharges near each site. Our findings indicate the most contaminated sediments of biologic concern on the UMRNW&FR occur near the Wabasha (MN), Stoddard (WI), and LaCrescent (MN) WTFs. Sediments near these facilities exhibited a high degree of contamination and toxicity based on the results of the Microtox bioassay, metal enrichment ratios, exceedence of sediment guidelines, and bulk chemical analyses. Other discharge sites of concern include the Heileman-Norplex-combined stormwater outfall (LaCrosse, WI), Dairyland Power Plant (Genoa, WI), and the Prairie du Chien (WI), Winona (north end) (MN), and Lansing (IA) WTFs.

Sediments from several sites (e.g., the Wabasha and Stoddard WTFs) indicated metal toxicity of serious biological concern. Metal-enriched sediments frequently have a considerably

reduced species richness, reduced macroinvertebrate abundance, and a community composition dominated by pollution-tolerant taxa (e.g., Orthocladiinae chironomids and caddisflies) (Hoiland et al. 1994, Clements 1994, Winner et al. 1980). Many studies have shown deleterious effects of zinc and other metals on macroinvertebrate communities (Winner et al. 1980, Clements 1994).

Sediments from the Heileman-Norplex-combined stormwater outfall and Prairie du Chien WTF contained concentrations of PAHs. Aquatic organisms inhabiting PAH-contaminated environments often have an increased incidence of tumors, liver lesions and hyperplastic diseases (Eisler 1987; Baumann et al. 1987). Moreover, the acute toxicity of PAHs to fish larvae (Landrum et al. 1986) and macroinvertebrates (Dr. Dan Call, Lake Superior Research Institute, pers. comm.) is increased in the presence of sunlight.

Although sediments may serve as a repository for metals, PAHs, and other contaminants in aquatic systems, they are not always an ultimate sink for these materials. Sediment-associated contaminants can be mobilized and made available to aquatic organisms due to a variety of physical, chemical, and biological processes. Benthic invertebrates may play an important role in the trophic transfer and cycling of contaminants through the aquatic food chain because of their intimate association with sediments and their significance as a food source for bottom-feeding fish and other benthic predators.

RECOMMENDATIONS

Several point source discharge sites were determined to have sediment contaminants (whether released presently or historically) that may have negative effects on the benthic fauna. Effluents near particular sites appear to have discharged contaminants that have accumulated in sediments to levels that are known to adversely impact sensitive aquatic organisms. Our recommendations to help correct these concerns are:

1. A critical review of existing NPDES permits during reissuance (when available on a five-year basis) should be conducted by the respective Ecological Services Field Offices (MN, WI, IA) for specific point source discharges of concern.

2. Intensive review of state water quality standards and point-source monitoring requirements (for the states of Minnesota, Wisconsin and Iowa) by the Environmental Contaminants staff may be necessary to correct specific chemical issues where NPDES permits do not yet address a specific compound.

3. Based on the results of this study, site-specific investigations of two or three point-sources discharges may be useful to determine biological impacts of contaminants to UMRNW&FR resources. For instance, an integrated assessment approach (Burton and MacPherson 1995) that utilizes measures of chemical concentrations, physical habitat, *in situ* biological communities, and sediment toxicity would further define the implications of

specific point source discharges to resources of concern.

Because benthic community responses to metals will most likely always be confounded by natural temporal and spatial variation, these factors would need to be included when the monitoring studies are designed and when appropriate community-level measures of metal pollution are selected (Clements 1994).

This approach would compliment our preliminary multi-tiered findings and may eliminate spending unnecessary effort on areas that are not causing significant resource damage. In addition, justifications for specific recommendations to improve water and sediment quality at these sites would be based on the site-specific integrated assessment studies.

4. Based on the results of #3, determine the degree and extent of contamination and necessary actions to prevent further harmful discharges (mutually developed by the appropriate state, Service refuge and Environmental Contaminants staff). In addition, site remediation may be warranted at specific sites.

5. We suggest that ammonia levels be assessed at select locations. The Microtox bioassay is not an appropriate technique to determine ammonia toxicity. Therefore, alternative ammonia-sensitive bioassay procedures are recommended to obtain a clearer understanding of the potential for sediment-related ammonia toxicity to aquatic life in the UMRNW&FR.

TABLES

Table 1. Type of facility and locations of UMRNW&FR sediment samples collected in July, 1992.

Sample #	Facility Location	Appoximate River Mile	Longitude	Latitude	Municipality	Industrial
TC92-01D TC92-01U	Prairie du Chien, WI	633.5 (east bank)	91° 8.53 91° 8.54	43° 1.47 43° 1.54	X	X
TC92-02D TC92-02U	McGregor, IA	634 (west bank)	Not determined	Not determined	X	
TC92-03D TC92-03U	Marquette, IA	634.6 (west bank)	91° 10.38 91° 10.38	43° 2.29 43° 2.35	X	
TC92-04D TC92-04U	Harper's Ferry, IA	646 (upper end of Joyce Lake)	Not determined	Not determined	X	
TC92-05D TC92-05U	Ferryville, WI	658 (east bank)	Not determined	Not determined	X	
TC92-06D TC92-06U	Interstate Power Co. Lansing, IA	660.2 659.9 (west bank)	91° 9.54 91° 10.22	43° 20.13 43° 20.22		X
TC92-07D TC92-07U	Lansing, IA	663.0 (west bank)	91° 12.48	43° 21.40	X	
TC92-08D	Brownsville, MN	688.2 (west bank)	91° 16.36	43° 41.10	X	
TC92-09D	Heileman/Norplex/ stormwater LaCrosse, WI	696.7 (west bank)	91° 15.16	43° 47.52	X	X
TC92-10D	Isle La Plume LaCrosse, WI	696.7 (boat harbor)	91° 15.28	43° 47.52	X	

Table 1 (con't). Type of facility and locations of UMRNW&FR sediment samples collected in July, 1992.

Sample #	Facility Location	Appoximate River Mile	Longitude	Latitude	Municipality	Industrial
TC92-11D	LaCrescent, MN	699.0 (w. shore Blue L.)	91° 18.6	43° 49.24	X	
TC92-12D	Barron Island LaCrosse, WI	698.3 (west channel)	91° 16.8	43° 49.2	X	
TC92-13D	Genoa Power Plant Genoa, WI	678.5 (east bank)	91° 13.54	43° 33.13		X
TC92-14D	Stoddard, WI (Bullhead Slough)	685.6 (east bank)	91° 13.19	43° 39.16	X	
TC92-15D	Metallics, Inc. LaCrosse, WI	704.2 (east shore)	91° 15.31	43° 54.60		X
TC92-16D TC92-16U	Trempealeau, WI	714.0 (east shore)	91° 25.26	44° 0.10	X	
TC92-17D TC92-17U	Winona-North End, MN	726.3 (east) 727.3 (east shore)	91° 39.4 91° 40.7	44° 3.41 44° 3.49		X
TC92-18D TC92-18U	Winona, MN	722.8 (west shore)	91° 35.58	44° 2.3	X	
TC92-19D TC92-19U	Wabasha, MN	757.8 (west shore)	92° 0.14	44° 21.16	X	
TC92-20D	Dairyland Power Alma, WI	751.2 (east shore)	91° 54.45	44° 18.24	X	X

Table 2. List of specific analyses measured within individual UMRNW&FR sediment samples collected in July, 1992*.

Sample #	Facility Location	% Moisture	Metals	OC/PCBs	PAHs	Grain Size	TOC
TC92-01D	Prairie du Chien WI	✓	✓	✓	✓	✓	✓
TC92-01U		✓	✓	✓	✓	✓	✓
TC92-02D	McGregor, IA	NA	NA	NA	NA	NA	NA
TC92-02U		NA	NA	NA	NA	NA	NA
TC92-03D	Marquette, IA	✓	NA	✓	✓	NA	✓
TC92-03U		✓	NA	✓	✓	NA	✓
TC92-04D	Harper's Ferry, IA	NA	NA	NA	NA	NA	NA
TC92-04U		NA	NA	NA	NA	NA	NA
TC92-05D	Ferryville, WI	NA	NA	NA	NA	NA	NA
TC92-05U		NA	NA	NA	NA	NA	NA
TC92-06D	Interstate Power Lansing, IA	✓	✓	✓	✓	✓	✓
TC92-06U		✓	✓	✓	✓	✓	✓
TC92-07D	Lansing, IA	✓	✓	NA	NA	✓	✓
TC92-07U		✓	✓	NA	NA	✓	✓
TC92-08D	Brownsville, MN	✓	✓	NA	NA	✓	✓
TC92-09D	Heileman/Norplex/ LaCrosse, WI	✓	✓	✓	✓	✓	✓
TC92-10D	Isle La Plume LaCrosse, WI	✓	✓	✓	✓	✓	✓
TC92-11D	LaCrescent, MN	✓	✓	NA	NA	✓	✓

Table 2 (con't). List of specific analyses measured within individual UMRNW&FR sediment samples collected in July, 1992*.

Sample #	Facility Location	% Moisture	Metals	OC/PCBs	PAHs	Grain Size	TOC
TC92-12D	Barron Island LaCrosse, WI	✓	NA	✓	✓	NA	✓
TC92-13D	Genoa Power Plant Genoa, WI	✓	✓	NA	NA	✓	✓
TC92-14D	Stoddard, WI (Bullhead Slough)	✓	✓	NA	NA	✓	✓
TC92-15D	Metallics, Inc. LaCrosse, WI	✓	NA	✓	✓	NA	✓
TC92-16D	Trempeleau, WI	✓	✓	NA	NA	✓	✓
TC92-16U		NA	NA	NA	NA	NA	NA
TC92-17D	Winona-N end, MN	✓	✓	✓	✓	✓	✓
TC92-17U		✓	✓	✓	✓	✓	✓
TC92-18D	Winona, MN	✓	✓	NA	NA	✓	✓
TC92-18U		✓	✓	NA	NA	✓	✓
TC92-19D	Wabasha, MN	✓	✓	NA	NA	✓	✓
TC92-19U		✓	✓	NA	NA	✓	✓
TC92-20D	Dairyland Power Alma, WI	✓	✓	✓	✓	✓	✓

* All samples were analyzed by MICROTOX assay.
** NA = not analyzed.

Table 3. The threshold metal and organic compound concentration (ppm, dry weight) presented in two different guidelines for the evaluation of sediment-sorbed contaminants.

Chemical Analyte	MOE[a] Lowest Effect Level[c]	MOE[a] Limit of Tolerance Level[d,e]	NOAA[b] Effects Range-Low (ER-L)[f]	NOAA[b] Effects Range-Medium (ER-M)[g]	NOAA[b] Apparent Effects Threhold (AET)[h]
Metals					
Aluminum	---	---	---	---	---
Arsenic	6.0	33.0	33.0	85.0	50.0
Cadmium	1.0	10.0	5.0	9.0	5.0
Chromium	31.0	110.0	80.0	145.0	---
Copper	25.0	110.0	70.0	390.0	300.0
Iron (%)	3.0	4.0	---	---	---
Mercury	0.2	2.0	0.15	1.3	1.0
Manganese	460.0	1200.0	---	---	---
Nickel	31.0	90.0	30.0	50.0	---
Lead	31.0	250.0	35.0	110.0	300.0
Selenium	---	---	---	---	---
Zinc	120.0	820.0	120.0	270.0	260.0
Organochlorines					
Total PCBs	0.07	530	.050	.400	.370
Heptachlor epoxide	0.005	6	---	---	---
Total DDT	0.007	12	.003	.350	---
p,p'-DDD	0.008	9	.002	.020	---
p,p'-DDE	0.005	20	.002	.015	---
p,p'-DDT	0.01	14	.001	.007	.006

Table 3 (con't). The threshold metal and organic compound concentration (ppm, dry weight) presented in two different guidelines for the evaluation of sediment-sorbed contaminants.

