CONTAMINANT CONCENTRATIONS IN STORMWATER FROM EIGHT LAKE SUPERIOR BASIN CITIES, 1993–94

By J.J. Steuer, W.R. Selbig, and N.J. Hornewer

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CONTENTS

FIGURE

TABLES

CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To Obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter

Abbreviated water-quality units used in this report: Chemical concentration and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

Contaminant Concentrations in Stormwater from Eight Lake Superior Basin Cities, 1993–94

By J.J Steuer, W.R. Selbig *and* N.J. Hornewer

Abstract

The U.S. Geological Survey collected stormwater samples from eight Lake Superior Basin cities to determine the quality of urban runoff entering Lake Superior from urban areas. The samples were collected during July 1993–September 1994 from storm sewers in Ishpeming, Negaunee, Sault Ste. Marie, and Houghton, Michigan; Virginia and Hibbing, Minnesota; and Ashland and Hurley, Wisconsin. Automated samplers were installed in manholes draining the selected sewers within each city. Water samples were collected for analyses of total recoverable metals, nutrients, and polycyclic aromatic hydrocarbons. Concentrations of these constituents for each site are listed in data tables.

INTRODUCTION

Lake Superior, the largest of the Great Lakes, is bordered by parts of Minnesota, Wisconsin, Michigan, and Canada (fig. 1). The governments of Canada and the United States, as part of the Lake Superior Binational Program, have begun to monitor water-quality characteristics and the influx of contaminants to Lake Superior and its tributaries. The United States effort is coordinated by the U.S. Environmental Protection Agency (USEPA), with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Geological Survey (USGS) as cooperating agencies.

Stormwater from eight Lake Superior Basin cities in the United States with populations greater than 5,000 people was monitored by the USGS for conventional stormwater constituents such as common ions, nutrients, bacteria, metals, and polycyclic aromatic hydrocarbons (PAH) during July 1993 to September 1994. A more extensive constituent list, including additional organic compounds, was used in a separate phase of the study that focused on more populated Lake Superior cities. Water analyses were done by the Wisconsin State Laboratory of Hygiene (WSLH). The eight sampled basins contained mixed land uses ranging from heavy commercial and industrial to predominantly residential areas. Time composite water-quality data obtained from rainfall events will be used to educate cities regarding selected constituents in their urban runoff and to determine whether small communities need to be included in the stormwater permitting process. Additionally, the data collected by the WDNR and the USGS will be used in the urban component of the overall analysis of contaminant loading to Lake Superior.

The conscientious efforts of Wallace Larson, John Knudson, Brett Esser, Dan Olson, Thomas Gambucci of the USGS; and John Thomas of the Minnesota Pollution Control Agency were crucial to the success of this project. Their attention to detail during equipment installation coupled with their consistent quality control procedures during sampler servicing and sample processing ensured data quality.

SAMPLE-COLLECTION PROCEDURES

Model 3700 non-refrigerated ISCO[1] automated samplers equipped with four 1-gallon bottles, were suspended from storm-sewer manholes to obtain the stormwater samples. A 3/8-in. Teflon sample suction tube was weighted with a polycarbonate rod and freely suspended 2 to 4 in. above the bottom of the storm-sewer pipe. The sample line in Houghton, Mich., was secured to the storm-sewer pipe perpendicular to the flow direction. Care was taken to ensure that the securing materials did not contact the sampled water. The Teflon sample line was purged prior to and immediately after obtaining a sample. The open collection bot-