	MOE[a]		NOAA[b]		
Chemical Analyte	Lowest Effect Level[c]	Limit of Tolerance Level[d,e]	Effects Range-Low (ER-L)[f]	Effects Range-Medium (ER-M)[g]	Apparent Effects Threhold (AET)[h]
PAHs					
Total PAHs	2.00	11,000	4.000	35.000	22.000
Acenaphthene	---	---	.150	.650	.150
Anthracene	---	---	.085	.960	.300
Benzo(a)pyrene	---	---	.400	2.500	.700
Chrysene	---	---	.400	2.800	.900
Fluoranthene	---	---	.600	3.600	1.000
Fluorene	---	---	.035	.640	.350
Napthalene	---	---	.340	2.100	.500
Phenanthrene	---	---	.225	1.380	.260
Pyrene	---	---	.350	2.200	1.000

[a] MOE - Ontario Ministry of the Environment (Persaud et al. 1990).
[b] NOAA - National Oceanic Atmospheric Administration (Long and Morgan 1990).
[c] Lowest effect level - level of sediment contamination that can be tolerated by the majority of benthic organisms.
[d] Limit of tolerance level - level of contamination at which pronounced disturbance of the sediment-dwelling community can be expected.
[e] Numbers in this column (organics only) are to be converted to bulk sediment values by multiplying by the actual TOC concentration of the sediments (to maximum of 10%), e.g., @TOC of 5%, PCB values is 530 x 0.05 or 26.5 ppm.
[f] Effects Range - Low (ER-L) - concentration at low end of range where effects have been observed.
[g] Effects Range - Medium (ER-M) - concentration midway in the range of reported values associated with biological effects.
[h] Apparent Threshold (AET) - concentration above which statistically significant ($P \leq 0.05$) biological effects

Table 4. Metal concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Al	As	Cd	Cr	Cu	Fe	Hg	Mn
TC92-01D	3582	4.29	0.70	23.66	31.1	13270	0.24	652
TC92-01U	7926	4.42	0.47	19.29	18.85	17825	<0.1	940
TC92-02D	NA*	NA	NA	NA	NA	NA	NA	NA
TC92-02U	NA	NA	NA	NA	NA	NA	NA	NA
TC92-03D	NA	NA	NA	NA	NA	NA	NA	NA
TC92-03U	NA	NA	NA	NA	NA	NA	NA	NA
TC92-04D	NA	NA	NA	NA	NA	NA	NA	NA
TC92-04U	NA	NA	NA	NA	NA	NA	NA	NA
TC92-05D	NA	NA	NA	NA	NA	NA	NA	NA
TC92-05U	NA	NA	NA	NA	NA	NA	NA	NA
TC92-06D	5022	5.13	0.45	19.17	20.84	18282	<0.1	1645
TC92-06U	6521	4.73	0.42	14.89	13.05	16675	<0.1	973
TC92-07D	3381	2.59	0.26	8.68	16.24	8185	0.21	401
TC92-07U	4739	3.43	0.35	14.89	17.85	14858	<0.1	683
TC92-08D	6767	4.81	0.26	22.16	18.52	26808	<0.1	1437
TC92-09D	2468	2.74	0.32	12.35	16.77	10153	<0.1	402
TC92-10D	5708	4.66	0.54	21.70	28.30	19523	0.11	906

* NA=not analyzed

Table 4 (con't). Metal concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Al	As	Cd	Cr	Cu	Fe	Hg	Mn
TC92-11D	3879	2.91	0.84	15.07	92.29	11230	0.64	197
TC92-12D	NA	NA	NA	NA	NA	NA	NA	NA
TC92-13D	4688	9.37	1.08	35.25	20.17	14488	<0.1	194
TC92-14D	4173	3.55	1.33	14.88	123.23	13196	0.38	461
TC92-15D	NA	NA	NA	NA	NA	NA	NA	NA
TC92-16D	5531	9.34	0.42	36.37	18.12	25765	<0.1	5892
TC92-16U	NA	NA	NA	NA	NA	NA	NA	NA
TC92-17D	4510	3.13	0.34	15.77	12.56	11761	<0.1	441
TC92-17U	7461	7.28	0.47	26.13	21.95	29486	<0.1	2942
TC92-18D	2049	2.14	<0.2	8.16	4.21	6825	<0.1	187
TC92-18U	2038	1.83	<0.2	7.29	4.43	6285	<0.1	207
TC92-19D	4941	4.95	1.36	30.50	89.43	13305	0.75	152
TC92-19U	5253	9.74	1.88	39.74	93.53	14911	0.75	208
TC92-20D	3232	3.56	0.41	14.58	13.50	11226	<0.1	495

* NA=not analyzed

Table 4 (con't). Metal concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Ni	Pb	Se	Zn
TC92-01D	15.91	29.61	<1.0	107.06
TC92-01U	18.95	14.10	<1.0	78.06
TC92-02D	NA*	NA	NA	NA
TC92-02U	NA	NA	NA	NA
TC92-03D	NA	NA	NA	NA
TC92-03U	NA	NA	NA	NA
TC92-04D	NA	NA	NA	NA
TC92-04U	NA	NA	NA	NA
TC92-05D	NA	NA	NA	NA
TC92-05U	NA	NA	NA	NA
TC92-06D	21.03	15.89	<1.0	75.91
TC92-06U	17.41	13.88	<1.0	58.23
TC92-07D	9.89	13.79	<1.0	53.77
TC92-07U	16.15	17.06	<1.0	67.51
TC92-08D	23.79	18.85	<1.0	93.63
TC92-09D	10.44	16.31	<1.0	73.70
TC92-10D	20.05	17.56	<1.0	90.50

* NA=not analyzed

Table 4 (con't). Metal concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Ni	Pb	Se	Zn
TC92-11D	16.74	31.61	<1.0	227.02
TC92-12D	NA	NA	NA	NA
TC92-13D	20.06	10.65	1.61	67.81
TC92-14D	16.65	34.18	1.10	327.33
TC92-15D	NA	NA	NA	NA
TC92-16D	18.77	18.40	1.90	78.03
TC92-16U	NA	NA	NA	NA
TC92-17D	13.82	10.31	<1.0	55.12
TC92-17U	20.11	20.61	<1.0	103.97
TC92-18D	6.44	<5.00	<1.0	29.96
TC92-18U	6.80	5.38	<1.0	24.35
TC92-19D	25.94	42.99	1.89	243.11
TC92-19U	32.95	43.48	3.75	246.67
TC92-20D	11.51	11.77	<1.0	56.44

*NA=not analyzed

Table 5. Particle size, moisture percentage, and total organic carbon (TOC) in UMRNW&FR sediment samples collected in July, 1992.

Sample #	Facility Location	% Moisture	% TOC	Particle Size % Sand	% Silt	% Clay
TC92-01D	Prairie du Chien,	54.0	4.3	27.4	55.4	17.2
TC92-01U	WI	61.8	2.6	3.7	68.7	27.6
TC92-02D	McGregor, IA	NA*	NA	NA	NA	NA
TC92-02U		NA	NA	NA	NA	NA
TC92-03D	Marquette, IA	37.0	2.4	NA	NA	NA
TC92-03U		52.0	2.6	NA	NA	NA
TC92-04D	Harper's Ferry, IA	NA	NA	NA	NA	NA
TC92-04U		NA	NA	NA	NA	NA
TC92-05D	Ferryville, WI	NA	NA	NA	NA	NA
TC92-05U		NA	NA	NA	NA	NA
TC92-06D	Interstate Power Co.	60.6	3.4	3.8	60.9	35.3
TC92-06U	Lansing, IA	56.4	2.8	9.1	68.6	22.3
TC92-07D	Lansing, IA	40.7	1.2	57.1	29.1	13.8
TC92-07U		50.2	1.7	35.0	45.1	19.9
TC92-08D	Brownsville, MN	56.9	2.7	13.0	61.7	25.3
TC92-09D	Heileman/Norplex/ LaCrosse, WI	37.0	2.2	70.7	21.9	7.5
TC92-10D	Isle La Plume LaCrosse, Wi	64.2	3.4	8.9	64.0	27.1
TC92-11D	LaCrescent, MN	68.2	6.3	74.3	14.7	11.0

Table 5 (con't). Particle size, moisture percentage, and total organic carbon (TOC) in UMRNW&FR sediment samples collected in July, 1992.

Sample #	Facility Location	% Moisture	% TOC	Particle Size % Sand	% Silt	% Clay
TC92-12D	Barron Island LaCrosse, WI	37.0	0.8	NA	NA	NA
TC92-13D	Genoa Power Plant Genoa, WI	40.7	1.3	39.3	55.3	5.4
TC92-14D	Stoddard, WI (Bullhead Slough)	69.1	1.7	81.5	6.3	12.3
TC92-15D	Metallics, Inc. LaCrosse, WI	56.9	4.0	NA	NA	NA
TC92-16D	Trempealeau, WI	79.6	11.9	56.9	31.0	12.1
TC92-16U		NA	NA	NA	NA	NA
TC92-17D	Winona-North End, MN	47.2	2.2	49.3	35.8	14.9
TC92-17U		74.4	4.2	23.6	48.5	27.9
TC92-18D	Winona, MN	17.0	0.1	96.5	1.4	2.2
TC92-18U		18.8	0.1	84.7	8.6	6.7
TC92-19D	Wabasha, MN	75.9	8.6	52.9	27.6	19.5
TC92-19U		81.0	10.9	45.9	34.9	19.2
TC92-20D	Dairyland Power Alma, WI	48.7	2.4	34.1	56.1	9.8

*NA=not analyzed

Table 6. Facility locations and compounds that exceeded OMOE[a] and/or NOAA[b] sedime... quality guidelines.

Facility Location and Relation to Point Source (Sample #)		Limit of Tolerance Level[c,d] (OMOE)	Lowest Effect Level[e] (OMOE)	No Effect Level[f] (OMOE)	Effects Range-Low[g] (NOAA)	Effects Range-Medium[h] (NOAA)	Apparent Effect Threshold (NOAA)[i]
Prairie du Chien	(01D)	---	Cu,Mn, Hg	Cu,Pb, Hg,Zn, Mn,Hg	Hg total PAHs flouranthene anthracene pyrene phenanthrene	---	phenanthrene
	(01U)	---	Mn	Mn,Zn	---	---	---
Interstate Power Lansing, IA	(06D)	Mn	Mn	Mn, Zn	---	---	---
	(06U)	---	Mn	As,Mn, Hept. ep.	---	---	---
Lansing, IA	(07D)	---	Hg	Mn,Hg	Hg	---	---
	(07U)	---	Mn	Mn,Zn	---	---	---
Brownsville, MN	(08D)	Mn	Mn	As,Mn, Zn	---	---	---
Heilemann/ Norplex, LaCrosse, WI	(09D)	---	---	Mn,Zn	total PAHS anthracene benzo(a)pyrene pyrene chrysene flouranthene flourene phenathrene	total PAHs, benzo(a)-pyrene, pyrene, flouranthene, phenanthrene	total PAHs anthracene benzo(a)-pyrene, pyrene, chrysene, flouranthene phenanthene

Table 6 (con't). Facility locations and compounds that exceeded OMOE[a] and/or NOAA[b] sediment quality guidelines.

Facility Location and Relation to Point Source (Down or Upstream)		Limit of Tolerance Level (OMOE)	Lowest Effect Level[c,d] (OMOE)	No Effect Level[e] (OMOE)	Effects Range-Low[f] (NOAA)	Effects Range-Medium[g] (NOAA)	Apparent Effect Threshold (NOAA)[i]
Isle La Plume LaCrosse, WI	(10D)	---	Cu,Mn	As,Cu, Mn,Hg, Zn	---	---	---
La Crescent, MN	(11D)	---	Cu,Pb, Hg,Zn	Cu,Pb, Hg,Zn	Cu,Hg, Zn	---	---
Barron Island LaCrosse, WI	(12D)	---	---	---	flourene phenanthrene	---	flourene phenanthrene
Genoa Power Plant Genoa, WI	(13D)	---	As,Cd, Cr	As,Cd, Cr,Zn	---	---	---
Stoddard, WI	(14D)	Cu	Cd,Cu, Pb,Mn, Hg, Zn	Cd,Cu, Hg,Zn, Pb,Mn	Cu,Hg, Zn	Zn	Zn
Metallics, Inc.	(15D)	---	---	---	pyrene phenanthrene	---	phenanthrene
Trempealeau,WI	(16D)	Mn	As,Cr, Mn	Cr,Mn, Zn	---	---	---
Winona, N end, MN	(17D)	---	---	Mn	---	---	---
	(17U)	Mn	As,Mn	Mn,Zn	---	---	---
Winona, MN	(18D)	---	---	---	---	---	---
	(18U)	---	---	---	---	---	---

Table 6 (con't). Facility locations and compounds that exceeded OMOE[a] and/or NOAA[b] sediment quality guidelines.

Facility Location and Relation to Point Source (Down or Upstream)		Limit of Tolerance Level (OMOE)	Lowest Effect Level[c,d] (OMOE)	No Effect Level[e] (OMOE)	Effects Range-Low[f] (NOAA)	Effects Range-Medium[g] (NOAA)	Apparent Effect Threshold (NOAA)[i]
Wabasha, MN	(19D)	---	Cd,Cr, Cu,Pb Hg,Zn	As,Cd, Cr,Cu Pb,Hg, Zn	Cu,Pb, Hg,Zn	---	---
	(19U)	---	As,Cd, Cr,Cu, Pb,Hg, Ni,Zn	As,Cd, Pb,Hg, Cr,Cu, Ni,Zn	Cu,Pb, Hg,Ni, Zn	---	---
Dairyland Power Alma, WI	(20D)	---	Mn	Mn	---	---	---

[a] OMOE - Ontario Ministry of the Environment (Persaud et al. 1990).
[b] NOAA - National Oceanic Atmospheric Administration (Long and Morgan 1990).
[c] Limit of tolerance level - level of contamination at which pronounced disturbance of the sediment-dwelling community can be expected.
[d] Numbers in this column (organics only) are to be converted to bulk sediment values by multiplying by the actual TOC concentration of the sediments (to maximum of 10%), e.g., @TOC of 5%, PCB values is 530 x 0.05 or 26.5 ppm.
[e] Lowest effect level - level of sediment contamination that can be tolerated by the majority of benthic organisms.
[f] No effect level - level where no toxic effects have been observed on aquatic organisms
[g] Effects Range - Low (ER-L) - concentration at low end of range where effects have been observed.
[h] Effects Range - Medium (ER-M) - concentration midway in the range of reported values associated with biological effects.
[i] Apparent Effect Threshold (AET) - concentration above which statistically significant ($P \leq 0.05$) biological effects always occur and, therefore, are always expected.