[1]Use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

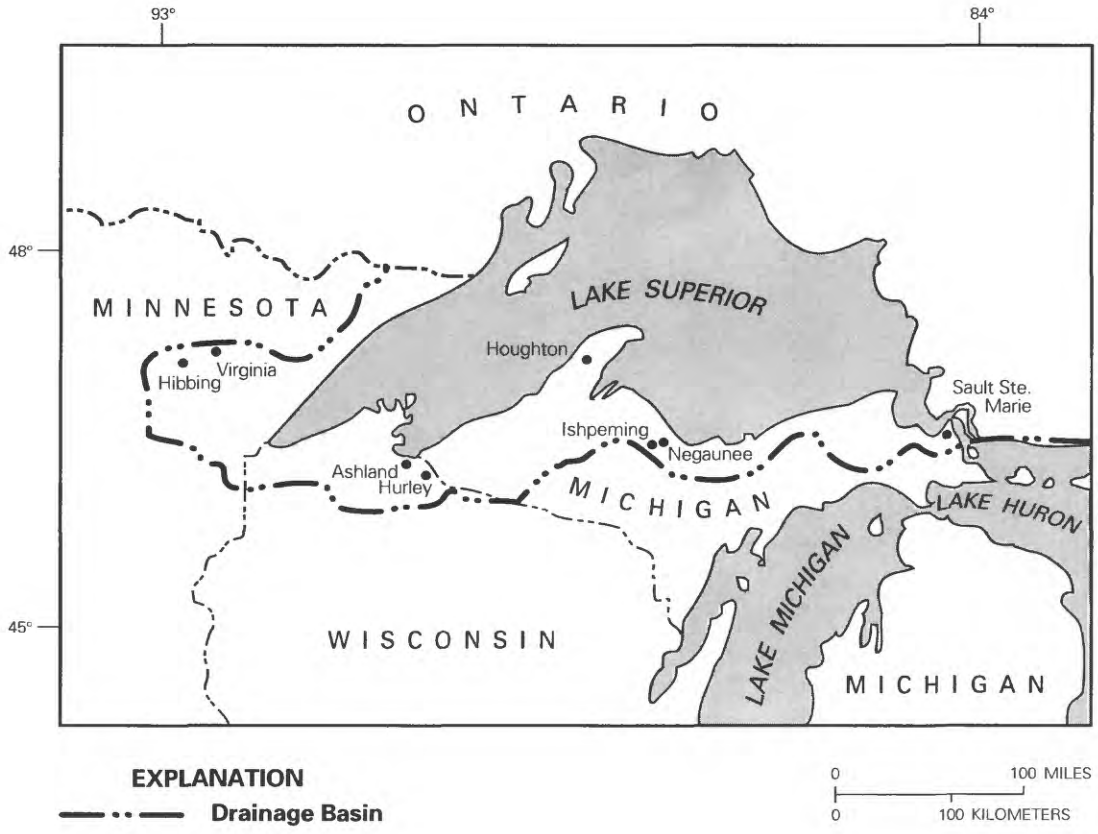

Figure 1. Locations of the eight monitored Lake Superior Basin cities.

les were retrieved from the covered sampler within 24 hours of rainfall termination.

Collection of time-composited samples was initiated upon flow detection by a liquid-level actuator. The sampler was programmed to collect a 1/2-gal sample every 5 to 10 minutes for a total of up to eight subsamples. Sample dates and times were downloaded onsite from the ISCO sampler data logger.

A Teflon-coated stainless steel churn splitter was used to composite and split samples; sample filtering was conducted at the analyzing laboratory. Processed samples were preserved, put on ice, and sent to WSLH for analysis. In most cases samples were received by the WSLH within 24 to 48 hours of runoff termination. Results of the analyses are listed in tables 1-3 (at back of report). The "Water Resources Data Wisconsin Water Year 1994" report (B.K. Holmstrom and others, 1995) discusses laboratory methods and the 5-digit WATSTORE constituent codes used in tables 1-3. A summation of the polycyclic aromatic hydrocarbon (PAH) data is included in the table because this is a quantity often used by cooperators to compare sites. Less than detection values were considered zero in the summation calculation.

QUALITY CONTROL

To ensure sample integrity, field and sample processing equipment blanks were collected onsite from the Ashland, Wis.; Virginia, Minn.; and Hibbing, Minn., sites. Approximately 10 percent of the laboratory budget was dedicated to quality assurance samples. Budgetary constraints prevented obtaining quality assurance samples at all eight locations.

A field and sample-processing equipment blank sample was obtained by drawning analyte-free Milli-Q water through the suction line and sampler into a collection bottle. The water was processed as detailed in the sample collection procedure section. The Teflon suction and ISCO sampler were not cleaned prior to obtaining the blank samples. These results are included in tables 2 and 3 (at back of report). A significant concentration of nitrate plus nitrite-N was detected in the

Hibbing blank collected on April 20, 1994. This blank sample may have been contaminated with nitric acid; thus, the actual field nitrate plus nitrite-N data are considered to be representative of urban runoff.

Sampler collection bottles were cleaned with a nonphosphate detergent and rinsed with tap water, hydrochloric acid, Milli-Q water rinses, a methanol rinse, and air dried. Clean bottles replaced soiled bottles upon collection of the samples and remained in the sampler housing until the next storm occurred.

WSLH analytical methods for PAH were modified for all samples collected in 1994. The laboratory method used in 1993 may not have included the entire suspended particulate fraction. As a result, the samples analyzed in 1993 have substantially lower concentrations than those analyzed in 1994. These data are included because they provide a lower bound and are useful in a qualitative sense.

SITE LOCATIONS AND SAMPLING DATES

Site visitation details are provided, along with the site location information, to indicate the efforts required to sample four events at eight distant sites.

1. Negaunee, Mich. (USGS site 04044367): The sampler was installed in a 24-in.-diameter pipe at the intersection of Keewaydin and Maas Streets (lat 46°30'49"N., long 87°36'41"W.). The pipe eventually drains to Teal Lake. The sampler was visited 12 times; samples were collected on September 14, 1993, October 8, 1993, October 20, 1993, and October 28, 1993.

2. Ishpeming, Mich. (USGS site 04044211): The sampler was installed on July 21, 1993, in the diversion chamber manhole 300 ft south of the Carp River outfall (lat 46°29'34"N., long 87°40'55"W.). The site was visited 10 times; samples were collected on July 27, 1993, August 23, 1993, and twice on September 13, 1993.

3. Sault Ste. Marie, Mich. (USGS site 04045581): The sampler was installed on September 1, 1993, in the Court Street manhole (lat 46°29'38"N., long 84°20'54"W.). The pipe eventually drains to the St. Mary's River. The site was visited five times; samples were collected on September 9, 1993, September 13, 1993, September 14, 1993, and October 1, 1993.

4. Houghton, Mich. (USGS site 04043018): The sampler was installed in a 24-in.-diameter pipe at the center of Quincy Street (lat 47°07'20"N., long 88°34'20"W.). The pipe eventually drains into Portage Lake. The site was visited 12 times; samples were collected twice on August 30, 1994, and once on September 13, 1994, September 15, 1994, and September 26, 1994.

5. Hurley, Wis. (USGS site 04027995): The sampler was installed on April 14, 1994, in a 30-in.-diameter pipe at the intersection of Copper Street and First Avenue (lat 46°26'57"N., long 90°10'48"W.). The pipe eventually drains into the Montreal River. The site was visited 10 times; samples were collected twice on August 19, 1994, and once on August 27, 1994, and September 5, 1994.

6. Ashland, Wis. (USGS site 04026357): The sampler was installed on April 14, 1994, in a 12-in.-diameter pipe at the intersection of East Third Avenue and St. Claire Street (lat 46°35'40"N., long 90°52'57"W.). The pipe eventually drains into Lake Superior. The site was visited eight times; samples were collected April 29, 1994, June 20, 1994, June 23, 1994, and June 28, 1994. A field blank sample was collected April 29, 1994.

7. Virginia, Minn. (USGS site 04018790): The sampler was installed on April 13, 1994, in a 21-in.-diameter pipe at the corner of Sixth Avenue and Eighth Street in the parking lot between Pohaki Lumber Company and J&D Services (lat 47°31'47"N., long 92°32'31"W.). The pipe eventually discharges into northwest Virginia Lake. The site was visited five times; samples were collected April 15, 1994, May 23, 1994, June 14, 1994, and June 16, 1994. A field blank sample was collected on April 20, 1994.

8. Hibbing, Minn. (USGS site 04019460): The sampler was installed on April 13, 1994, in a 24-in.-diameter pipe at the intersection of Grant Street and First Avenue approximately 50 ft north of the railroad tracks (lat 47°25'43"N., long 92°56'31"W.). The pipe eventually discharges into a tributary of Barber Creek. The site was visited five times; samples were collected on April 15, 1994, April 26, 1994, May 23, 1994, and May 24, 1994. A field blank sample was collected on April 20, 1994.

Table 4 (at back of report) summarizes land-use characteristics in the eight monitored basins.

REFERENCE CITED

Holmstrom, B.K., Kammerer, P.A., Jr., and Ellefson, B.R., 1995, Water resources data, Wisconsin, water year 1994: U.S. Geological Survey Water-Data Report WI-94-1, 2 vol., 645 p.

DATA TABLES

Table 1. Contaminant concentrations in stormwater, Michigan sites

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; cols/100 mL, colonies per 100 milliters of sample; <, less than; N/A, not available; [1], exceeds quality-control limit; [2], interference]