Table 7. Polycyclic aromatic hydrocarbon (PAH) concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Total PAHs	1,2,5,6,-dibenzan-thracene	1,2,-benzan-thracene	1,6,7,-trimethyl-napthalene	acenaph-thalene	acenaph-thene
TC92-01D	5.13	0.11	0.33	0.02	0.05	<.01
TC92-01U	0.53	<.01	0.02	<.01	<.01	<.01
TC92-02D	NA*	NA	NA	NA	NA	NA
TC92-02U	NA	NA	NA	NA	NA	NA
TC92-03D	0.33	<.01	0.01	0.01	<.01	<.01
TC92-03U	1.20	0.01	0.09	0.01	<.01	<.01
TC92-04D	NA	NA	NA	NA	NA	NA
TC92-04U	NA	NA	NA	NA	NA	NA
TC92-05D	NA	NA	NA	NA	NA	NA
TC92-05U	NA	NA	NA	NA	NA	NA
TC92-06D	0.56	<.01	0.02	<.01	<.01	<.01
TC92-06U	0.63	<.01	0.03	0.02	<.01	<.01
TC92-07D	NA	NA	NA	NA	NA	NA
TC92-07U	NA	NA	NA	NA	NA	NA
TC92-08D	NA	NA	NA	NA	NA	NA
TC92-09D	35.18	0.46	1.95	0.04	0.03	0.12
TC92-10D	1.86	0.12	0.12	<.01	<.01	<.01

Table 7 (con't). Polycyclic aromatic hydrocarbon (PAH) concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Total PAHs	1,2,5,6,-dibenzan-thracene	1,2,-benzan-thracene	1,6,7,-trimethyl-napthalene	acenaph-thalene	acenaph-thene
TC92-11D	NA	NA	NA	NA	NA	NA
TC92-12D	2.02	0.02	0.21	0.01	<.01	0.04
TC92-13D	NA	NA	NA	NA	NA	NA
TC92-14D	NA	NA	NA	NA	NA	NA
TC92-15D	2.87	0.03	0.23	<.01	.01	0.02
TC92-16D	NA	NA	NA	NA	NA	NA
TC92-16U	NA	NA	NA	NA	NA	NA
TC92-17D	0.40	<.01	0.02	<.01	<.01	<.01
TC92-17U	1.91	0.02	0.16	0.05	<.01	<.01
TC92-18D	NA	NA	NA	NA	NA	NA
TC92-18U	NA	NA	NA	NA	NA	NA
TC92-19D	NA	NA	NA	NA	NA	NA
TC92-19U	NA	NA	NA	NA	NA	NA
TC92-20D	1.35	0.01	0.07	0.01	0.03	<.01

*NA=not analyzed

Table 7 (con't). Polycyclic aromatic hydrocarbon (PAH) concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	anthra-cene	benzo(a)-pyrene	benzo(b)-fluor-anthene	benzo(e)-pyrene	benzo-(g,h,i)-perylene	pyrene	napthalene
TC92-01D	0.11	0.36	0.48	0.27	0.28	0.69	0.01
TC92-01U	<.01	0.02	0.02	0.02	0.02	0.04	<.01
TC92-02D	NA*	NA	NA	NA	NA	NA	NA
TC92-02U	NA	NA	NA	NA	NA	NA	NA
TC92-03D	<.01	<.01	0.02	0.02	0.01	0.03	<.01
TC92-03U	0.02	0.07	0.07	0.05	0.05	0.15	0.01
TC92-04D	NA	NA	NA	NA	NA	NA	NA
TC92-04U	NA	NA	NA	NA	NA	NA	NA
TC92-05D	NA	NA	NA	NA	NA	NA	NA
TC92-05U	NA	NA	NA	NA	NA	NA	NA
TC92-06D	<.01	0.02	0.02	0.02	0.02	0.04	<.01
TC92-06U	<.01	0.02	0.02	0.02	0.01	0.06	0.01
TC92-07D	NA	NA	NA	NA	NA	NA	NA
TC92-07U	NA	NA	NA	NA	NA	NA	NA
TC92-08D	NA	NA	NA	NA	NA	NA	NA
TC92-09D	0.46	2.82	2.49	1.87	2.23	5.07	0.04
TC92-10D	0.02	0.11	0.11	0.09	0.08	0.24	<.01

Table 7 (con't). Polycyclic aromatic hydrocarbon (PAH) concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	anthra-cene	benzo(a)-pyrene	benzo(b)-fluor-anthene	benzo(e)-pyrene	benzo-(g,h,i)-perylene	pyrene	napthalene
TC92-11D	NA	NA	NA	NA	NA	NA	NA
TC92-12D	0.08	0.13	0.10	0.08	0.07	0.25	0.04
TC92-13D	NA	NA	NA	NA	NA	NA	NA
TC92-14D	NA	NA	NA	NA	NA	NA	NA
TC92-15D	0.04	0.18	0.18	0.13	0.12	0.37	0.01
TC92-16D	NA	NA	NA	NA	NA	NA	NA
TC92-16U	NA	NA	NA	NA	NA	NA	NA
TC92-17D	<.01	0.02	0.02	0.02	0.01	0.04	<.01
TC92-17U	0.03	0.12	0.13	0.10	0.08	0.21	0.04
TC92-18D	NA	NA	NA	NA	NA	NA	NA
TC92-18U	NA	NA	NA	NA	NA	NA	NA
TC92-19D	NA	NA	NA	NA	NA	NA	NA
TC92-19U	NA	NA	NA	NA	NA	NA	NA
TC92-20D	0.02	0.07	0.07	0.06	0.06	0.16	0.08

*NA=not analyzed

Table 7 (con't). Polycyclic aromatic hydrocarbon (PAH) concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	benzo(k)-fluor-anthene	chrysene	fluor-anthene	fluorene	indeno-(1,2,3-cd) pyrene	perylene	phenanthrene
TC92-01D	0.50	0.35	0.71	0.02	0.28	0.21	0.34
TC92-01U	0.02	0.02	0.04	<.01	0.02	0.23	0.02
TC92-02D	NA*	NA	NA	NA	NA	NA	NA
TC92-02U	NA	NA	NA	NA	NA	NA	NA
TC92-03D	0.02	0.02	0.03	<.01	0.01	0.08	0.03
TC92-03U	0.07	0.09	0.17	<.01	0.05	0.17	0.10
TC92-04D	NA	NA	NA	NA	NA	NA	NA
TC92-04U	NA	NA	NA	NA	NA	NA	NA
TC92-05D	NA	NA	NA	NA	NA	NA	NA
TC92-05U	NA	NA	NA	NA	NA	NA	NA
TC92-06D	0.02	0.02	0.04	<.01	0.02	0.26	0.02
TC92-06U	0.02	0.03	0.07	<.01	0.01	0.23	0.05
TC92-07D	NA	NA	NA	NA	NA	NA	NA
TC92-07U	NA	NA	NA	NA	NA	NA	NA
TC92-08D	NA	NA	NA	NA	NA	NA	NA
TC92-09D	2.49	2.09	6.60	0.25	2.51	0.66	3.00
TC92-10D	0.11	0.16	0.30	0.01	0.08	0.26	0.13

Table 7 (con't). Polycyclic aromatic hydrocarbon (PAH) concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	benzo(k)-fluor-anthene	chrysene	fluor-anthene	fluorene	indeno-(1,2,3-cd) pyrene	perylene	phenanthrene
TC92-11D	NA	NA	NA	NA	NA	NA	NA
TC92-12D	0.10	0.13	0.28	0.04	0.08	0.07	0.28
TC92-13D	NA	NA	NA	NA	NA	NA	NA
TC92-14D	NA	NA	NA	NA	NA	NA	NA
TC92-15D	0.18	0.21	0.48	0.03	0.14	0.23	0.27
TC92-16D	NA	NA	NA	NA	NA	NA	NA
TC92-16U	NA	NA	NA	NA	NA	NA	NA
TC92-17D	0.02	0.03	0.04	<.01	0.01	0.11	0.02
TC92-17U	0.13	0.16	0.27	0.02	0.10	0.12	0.16
TC92-18D	NA	NA	NA	NA	NA	NA	NA
TC92-18U	NA	NA	NA	NA	NA	NA	NA
TC92-19D	NA	NA	NA	NA	NA	NA	NA
TC92-19U	NA	NA	NA	NA	NA	NA	NA
TC92-20D	0.07	0.09	0.17	0.01	0.05	0.21	0.10

*NA=not analyzed

Table 8. Total polychlorinated biphenhyl (PCB) and organochlorine pesticide concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Total PCBs	heptachlor epoxide	p,p'-DDD	p,p'-DDE	p,p'-DDT
TC92-01D	0.02	<.01	<.01	<.01	<.01
TC92-01U	<.01	<.01	<.01	<.01	<.01
TC92-02D	NA*	NA	NA	NA	NA
TC02-02U	NA	NA	NA	NA	NA
TC92-03D	<.01	<.01	<.01	<.01	<.01
TC92-03U	<.01	<.01	<.01	<.01	<.01
TC92-04D	NA	NA	NA	NA	NA
TC92-04U	NA	NA	NA	NA	NA
TC92-05D	NA	NA	NA	NA	NA
TC92-05U	NA	NA	NA	NA	NA
TC92-06D	<.01	<.01	<.01	<.01	<.01
TC92-06U	<.01	0.07	<.01	<.01	<.01
TC92-07D	NA	NA	NA	NA	NA
TC92-07U	NA	NA	NA	NA	NA
TC92-08D	NA	NA	NA	NA	NA
TC92-09D	0.03	<.01	0.02	0.02	<.01
TC92-10D	<.01	<.01	<.01	<.01	<.01

Table 8 (con't). Total polychlorinated biphenhyl (PCB) and organochlorine pesticide concentrations (ppm, dry weight) in sediment samples from UMRNW&FR, July, 1992.

Sample #	Total PCBs	heptachlor epoxide	p,p'-DDD	p,p'-DDE	p,p'-DDT
TC92-11D	NA	NA	NA	NA	NA
TC92-12D	0.02	<.01	<.01	<.01	<.01
TC92-13D	NA	NA	NA	NA	NA
TC92-14D	NA	NA	NA	NA	NA
TC92-15D	0.02	<.01	<.01	<.01	<.01
TC92-16D	NA	NA	NA	NA	NA
TC92-16U	NA	NA	NA	NA	NA
TC92-17D	0.02	<.01	<.01	<.01	<.01
TC92-17U	<.01	<.01	<.01	<.01	<.01
TC92-18D	NA	NA	NA	NA	NA
TC92-18U	NA	NA	NA	NA	NA
TC92-19D	NA	NA	NA	NA	NA
TC92-19U	NA	NA	NA	NA	NA
TC92-20D	0.02	<.01	<.01	<.01	<.01

*NA=not analyzed

No detections occurred in the following compounds: aldrin, hexachlorobenzene, heptachlor, alpha BHC, alpha chlordane, beta BHC, cis-nonachlor, delta BHC, dieldrin, endrin, gamma BHC, gamma chlordane, mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, oxychlordane, toxaphene, and trans-nonachlor.

Table 9. As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn Concentrations to Mn Concentrations (X 10^4) in Sediments from this study and Wiener et al. (1984)* along the UMRNW&FR (reported for Pools 4-10 only).

Facility Location	Approx. Sample Number	River Mile	Pool	As/Mn	Cd/Mn	Cr/Mn	Cu/Mn
*		615.6	10	48	4.0	--	--
Prairie du Chien WI	TC9201D	633.5	10	70	10	400	500
	TC9201U			50	10	200	200
*		648.7	9	37	2.3	--	--
Interstate Power Co. Lansing, IA	TC9206D	660.2	9	30	3.0	100	100
	TC9206U	659.9		50	4.0	200	100
Lansing, IA	TC9207D	663.0	9	60	6.0	200	400
	TC9207U			50	5.0	200	300
Genoa Power Plant Genoa, WI	TC9213D	678.5	9	500	100	1800	1000
*		680.1	8	42	4.0	--	--
Stoddard, WI	TC9214D	685.6	8	80	30	300	2700
Brownsville, MN	TC9208D	688.2	8	30	2.0	200	100
Heilmen/Norplex LaCrosse, WI	TC9209D	696.7	8	70	8.0	300	400
Isle La Plume LaCrosse, WI	TC9210D	696.7	8	50	6.0	200	300
LaCrescent, MN	TC9211D	699.0	7	100	40.0	800	4700
*		702.7	7	35	9.6	--	--

Table 9 (con't). As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn Concentrations to Mn Concentrations (X 10^4) in Sediments from this study and Wiener et al. (1984)* along the UMRNW&FR (reported for Pools 4-10 only).

Facility Location	Approx. Sample Number	River Mile	Pool	As/Mn	Cd/Mn	Cr/Mn	Cu/Mn
Trempealeau, WI	TC9216D	714.0	7	20	0.7	60	30
*		715.0	6	103	2.6	--	--
Winona, MN	TC9218D TC9218U	722.8	6	100 100	5.0 5.0	400 400	200 200
Winona-North end, MN	TC9217D TC9217U	726.3 727.3	6	70 20	8.0 2.0	400 100	300 100
*		729.5	5A	31	8.7	--	--
*		733.4	5A	24	1.0	--	--
*		739.8	5	47	3.7	--	--
*		743.0	5	42	1.3	--	--
Dairyland Power Alma, WI	TC9220D	751.2	5	100	8.0	300	300
*		753.5	4	50	2.1	--	--
Wabasha, MN	TC9219D TC9219U	757.8	4	300 500	100 100	2000 1900	5900 4500
*		765.2	4	35	21.0	--	--

Table 9 (con't). As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn Concentrations to Mn Concentrations (X 10^4) in Sediments from this study and Wiener et al. (1984)* along the UMRNW&FR (reported for Pools 4-10 only).

Facility Location	Approx. Sample Number	River Mile	Pool	Hg/Mn	Ni/Mn	Pb/Mn	Zn/Mn
*		615.6	10	0.2	--	80	--
Prairie du Chien WI	TC9201D	633.5	10	4.0	200	500	1640
	TC9201U			0.5	200	200	830
*		648.7	9	0.9	--	28	--
Interstate Power Co. Lansing, IA	TC9206D	660.2	9	0.3	100	100	500
	TC9206U	659.9		0.5	200	100	600
Lansing, IA	TC9207D	663.0	9	5.0	200	300	1300
	TC9207U			0.7	200	200	1000
Genoa Power Plant Genoa, WI	TC9213D	678.5	9	3.0	1000	500	3500
*		680.1	8	0.6	--	59	--
Stoddard, WI	TC9214D	685.6	8	8.0	400	700	7100
Brownsville, MN	TC9208D	688.2	8	0.3	200	100	700
Heilmen/Norplex LaCrosse, WI	TC9209D	696.7	8	1.0	300	400	1800
Isle La Plume LaCrosse, WI	TC9210D	696.7	8	1.0	200	200	1000
LaCrescent, MN	TC9211D	699.0	7	30.0	800	1600	11500
*		702.7	7	0.4	--	130	--

Table 9 (con't). As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn Concentrations to Mn Concentrations (X 10^4) in Sediments from this study and Wiener et al. (1984)* along the UMRNW&FR (reported for Pools 4-10 only).

Facility Location	Approx. Sample Number	River Mile	Pool	Hg/Mn	Ni/Mn	Pb/Mn	Zn/Mn
Trempealeau, WI	TC9216D	714.0	7	0.1	30	30	100
*		715.0	6	0.1	--	34	--
Winona, MN	TC9218D	722.8	6	3.0	300	100	1600
	TC9218U			2.0	300	300	1200
Winona-North end, MN	TC9217D	726.3	6	1.0	300	200	1200
	TC9217U	727.3		0.2	70	70	400
*		729.5	5A	0.1	74		
*		733.4	5A	0.0	--	9	--
*		739.8	5	0.6	--	42	--
*		743.0	5	0.3	--	69	--
Dairyland Power Alma, WI	TC9220D	751.2	5	1.0	200	200	1100
*		753.5	4	0.2	--	23	--
Wabasha, MN	TC9219D	757.8	4	50.0	1700	2800	16000
	TC9219U			40.0	1600	2100	11900
*		765.2	4	1.2	--	200	--

* Sediment collections included cross-sectional transects at 19 main channel and backwater locations.

Table 10. Comparisons of metal enrichment by pools in sediments from this study and Wiener et al. (1984) on the UMRNW&FR.

Pool	Study[a]	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
10	USFWS	60	10	300	350	<1	200	350	1235
	Wiener	48	4	*	*	2	*	80	*
9	USFWS	138	24	500	380	2	340	240	1380
	Wiener	37	2	*	*	1	*	28	*
8	USFWS	58	12	250	875	3	275	350	2650
	Wiener	42	4	*	*	1	*	59	*
7	USFWS	60	20	430	2365	15	415	815	5800
	Wiener	35	10	*	*	<1	*	130	*
6	USFWS	73	5	325	200	2	243	168	1100
	Wiener	103	3	*	*	<1	*	34	*
5A	USFWS	*	*	*	*	*	*	*	*
	Wiener	28	5	*	*	1	*	74	*
5	USFWS	100	8	300	300	1	200	200	1100
	Wiener	45	3	*	*	<1	*	56	*
4	USFWS	400	100	1950	5200	45	1650	2450	13950
	Wiener	43	12	*	*	1	*	11	*

[a] USFWS = this study - utilized averages of each pool's metal/Mn concentration ratios for metal enrichment comparisons;
Wiener = Wiener et al. 1984 - utilized metal/Mn concentration ratios for metal enrichment comparison.

* = not analyzed

Table 11. Inhibition of *Photobacterium phosphoreum* bioluminescence (EC50<100%) by 5 and 15-minute incubation with pore water (100% assay procedure) extracted from sediments collected at select NPDES permit discharge sites on the UMRNW&FR, 1992*.

Sample	Location	Test Time[a]	EC50[b]	R	R^2	Slope
TC9207	Lansing, IA	E5	54.04	0.98	0.96	1.05
		E15	99.55	0.98	0.95	0.88
TC9211	LaCrescent, MN	E5	12.17	0.99	0.97	2.02
		E15	13.91	0.98	0.96	2.31
TC9214	Stoddard, WI	E5	59.14	0.99	0.99	0.84
		E15	>100.00*			
TC9217	Winona, MN (North end)	E5	65.44	0.98	0.95	1.22
		E15	83.86	0.98	0.96	0.95
TC9219	Wabasha, MN	E5	24.47	0.99	0.99	1.2
		E15	29.52	0.99	0.99	1.1

[a] Exposure time of test organisms to the sample (5 minutes and 15 minutes).

[b] The sample concentration that reduces the reagent light output by 50%. This value is obtained by calculating the point at which Gamma equals 1.0 on the dose-response curve. The effect measured by the Microtox System, light loss, is a rate of biological activity, rather than a count of organisms affected. The light is a byproduct of the organism's respiration, and reflects change in respiration.

* All other NPDES permit sites sampled for this study reflected non-toxicity with EC50 estimates greater than 100%. This does not mean that these sediment pore waters did not cause some inhibition of luminescence of *P. phosphoreum*, but rather that it would take a pore water concentration of greater than 100% to cause a 90% reduction in bioluminescence.

Table 12. Microtox, metal enrichment, and sediment guideline exceedence (✓) results for wastewater treatment facilities and industrial sites on the UMRNW&FR, July, 1992.

Location	Sample Number	Microtox EC50<100%	Sediment Guidelines*				
			OMOE		NOAA		
			>LOTL	>LEL	>ER-L	>ER-M	>AET
Prairie du Chien, WI	01D			✓	✓		✓
	01U			✓			
McGregor, IA	02D						
	02U						
Marquette, IA	03D						
	03U						
Harper's Ferry, IA	04D						
	04U						
Ferryville, WI	05D						
	05U						
Interstate Power Lansing, IA	06D		✓	✓			
	06U			✓			
Lansing, IA	07D	✓		✓	✓		
	07U			✓			
Brownsville, MN	08D		✓	✓			
Heileman/Norplex/ stormwater LaCrosse, WI	09D				✓	✓	✓
Isle La Plume LaCrosse, WI	10D			✓			

* refer to Table 6 for list of specific compounds

Table 12 (con't). Microtox, metal enrichment, and sediment guideline exceedence (✓) results for wastewater treatment facilities and industrial sites on the UMRNW&FR, July, 1992.

Location	Sample Number	Microtox EC50<100%	Sediment Guidelines*				
			OMOE		NOAA		
			>LOTL	>LEL	>ER-L	>ER-M	>AET
LaCrescent, MN	11D	✓		✓	✓		
Barron Island LaCrosse, WI	12D				✓		✓
Genoa Power Genoa, WI	13D			✓			
Stoddard, WI	14D	✓	✓	✓	✓	✓	✓
Metallics, Inc. LaCrosse, WI	15D				✓		✓
Trempealeau, WI	16D		✓	✓			
	16U						
Winona-North end MN	17D	✓					
	17U		✓	✓			
Winona, MN	18D						
	18U						
Wabasha, MN	19D	✓		✓	✓		
	19U			✓	✓		
Dairyland Power and Alma, WI	20D			✓			

* refer to Table 6 for list of specific compounds

Table 12 (con't). Microtox, metal enrichment, and sediment guideline exceedence (✓) results for wastewater treatment facilities and industrial sites on the UMRNW&FR, July, 1992.

Location	Sample Number	Metal Enrichment (>25%)							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Prairie du Chien, WI	01D								
	01U								
McGregor, IA	02D								
	02U								
Marquette, IA	03D								
	03U								
Harper's Ferry, IA	04D								
	04U								
Ferryville, WI	05D								
	05U								
Interstate Power Lansing, IA	06D								
	06U								
Lansing, IA	07D								
	07U								
Brownsville, MN	08D								
Heileman/Norplex/ stormwater LaCrosse, WI	09D								
Isle La Plume LaCrosse, WI	10D								

Table 12 (con't). Microtox, metal enrichment, and sediment guideline exceedence (✓) results for wastewater treatment facilities and industrial sites on the UMRNW&FR, July, 1992.

Location	Sample Number	Metal Enrichment (>25%)							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
LaCrescent, MN	11D		✓	✓	✓	✓	✓	✓	✓
Barron Island LaCrosse, WI	12D								
Genoa Power	13D	✓	✓	✓			✓		
Genoa, WI									
Stoddard, WI	14D		✓		✓			✓	✓
Metallics, Inc. LaCrosse, WI	15D								
Trempealeau, WI	16D								
	16U								
Winona-North end MN	17D								
	17U								
Winona, MN	18D								
	18U								
Wabasha, MN	19D	✓	✓	✓	✓	✓	✓	✓	✓
	19U	✓	✓	✓	✓	✓	✓	✓	✓
Dairyland Power and Alma, WI	20D								

FIGURES

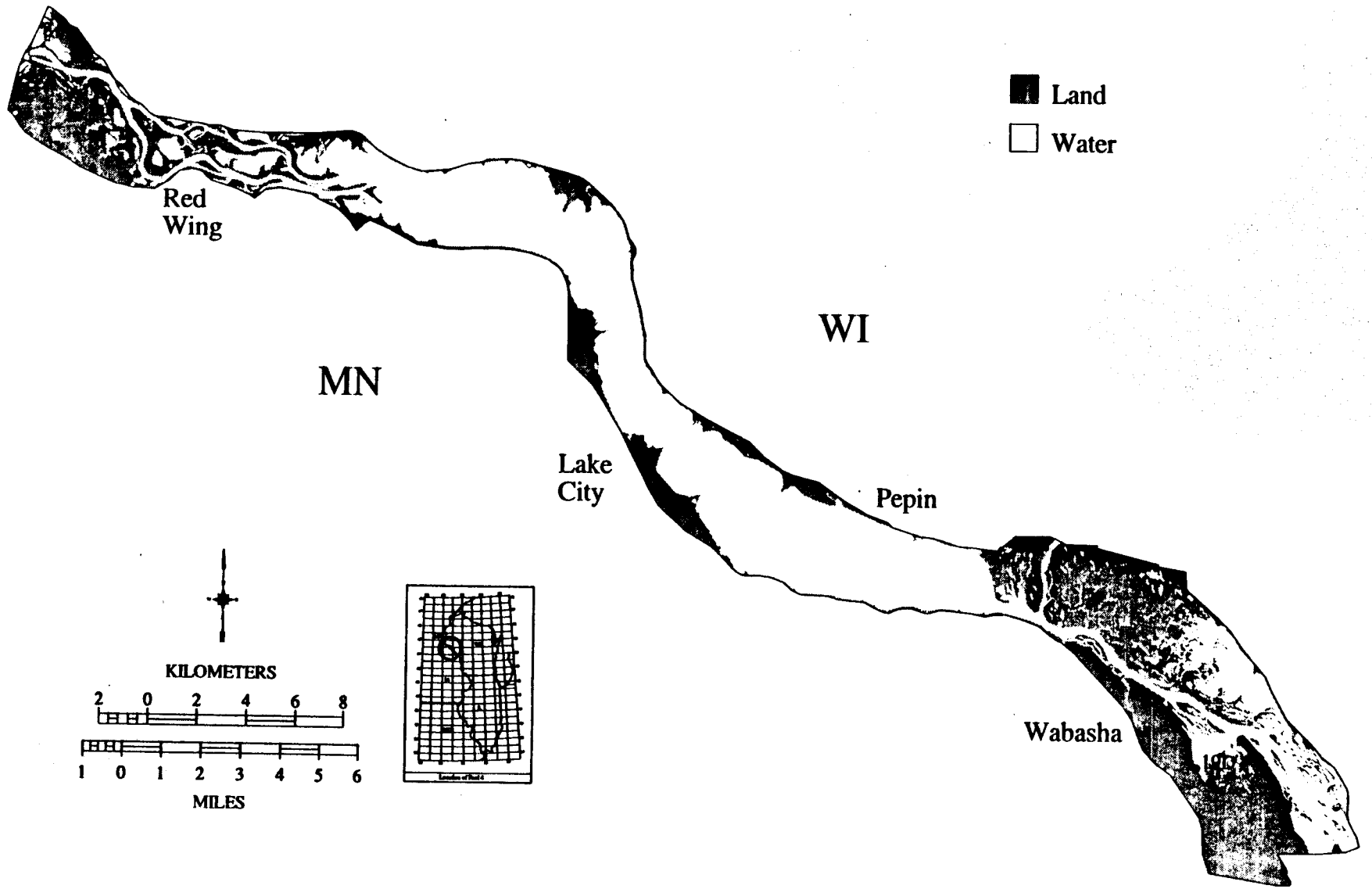

Figure 1. Sites along Pool 4, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

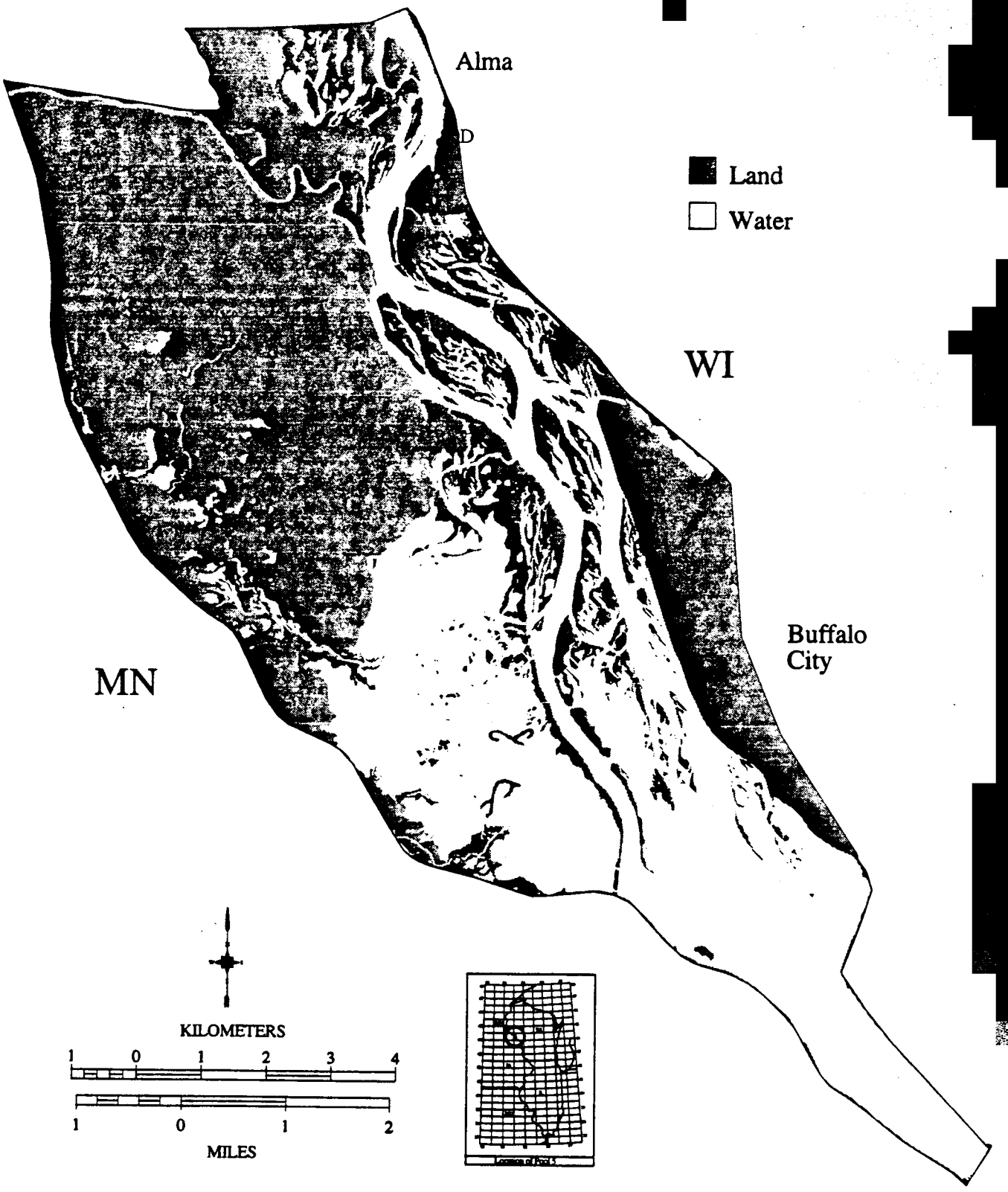

Figure 2. Sites along Pool 5, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