Site	Date	Start time	End time	Specific conductance, lab (µS/cm) (00095)	pH standard units, lab (00403)	Fecal coliform (cols/ 100 mL) (31625)	Hardness, total recoverable (mg/L) (00900)	Calcium, total recoverable (mg/L as Ca) (00916)	Magnesium, total recoverable (mg/L) (00921)	Alkalinity (mg/L) (00417)	Sulfate (mg/L as SO_4) (00946)	Chloride (mg/L as Cl) (00940)
Houghton												
1	08/30/94	1030	1035	168	6.5	100,000	39	12	2	40	13	16.6
2	08/30/94	1530	1535	276	7.2	15,000	85	25	6	59	14	38.3
3	09/13/94	0129	0204	114	6.8	15,000	36	10	3	24	10	10.0
4	09/15/94	2117	2152	71	7.3	N/A	88	21	9	28	3	3.2
5	09/26/94	1715	1720	113	6.8	9,100	58	13	6	24	9	12.6
Median				**114**	**6.8**	**15,000**	**58**	**13**	**6**	**28**	**10**	**12.6**
Ishpeming												
1	07/27/93	1331	1441	481	7.8	3,000	170	47	13	138	17	56.
2	08/23/93	2147	2257	115	7.3	12,000	52	14	4	31	7	11.2
3	09/13/93	1230	1402	130	7.4	7,500	57	15	5	35	7	13.8
4	09/13/93	1930	2040	97	7.0	N/A	38	10	3	28	5	9.0
Median				**123**	**7.4**	**7,500**	**55**	**15**	**5**	**33**	**7**	**12.5**
Negaunee												
1	09/14/93	1147	1257	30	6.8	N/A	9	2.9	<1	9	3	2.0
2	10/08/93	1530	1535	21	6.2	N/A	7	2.0	<1	7	5	1.8
3	10/20/93	2352	0019	87	6.5	420	30	8.8	2	25	17	6.4
4	10/28/93	1000	1100	3,200	6.5	2,600	73	23	4	23	18	997
Median				**59**	**6.5**	**1,500**	**20**	**5.9**	**<2**	**16**	**11**	**4.2**
Sault Ste. Marie												
1	09/09/93	0659	0736	84	7.0	N/A	35	10	2	24	6	7.7
2	09/13/93	1437	1512	116	7.1	4,900	98	24	9	34	7	12.6
3	09/14/93	0910	0930	45	7.2	5,500	18	5.4	<1	16	3	3.9
4	10/01/93	1702	1719	59	7.2	N/A	30	7.7	3	21	4	4.4
Median				**72**	**7.1**	**5,200**	**33**	**8.9**	**3**	**23**	**5**	**6.1**

Table 1. Contaminant concentrations in stormwater, Michigan sites—Continued

Site	Date	Start time	End time	Suspended solids (mg/L) (00530)	Total solids (mg/L) (00500)	Nitrate plus nitrite-N (mg/L as N) (00631)	Total kjeldahl nitrogen (mg/L) (00625)	Ammonia-N (mg/L) (00608)	Total phosphorus (mg/L as P) (00665)	Arsenic, total recoverable (µg/L) (99910)	Cadmium, total recoverable (µg/L) (01113)	Copper, total recoverable (µg/L) (01119)	Lead, total recoverable (µg/L) (01114)
Houghton													
1	08/30/94	1030	1035	284	302	0.804	2.1	0.038	0.22	<10	0.4	130	26
2	08/30/94	1530	1535	52	216	.785	.88	.145	.12	<10	.3	66	15
3	09/13/94	0129	0204	121	226	.634	1.7	.046	.28	<10	.3	110	22
4	09/15/94	2117	2152	720	860	.253	2.7	.094	.82	<10	1.0	580	210
5	09/26/94	1715	1720	370	462	.306	2.0	.230	.44	<10	.8	170	58
Median				**284**	**302**	**.634**	**2.0**	**.094**	**.28**	**<10**	**.4**	**130**	**26**
Ishpeming													
1	07/27/93	1331	1441	<2.00	300	1.25	.7	.190	.06	<10	<.2	8	<3
2	08/23/93	2147	2257	280	350	.439	1.7	.174	.47	<10	.7	55	67
3	09/13/93	1230	1402	268	354	.347	1.6	.196	.50	<10	.7	44	77
4	09/13/93	1930	2040	146	198	.236	1.1	.058	.25	<10	.5	35	41
Median				**207**	**325**	**.393**	**1.4**	**.185**	**.36**	**<10**	**.6**	**40**	**54**
Negaunee													
1	09/14/93	1147	1257	4	20	.199	.2	.099	.03	<10	.2	12	4
2	10/08/93	1530	1535	24	56	.102	.4	.150	.13	<10	.3	16	7
3	10/20/93	2352	0019	44	144	.848	1.1	.174	.48	<10	.4	17	11
4	10/28/93	1000	1100	324	2,000	.170	2.4	.125	1.25	<10	1.9	50	36
Median				**34**	**100**	**.185**	**.8**	**.138**	**.31**	**<10**	**.4**	**17**	**9**
Sault Ste. Marie													
1	09/09/93	0659	0736	92	164	.163	1.1	.025	.17	<10	.5	20	38
2	09/13/93	1437	1512	848	878	.238	2.6	.049	.66	<10	1.3	66	120
3	09/14/93	0910	0930	37	74	.175	.4	.119	.08	<10	.2	14	12
4	10/01/93	1702	1719	140	190	.149	1.1	.141	.26	<10	.7	31	52
Median				**116**	**177**	**.169**	**1.1**	**.084**	**.22**	**<10**	**.6**	**26**	**45**

Table 1. Contaminant concentrations in stormwater, Michigan sites—Continued

Site	Date	Start time	End time	Silver, total recoverable (µg/L) (01079)	Zinc, total recoverable (µg/L) (01094)	Acenaphthene (µg/L) (34205)	Acenaphthylene (µg/L) (34200)	Anthracene (µg/L) (34220)	Benzo[*a*]anthracene (µg/L) (34526)	Benzo[*b*]fluoranthene (µg/L) (34230)	Benzo[*k*]fluoranthene (µg/L) (34242)	Benzo[*ghi*]perylene (µg/L) (34521)
Houghton												
1	08/30/94	1030	1035	<0.5	100	<3.4	<8.2	<0.12	0.023	0.060	0.033	0.10
2	08/30/94	1530	1535	<.5	74	<3.4	<8.2	<.12	N/A[2]	N/A[2]	.15	.19
3	09/13/94	0129	0204	<.5	96	<3.4	<8.2	<.12	2.5[1]	.76	.30	.54
4	09/15/94	2117	2152	.6	260	<3.4	<8.2	N/A[1]	2.0	3.3	2.0	2.5[1]
5	09/26/94	1715	1720	1	260	<3.4	<8.2	.29	1.8	3.8	2.1	2.3
Median				**<.5**	**100**	**<3.4**	**<8.2**	**<.12**	**1.03**	**2.03**	**.30**	**.54**
Ishpeming												
1	07/27/93	1331	1441	<.5	13	<3.4	<8.2	<.12	<.0030	<.0045	<.0030	<.0047
2	08/23/93	2147	2257	7.5	170	<3.4	<8.2	<.12	.032	.047	.025	.035
3	09/13/93	1230	1402	2.1	130	<3.4	<8.2	<.12	.034	.060	.030	.049
4	09/13/93	1930	2040	2.5	110	<3.4	<8.2	<.12	.019	.039	.019	.031
Median				**2.3**	**120**	**<3.4**	**<8.2**	**<.12**	**.026**	**.043**	**.022**	**.033**
Negaunee												
1	09/14/93	1147	1257	.8	63	<3.4	<8.2	<.12	.0070	.018	.008	.025
2	10/08/93	1530	1535	<.5	38	<3.4[1]	<8.2[1]	<.12	.0090	.018	.010	.019
3	10/20/93	2352	0019	<.5	67	<3.4	<8.2[1]	<.12	.041	.12	.055	.11
4	10/28/93	1000	1100	.5	150	<3.4	<8.2	<.12	.019	.059	.030	.057
Median				**<.5**	**65**	**<3.4**	**<8.2**	**<.12**	**.014**	**.039**	**.020**	**.041**
Sault Ste. Marie												
1	09/09/93	0659	0736	<.5	120	<3.4	<8.2	<.12	.029	.045	.022	.042
2	09/13/93	1437	1512	.9	290	<3.4	<8.2	<.12	.036	.13	.051	.075
3	09/14/93	0910	0930	.8	40	<3.4	<8.2	<.12	.029	.095	.040	.068
4	10/01/93	1702	1719	.6	150	<3.4	<8.2	<.12	.12	.39	.22	.37
Median				**.7**	**135**	**<3.4**	**<8.2**	**<.12**	**.033**	**.11**	**.046**	**.072**

Table 1. Contaminant concentrations in stormwater, Michigan sites—Continued

Site	Date	Start time	End time	Benzo[*a*] pyrene (µg/L) (34247)	Chrysene (µg/L) (34320)	Dibenz [*a,h*] anthracene (µg/L) (34556)	Fluoran-thene (µg/L) (34376)	Fluorene (µg/L) (34381)	Indeno [1,2,3-*cd*] pyrene (µg/L) (34403)	Napthalene (µg/L) (34696)	Phenanthrene (µg/L) (34461)	Pyrene (µg/L) (34469)	PAH summation
Houghton													
1	08/30/94	1030	1035	0.040	0.065	N/A[2]	N/A	<0.60	0.097	<10	<0.17	0.14	0.558
2	08/30/94	1530	1535	.13	N/A[2]	N/A[2]	0.62[1]	<.60	.15	<10	.35	1.4	2.37
3	09/13/94	0129	0204	.46	.83	N/A[2]	2.0[1]	<.60	.56	<10	.81	1.4	5.91
4	09/15/94	2117	2152	2.7	2.8	N/A[2]	7.5[1]	<.60	2.8	<10	3.1	5.8	34.5
5	09/26/94	1715	1720	2.9	3.5	N/A[2]	11	<.60	2.8	<10	5.1	7.8	43.4
Median				**.46**	**1.8**	**N/A**	**4.8**	**<.60**	**.56**	**<10**	**.81**	**1.4**	**5.91**
Ishpeming													
1	07/27/93	1331	1441	<.0023	<.023	<.0054	<.0087	<.60	<.020	<10	<.17	<.0065	N/A
2	08/23/93	2147	2257	.041	.046	.0083	.096	<.60	.035	<10	<.17	.087	.452
3	09/13/93	1230	1402	.049	.044	<.011[2]	.093	<.60	.046	<10	<.17	.087	.492
4	09/13/93	1930	2040	.026	.026	<.0054	.060	<.60	.036	<10	<.17	.068	.324
Median				**.034**	**.035**	**<.0070**	**.077**	**<.60**	**.036**	**<10**	**<.17**	**.078**	**.452**
Negaunee													
1	09/14/93	1147	1257	<.012[2]	<.023	<.0054	.060	<.60	<.020	<10	<.17	.10	.218
2	10/08/93	1530	1535	.011	<.023	<.0054[1]	.071	<.60[1]	.025	<10[1]	<.17	.052	.215
3	10/20/93	2352	0019	.065	.055	<.0054[1]	.22	<.60	.14	<10[1]	<.17	.16	.966
4	10/28/93	1000	1100	.027	.038	<.0054	.15	<.60	.078	<10	<.17	.11	.568
Median				**.019**	**<.030**	**<.0054**	**.11**	**<.60**	**.078**	**<10**	**<.17**	**.11**	**.393**
Sault Ste. Marie													
1	09/09/93	0659	0736	.029	.047	<.0054	.12	<.60	<.042[2]	<10	<.17	.10	.434
2	09/13/93	1437	1512	.076	.040	.014	.21	<.60	.12	<10[1]	<.17	.13	.882
3	09/14/93	0910	0930	.066	.042	.012	.13	<.60	.079	<10[1]	<.17	.10	.561
4	10/01/93	1702	1719	.30	.32	<.045[2]	.67	<.60	.26	<10	.32	.58	3.55
Median				**.071**	**.045**	**<.0090**	**.17**	**<.60**	**.12**	**<10**	**<.17**	**.12**	**.772**