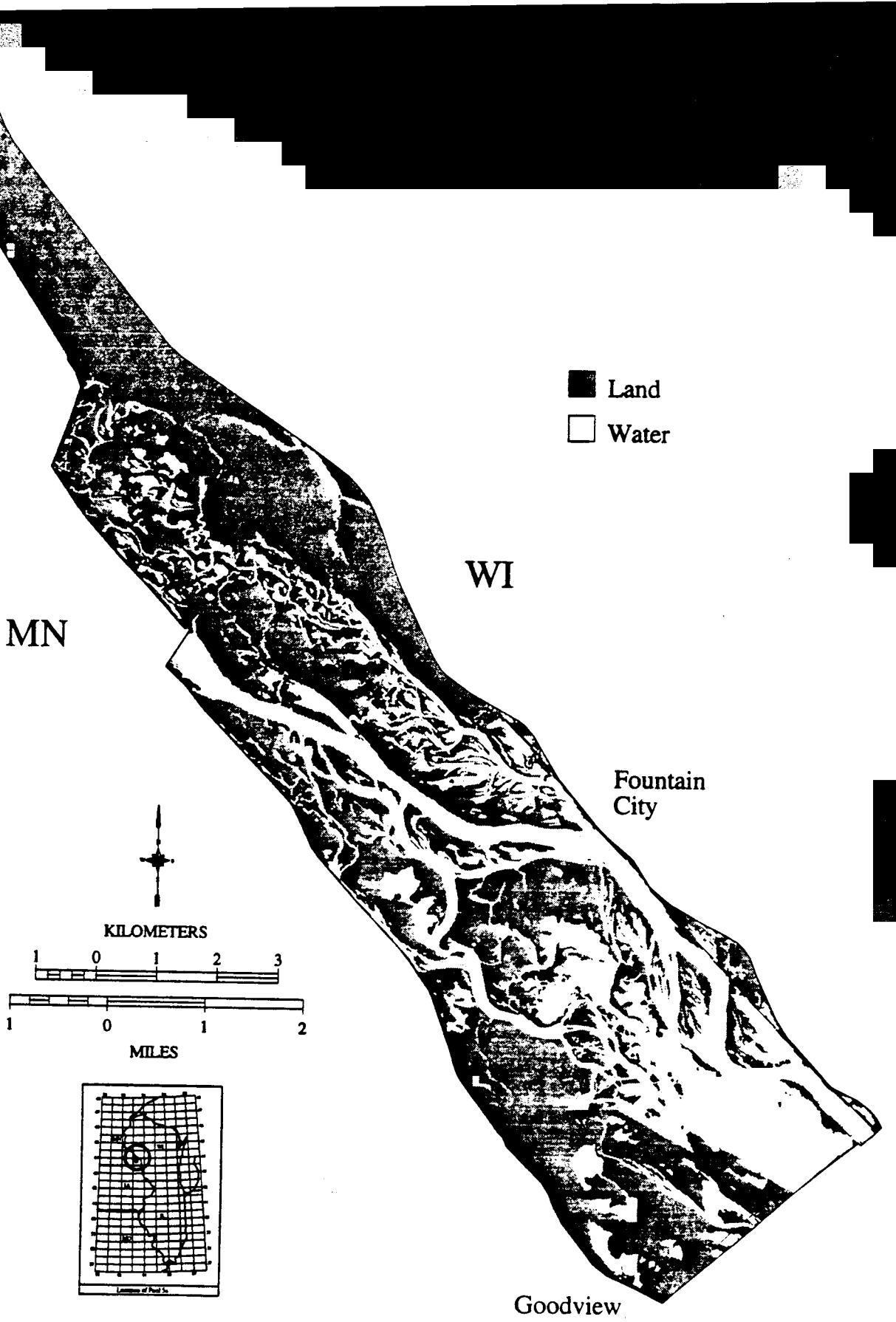

Figure 3. Pool 5A, Upper Mississippi River (no sediments were sampled in July, 1992).

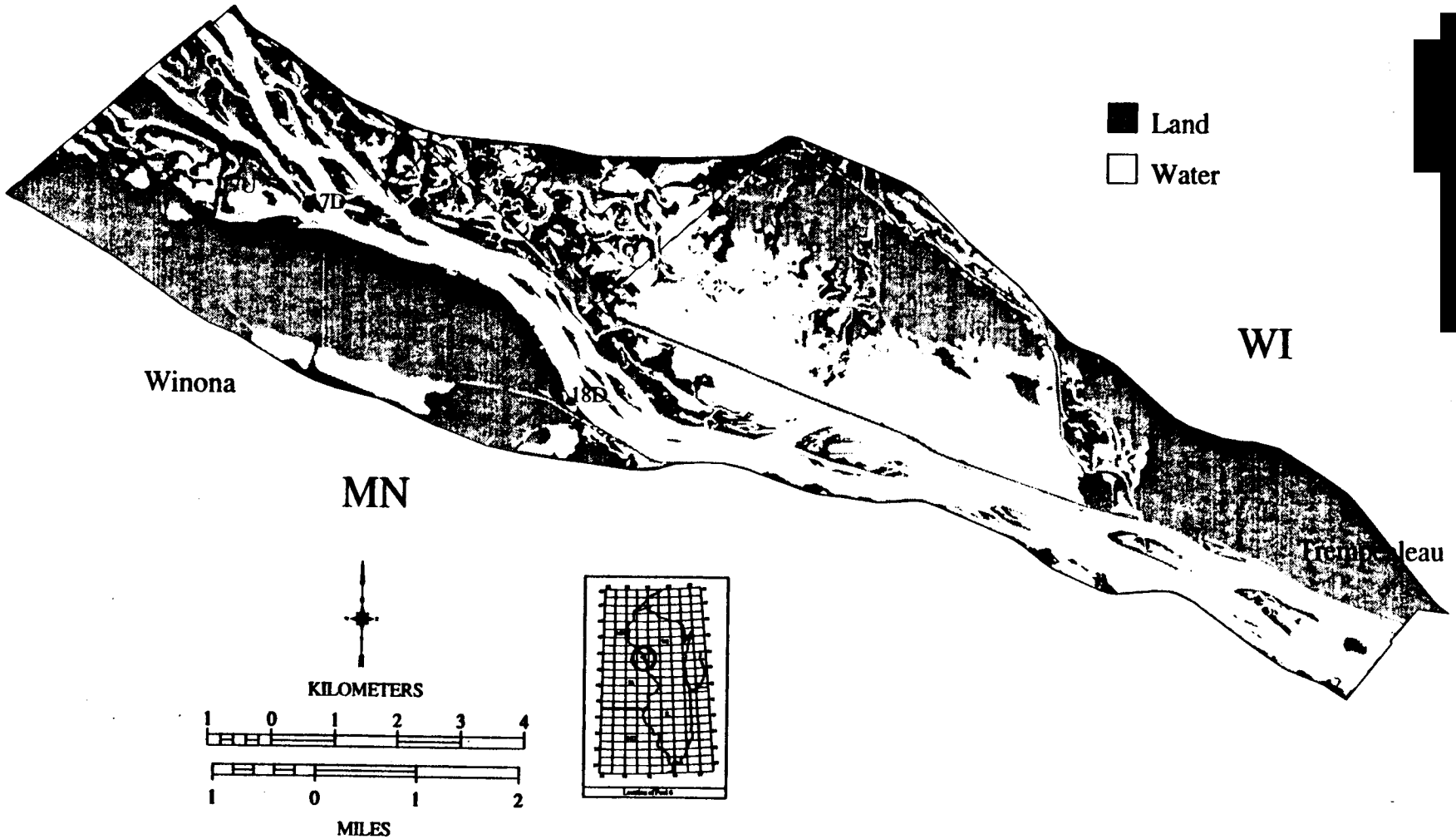

Figure 4. Sites along Pool 6, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

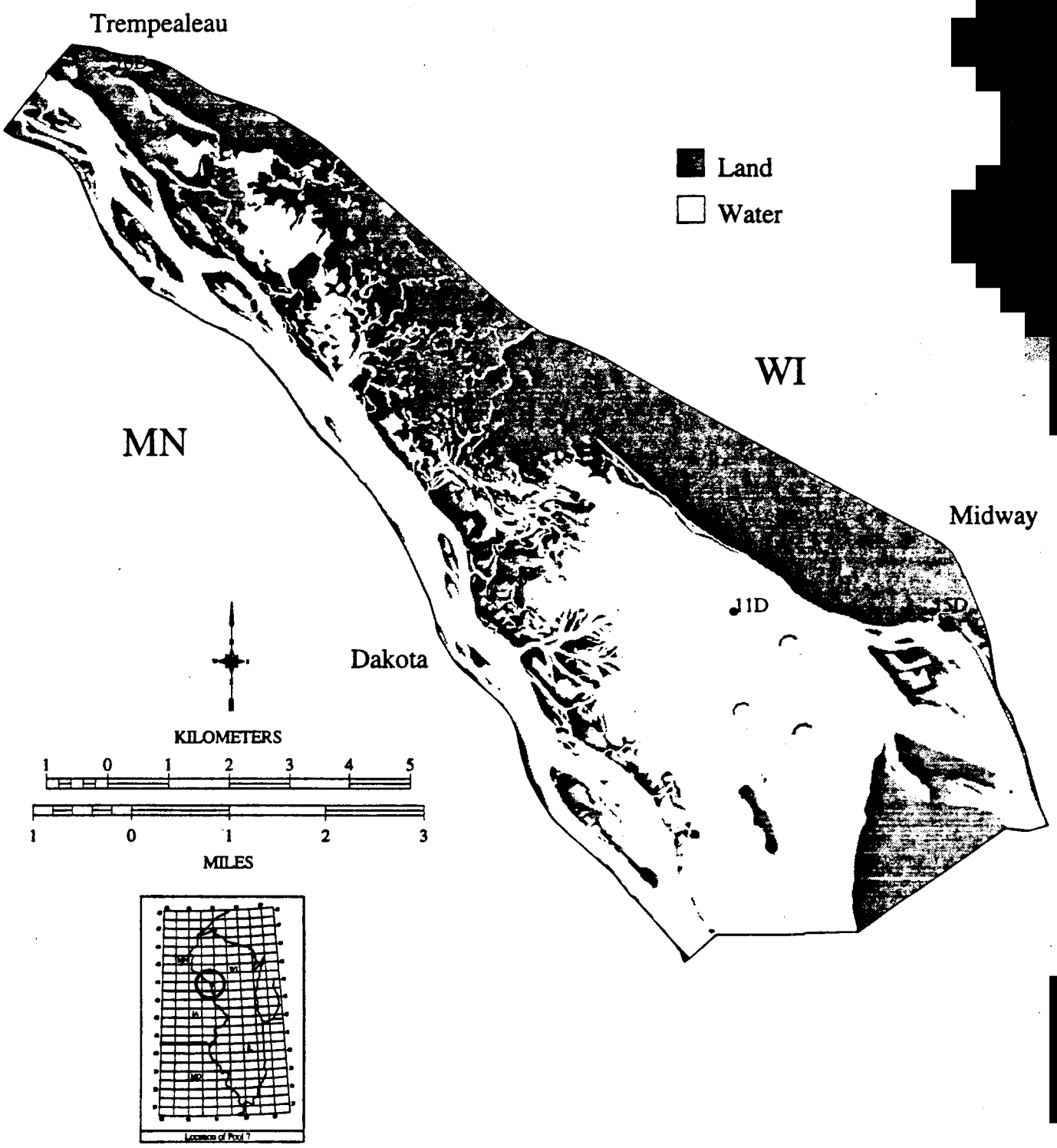

Figure 5. Sites along Pool 7, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