Table 2. Contaminant concentrations in stormwater, Minnesota sites

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; cols/100 mL, colonies per 100 milliters of sample; <, less than; N/A, not available; [1], exceeds quality-control limit; [2], interference]

Site	Date	Start time	End time	Specific conductance, lab (µS/cm) (00095)	pH standard units, lab (00403)	Fecal coliform (cols/ 100 mL) (31625)	Hardness, total recoverable (mg/L) (00900)	Calcium, total recoverable (mg/L as Ca) (00916)	Magnesium, total recoverable (mg/L) (00921)	Alkalinity (mg/L) (00417)	Sulfate (mg/L as SO_4) (00946)	Chloride (mg/L as Cl) (00940)
Hibbing												
1	04/15/94	0706	0816	104	6.8	370	45	8.9	6.0	22	6	15.7
2	04/26/94	0204	0314	47	6.5	80	26	5.2	3.0	11	5	4.7
3	05/23/94	2156	2246	74	6.3	4,900	31	7.2	3.0	17	7	6.1
4	05/24/94	1414	1424	126	6.5	4,800	60	13.0	7.0	25	8	15.4
Median				**89**	**6.5**	**2,585**	**38**	**8.1**	**4.5**	**20**	**7**	**10.8**
Equipment blank												
Hibbing	04/20/94	1130	1135	3	6.0	N/A	<6	<1.0	<1.0	3	<1	.1
Virginia												
1	04/15/94	0603	0713	114	6.9	240	89	12.0	14.0	26	5	18.8
2	05/23/94	2208	2238	120	6.5	36,000	34	7.8	3.0	19	9	16.7
3	06/14/94	0609	0719	78	6.7	1,800	42	8.0	5.0	17	5	10.1
4	06/16/94	0627	0737	82	6.9	29,000	27	5.4	3.0	18	5	11.9
Median				**98**	**6.8**	**15,400**	**38**	**7.9**	**4.0**	**19**	**5**	**14.3**
Equipment blank												
Virginia	04/20/94	1200	1205	N/A	N/A	N/A	<6	<1.0	<1.0	N/A	N/A	N/A

Table 2. Contaminant concentrations in stormwater, Minnesota sites—Continued

Site	Date	Start time	End time	Suspended solids (mg/L) (00530)	Total solids (mg/L) (00500)	Nitrate plus nitrite-N (mg/L as N) (00631)	Total kjeldahl nitrogen (mg/L) (00625)	Ammonia-N (mg/L) (00608)	Total phosphorus (mg/L as P) (00665)	Arsenic, total recoverable (µg/L) (99910)	Cadmium, total recoverable (µg/L) (01113)	Copper, total recoverable (µg/L) (01119)	Lead, total recoverable (µg/L) (01114)
Hibbing													
1	04/15/94	0706	0816	520	622	0.105	2.0	0.227	0.58	<10	1.9	110	140
2	04/26/94	0204	0314	316	336	.116	1.1	.162	.41	<10	1.3	59	92
3	05/23/94	2156	2246	492	528	.376	2.9	.508	.61	<10	1.2	97	84
4	05/24/94	1414	1424	712	894	.349	3.8	.045	.85	<10	2.0	150	150
Median				**506**	**575**	**.232**	**2.5**	**.195**	**.60**	<10	**1.6**	**104**	**116**
Equipment blank													
Hibbing	04/20/94	1130	1135	<2	<10	.746	<.2	.006	<.02	<10	<.2	<3	<3
Virginia													
1	04/15/94	0603	0713	1,270	1,280	.259	3.0	.166	1.12	<10	3.2	110	210
2	05/23/94	2208	2238	324	428	.634	2.2	.609	.48	<10	.9	28	72
3	06/14/94	0609	0719	968	1,190	.352	1.7	.342	.56	<10	1.4	44	98
4	06/16/94	0627	0737	296	334	.313	1.4	.128	.34	<10	.8	28	53
Median				**646**	**809**	**.333**	**2.0**	**.254**	**.52**	<10	**1.2**	**36**	**85**
Equipment blank													
Virginia	04/20/94	1200	1205	N/A	N/A	.010	<.2	<.005	<.02	<10	<.2	<3	<3

Table 2. Contaminant concentrations in stormwater, Minnesota sites—Continued

Site	Date	Start time	End time	Silver, total recoverable (µg/L) (01079)	Zinc, total recoverable (µg/L) (01094)	Acenaphthene (µg/L) (34205)	Acenaphthylene (µg/L) (34200)	Anthracene (µg/L) (34220)	Benzo[*a*]anthracene (µg/L) (34526)	Benzo[*b*]fluoranthene (µg/L) (34230)	Benzo[*k*]fluoranthene (µg/L) (34242)	Benzo[*ghi*]perylene (µg/L) (34521)
Hibbing												
1	04/15/94	0706	0816	<0.5	390	<3.4[1]	<8.2[1]	<0.12	0.63	1.2	0.67	0.66
2	04/26/94	0204	0314	<.5	230	<3.4	<8.2	.38	1.2	1.6	1.0	.65
3	05/23/94	2156	2246	<.5	260	<3.4	<8.2	.20	.87	1.4	.80	1.2
4	05/24/94	1414	1424	<.5	420	<3.4	<8.2	.20	.70	1.2	.74	.89
Median				**<.5**	**325**	**<3.4**	**<8.2**	**.20**	**.79**	**1.3**	**.77**	**.78**
Equipment blank												
Hibbing	04/20/94	1130	1135	<.5	<10	<3.4	<8.2	<.12	<.0030	<.0045	.0061	<.0047
Virginia												
1	04/15/94	0603	0713	<.5	520	<3.4[1]	<8.2[1]	.35	2.0	3.3	2.2	2.8
2	05/23/94	2208	2238	<.5	170	<3.4	<8.2	.17	.84	1.6	.99	1.4
3	06/14/94	0609	0719	<.5	210	<3.4	<8.2	.62	3.9	4.6	2.9	3.6
4	06/16/94	0627	0737	<.5	130	<3.4	<8.2	.28	1.3	1.5	1.0	1.3
Median				**<.5**	**190**	**<3.4**	**<8.2**	**.32**	**1.7**	**2.5**	**1.6**	**2.1**
Equipment blank												
Virginia	04/20/94	1200	1205	<.5	<10	<3.4	<8.2	<.12	<.0030	<.0045	<.0034	<.0047

Table 2. Contaminant concentrations in stormwater, Minnesota sites—Continued

Site	Date	Start time	End time	Benzo[*a*] pyrene (µg/L) (34247)	Chrysene (µg/L) (34320)	Dibenz [*a,h*] anthracene (µg/L) (34556)	Fluoran-thene (µg/L) (34376)	Fluorene (µg/L) (34381)	Indeno [1,2,3-*cd*] pyrene (µg/L) (34403)	Napthalene (µg/L) (34696)	Phenanthrene (µg/L) (34461)	Pyrene (µg/L) (34469)	PAH summation
Hibbing													
1	04/15/94	0706	0816	0.75	1.4	<0.067[2]	3.2	<0.60	0.8	<10	<0.17	2.1	11.41
2	04/26/94	0204	0314	1.4	1.7	<.062[1]	4.1	<.60	1.2	<10	2.1	2.9	18.23
3	05/23/94	2156	2246	1.1	1.6	<.026[1]	4.1	<.60	1.2	<10	1.7	2.3	16.47
4	05/24/94	1414	1424	.97	1.5	<.030[1]	3.1	<.60	1.1	<10	1.4	2.0	13.80
Median				**1.0**	**1.6**	**<.046**	**3.7**	**<.60**	**1.2**	**<10**	**1.6**	**2.2**	**15.14**
Equipment blank													
Hibbing	04/20/94	1130	1135	<.0023	<.023	<.0054	<.0087	<.60	<.020	<10	<.17	<.0065	.0061
Virginia													
1	04/15/94	0603	0713	3.2	3.6	<.21[2]	10.0	<.60	3.1	<10	5.6	7.0	43.15
2	05/23/94	2208	2238	1.4	1.7	<.043[2]	4.2	<.60	1.7	<10	2.0	2.7	18.70
3	06/14/94	0609	0719	4.7	5.0	<.60[2]	10.0	<.60	3.6	<10	4.5	8.2	51.62
4	06/16/94	0627	0737	1.6	1.8	<.30[2]	3.9	<.60	1.7	<10	2.0	3.0	19.38
Median				**2.4**	**2.7**	**<.26**	**7.1**	**<.60**	**2.4**	**<10**	**3.3**	**5.0**	**31.27**
Equipment blank													
Virginia	04/20/94	1200	1205	<.0023	<.023	<.0054	<.0087	<.60	<.020	<10	<.17	<.0065	N/A