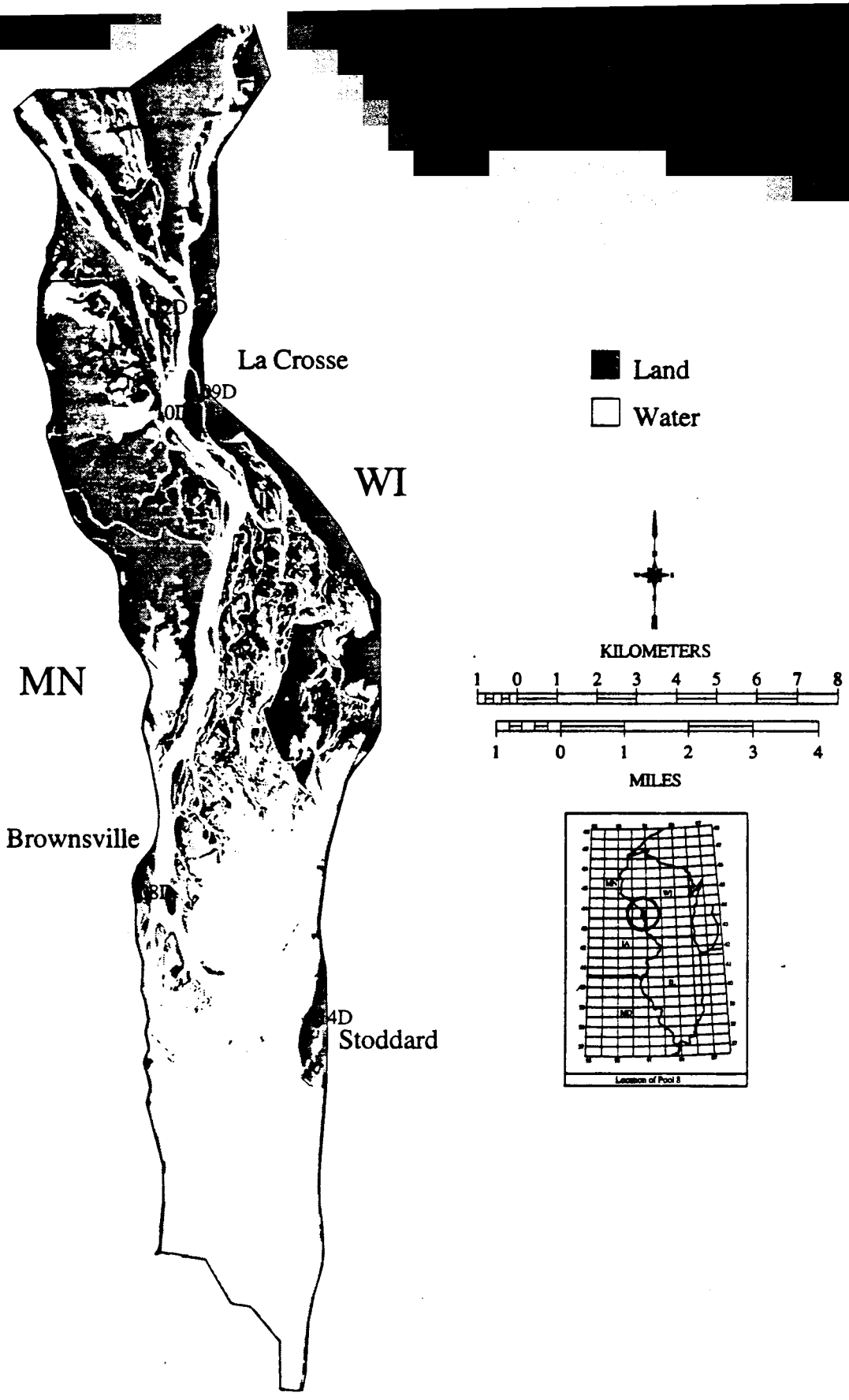

Figure 6. Sites along Pool 8, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

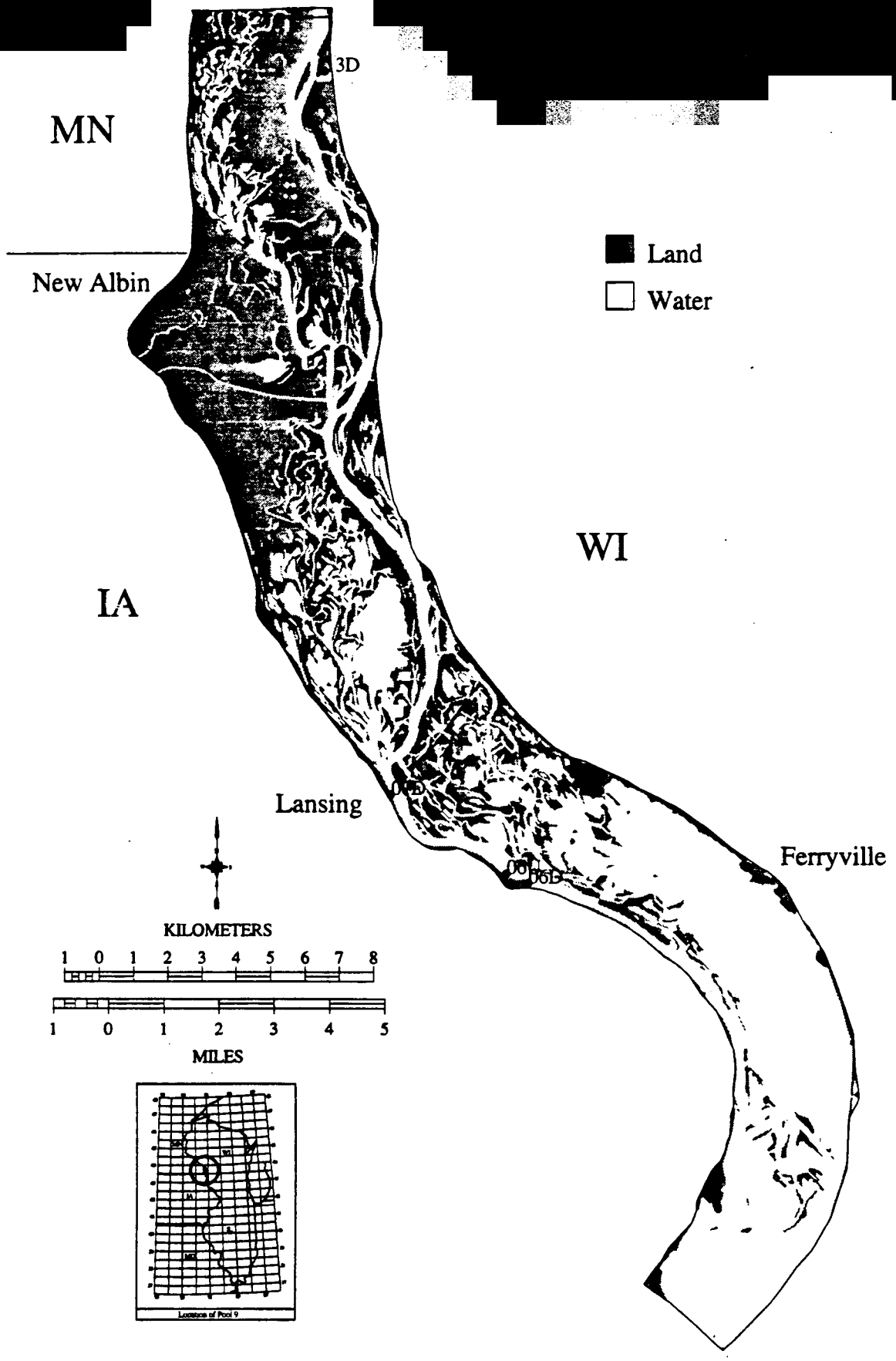

Figure 7. Sites along Pool 9, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

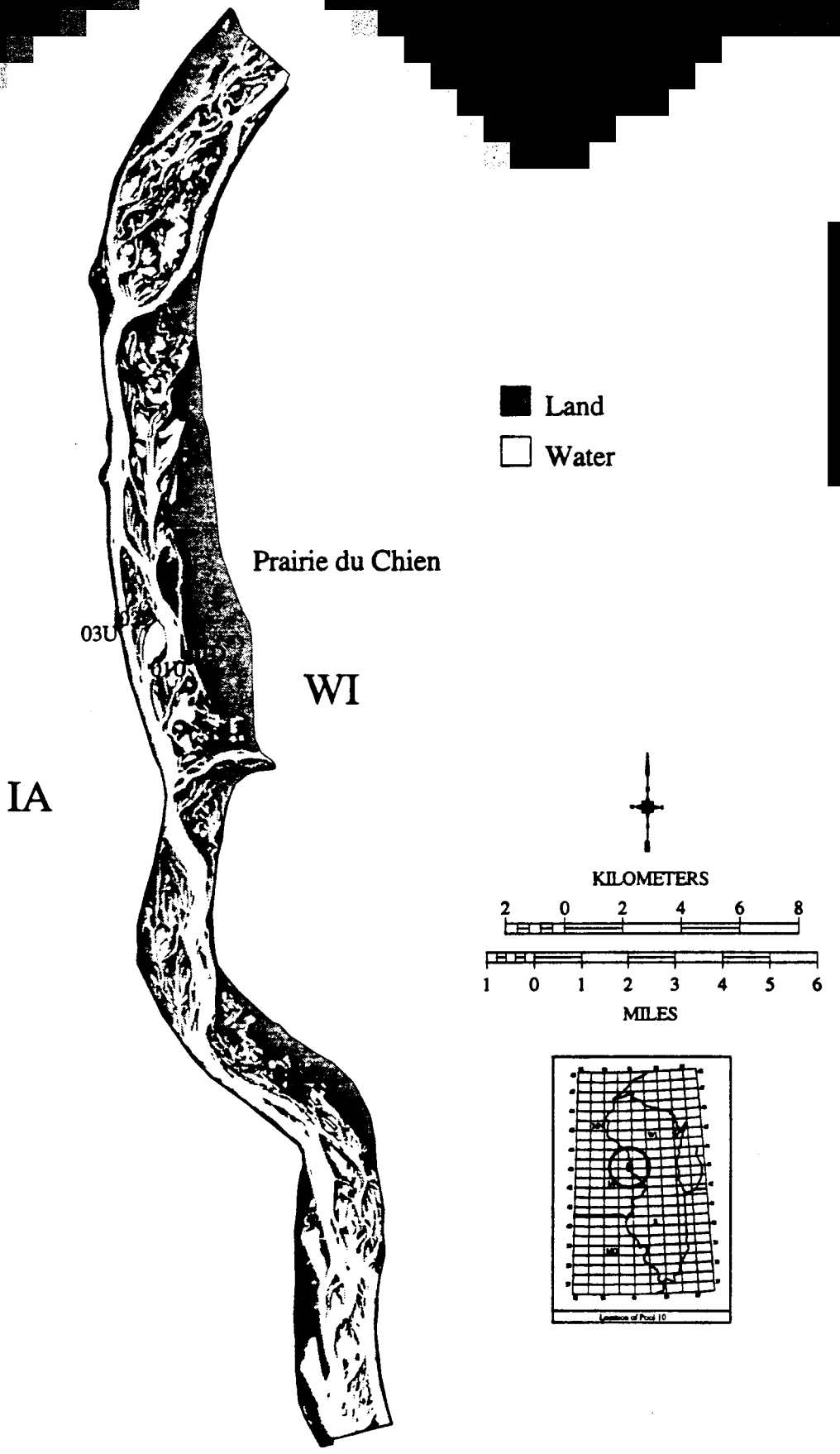

Figure 8. Sites along Pool 10, Upper Mississippi River, where sediments were sampled in July, 1992 (numbers indicate sample numbers).

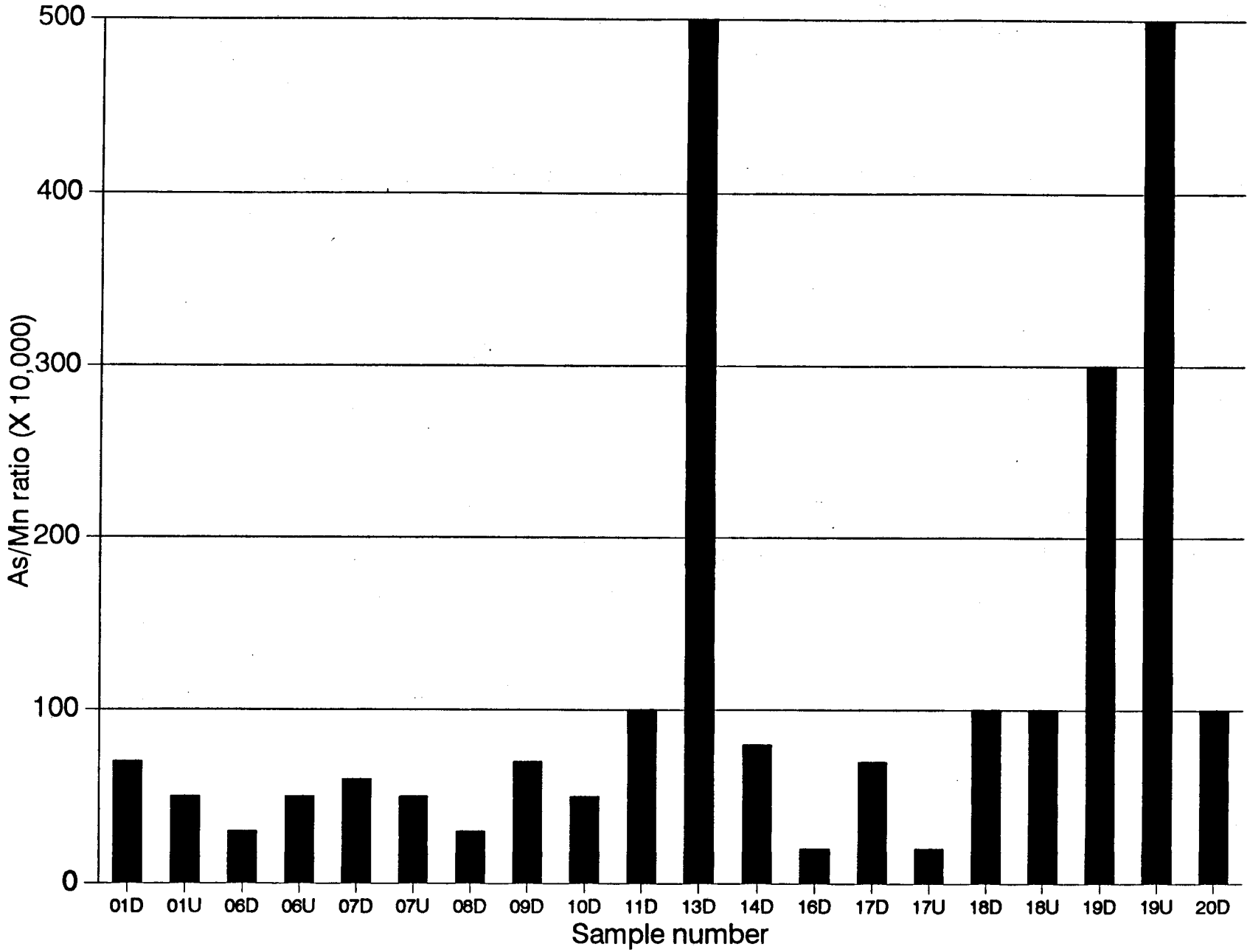

Figure 9. Ratios for arsenic/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

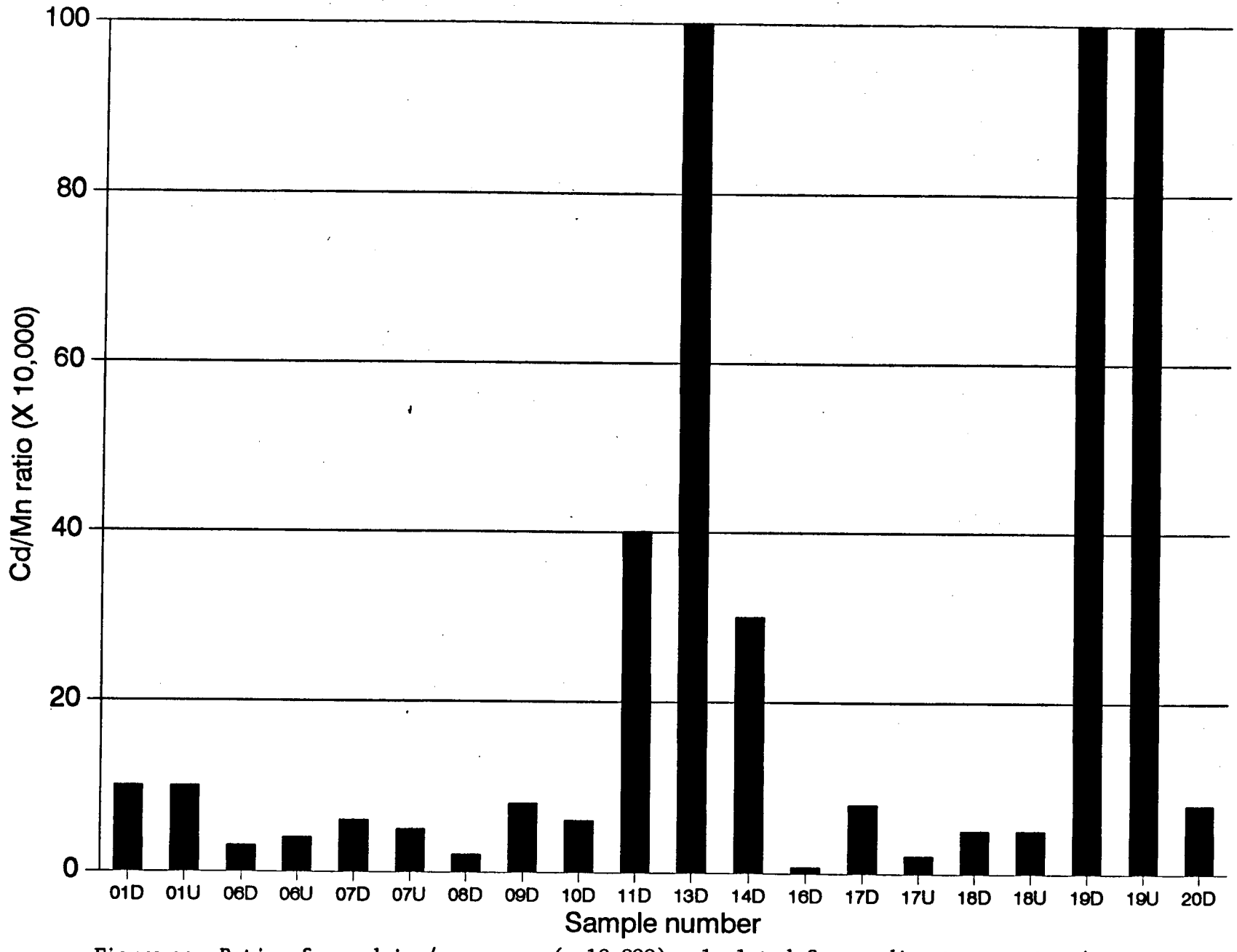

Figure 10. Ratios for cadmium/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

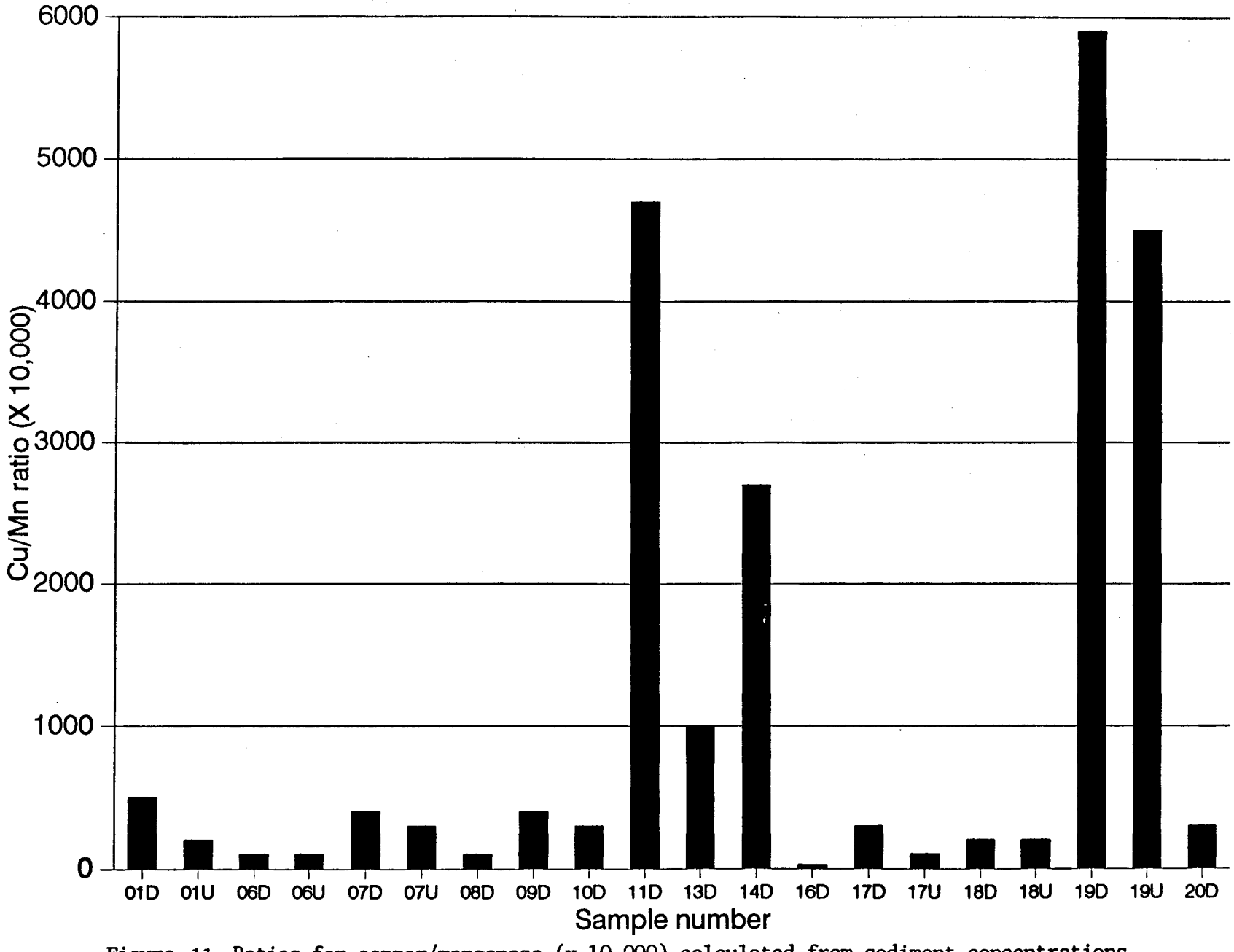

Figure 11. Ratios for copper/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

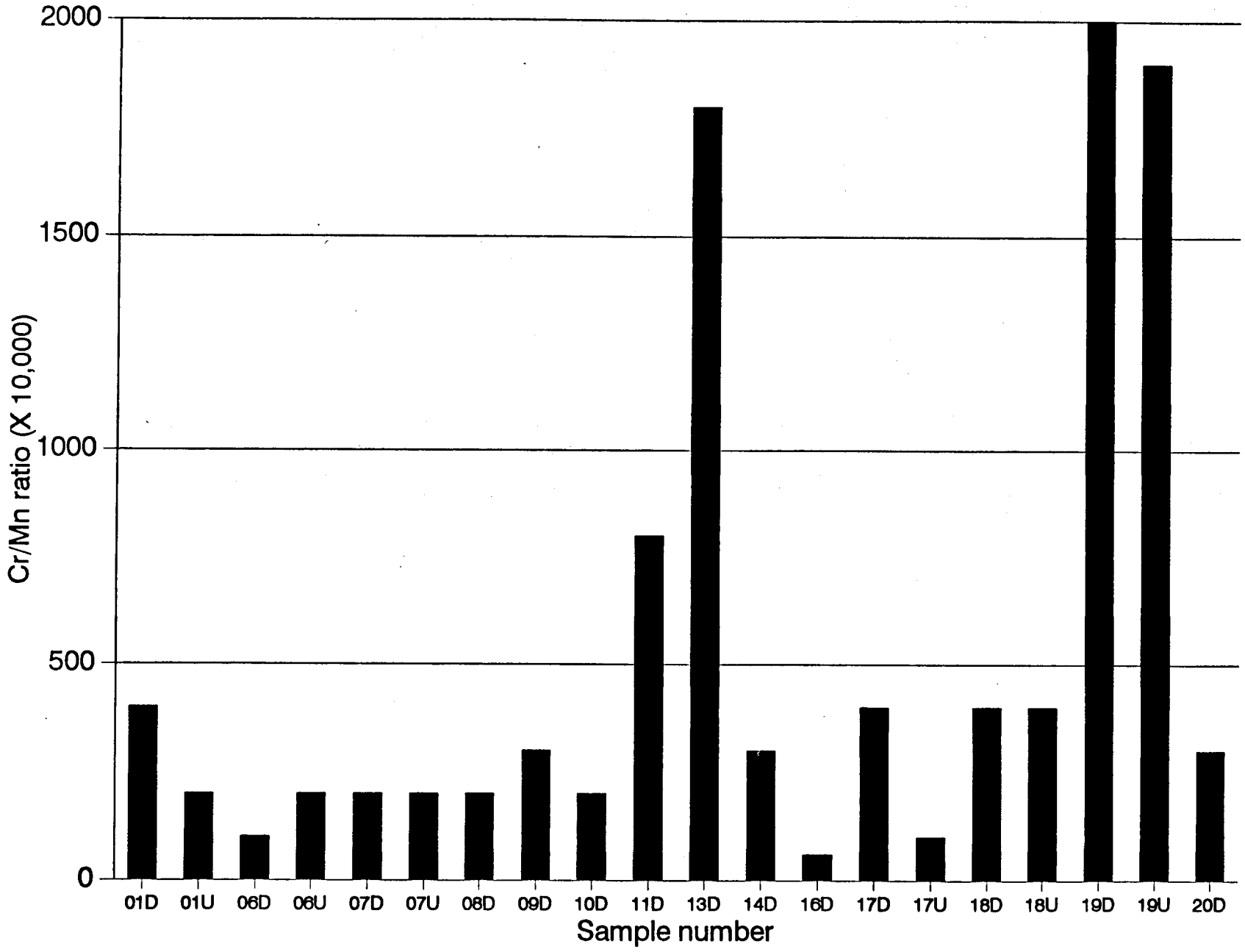

Figure 12. Ratios for chromium/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

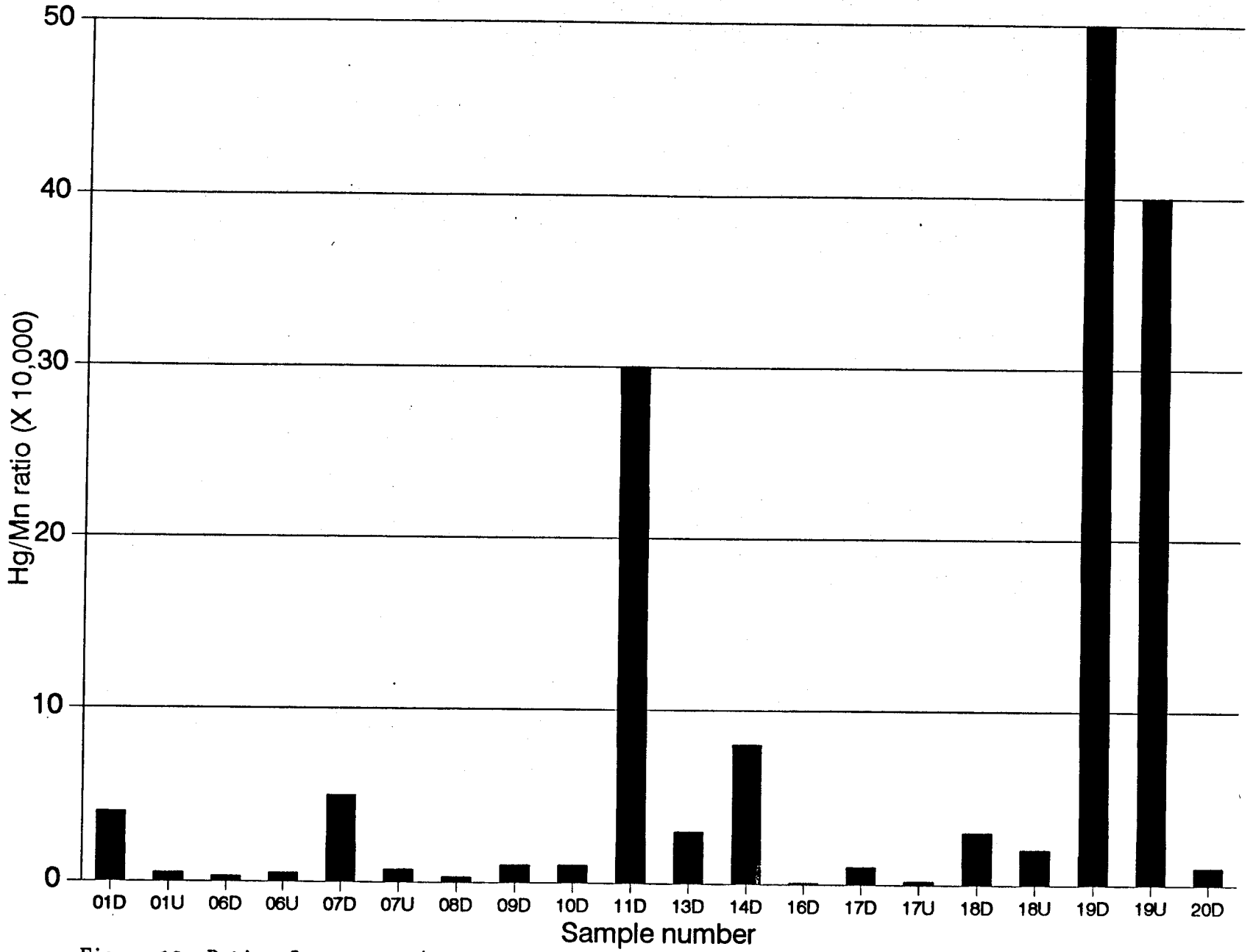

Figure 13. Ratios for mercury/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

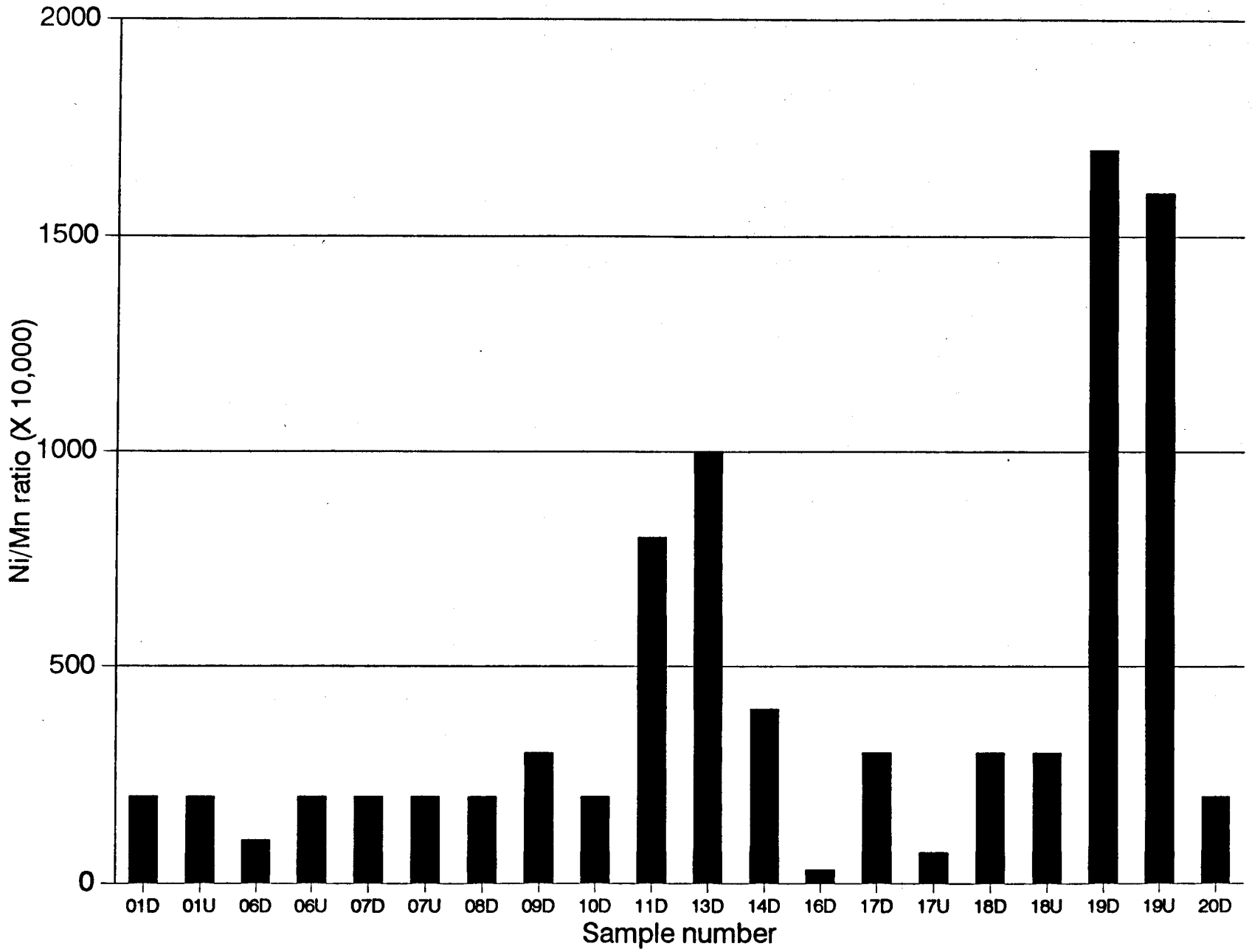

Figure 14. Ratios for nickel/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

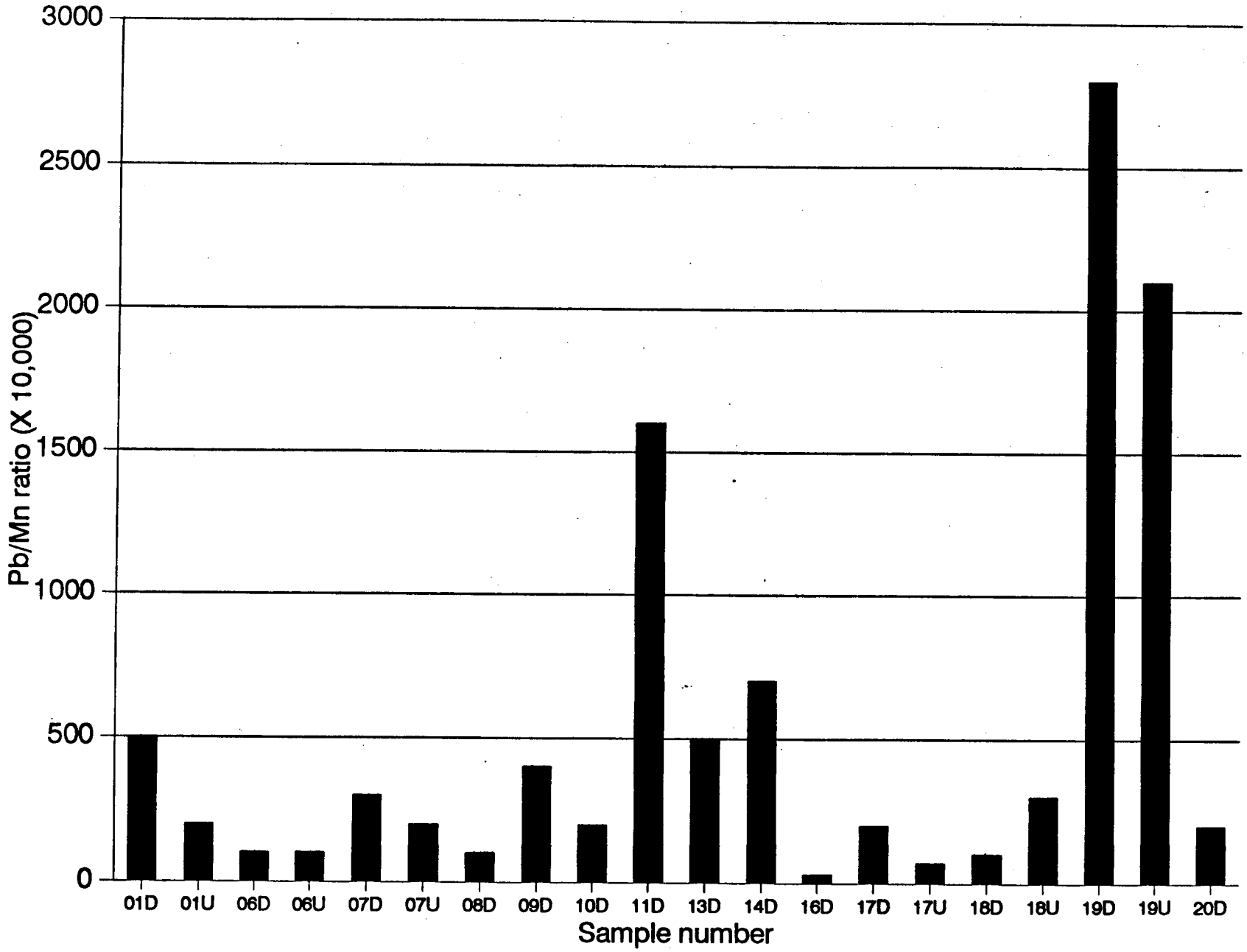

Figure 15. Ratios for lead/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

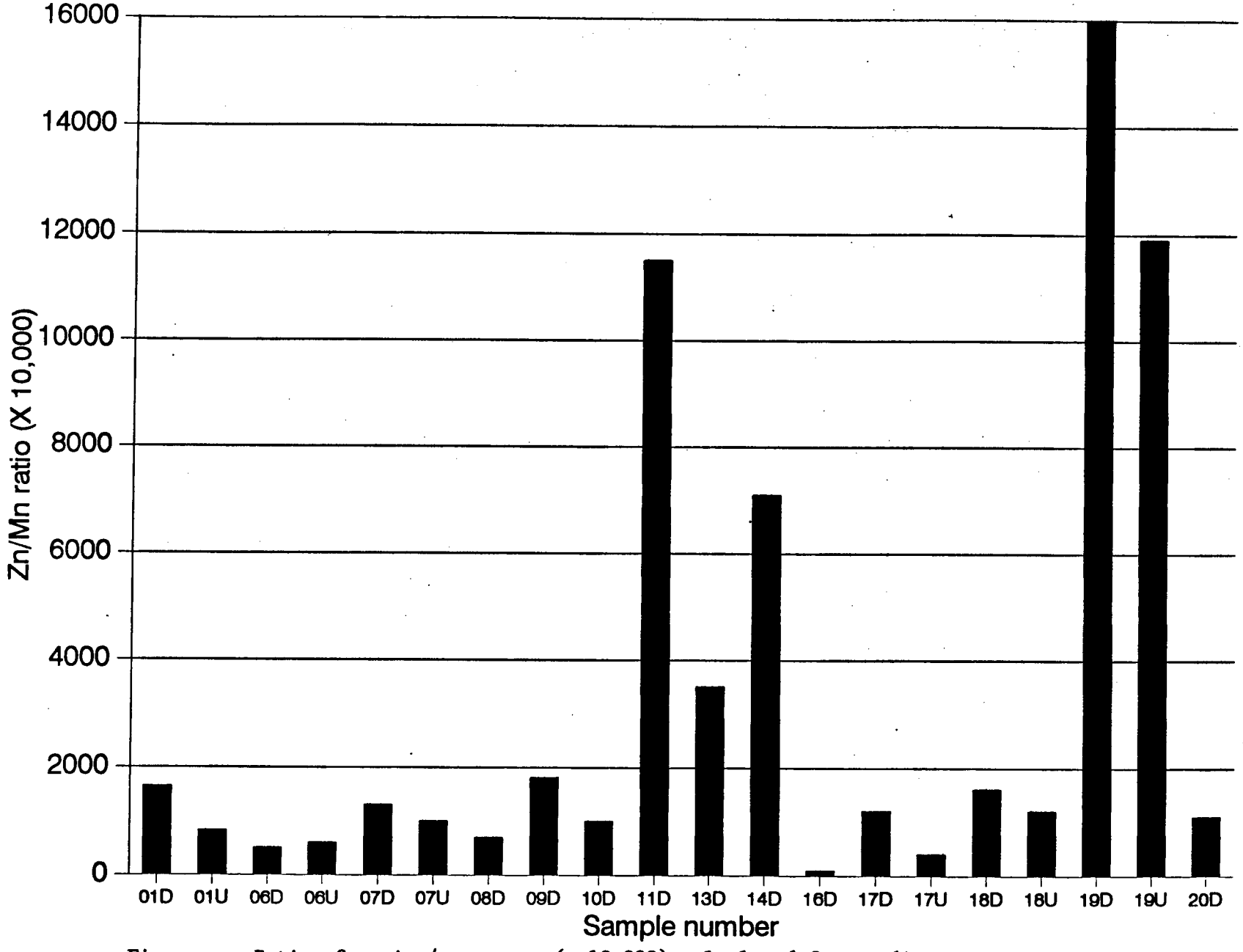

Figure 16. Ratios for zinc/manganese (x 10,000) calculated from sediment concentrations collected on the UMRNW&FR, July, 1992.

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