Table 3. Contaminant concentrations in stormwater, Wisconsin sites

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; cols/100 mL, colonies per 100 milliters of sample; <, less than; N/A, not available; [1], exceeds quality-control limit; [2], interference]

Site	Date	Start time	End time	Specific conductance, lab (µS/cm) (00095)	pH standard units, lab (00403)	Fecal coliform (cols/100 mL) (31625)	Hardness, total recoverable (mg/L) (00900)	Calcium, total recoverable (mg/L as Ca) (00916)	Magnesium, total recoverable (mg/L) (00921)	Alkalinity (mg/L) (00417)	Sulfate (mg/L as SO_4) (00946)	Chloride (mg/L as Cl) (00940)
Ashland												
1	04/29/94	0754	0815	331	7.1	N/A	54	15.0	4.0	28	8	82.3
2	06/20/94	0233	0333	79	6.8	1,800	25	7.8	1.0	21	7	5.4
3	06/23/94	0535	0645	120	6.9	1,600	52	16.0	3.0	31	11	8.8
4	06/28/94	1416	1516	54	7.2	3,500	33	9.3	2.0	20	4	2.8
Median				**100**	**7.0**	**1,800**	**43**	**12.2**	**2.5**	**25**	**8**	**7.1**
Equipment blank												
Ashland	04/29/94	0800	0805	3	5.9	N/A	<6	<1.0	<1.0	3	<1	<.1
Hurley												
1	08/19/94	0556	0606	57	6.6	N/A	48	9.2	6.0	11	7	4.8
2	08/19/94	1556	1626	29	6.3	N/A	34	6.9	4.0	10	3	1.8
3	08/27/94	1214	1324	37	6.6	N/A	50	10.0	6.0	11	5	1.7
4	09/05/94	0556	0706	52	7.0	N/A	31	6.6	3.0	14	6	2.7
Median				**45**	**6.6**	**N/A**	**41**	**8.1**	**5.0**	**11**	**6**	**2.3**

Site	Date	Start time	End time	Suspended solids (mg/L) (00530)	Total solids (mg/L) (00500)	Nitrate plus nitrite-N (mg/L as N) (00631)	Total kjeldahl nitrogen (mg/L) (00625)	Ammonia-N (mg/L) (00608)	Total phosphorus (mg/L as P) (00665)	Arsenic, total recoverable (µg/L) (99910)	Cadmium, total recoverable (µg/L) (01113)	Copper, total recoverable (µg/L) (01119)	Lead, total recoverable (µg/L) (01114)
Ashland													
1	04/29/94	0754	0815	248	468	0.287	1.4	0.309	0.33	<10	1.6	63	70
2	06/20/94	0233	0333	82	158	.613	1.2	.432	.22	<10	.3	34	23
3	06/23/94	0535	0645	260	294	.677	2.3	.614	.39	<10	.6	55	46
4	06/28/94	1416	1516	268	322	.153	.9	.042	.32	<10	.7	69	46
Median				**254**	**308**	**.450**	**1.3**	**.371**	**.33**	**<10**	**.7**	**59**	**46**
Equipment blank													
Ashland	04/29/94	0800	0805	<2	<10	<.007	<.2	.011	<.02	<10	<.2	<3	<3
Hurley													
1	08/19/94	0556	0606	696	744	.939	2.5	.359	.83	<10	.6	66	60
2	08/19/94	1556	1626	784	756	.238	.9	.151	.48	<10	.4	30	46
3	08/27/94	1214	1324	2,390	962	.609	1.5	.435	1.13	<10	.7	97	50
4	09/05/94	0556	0706	916	892	.203	2.2	.238	.62	<10	3.0	52	55
Median				**850**	**824**	**.424**	**1.9**	**.299**	**.73**	**<10**	**.7**	**59**	**53**

Table 3. Contaminant concentrations in stormwater, Wisconsin sites—Continued

Site	Date	Start time	End time	Silver, total recoverable (µg/L) (01079)	Zinc, total recoverable (µg/L) (01094)	Acenaphthene (µg/L) (34205)	Acenaphthylene (µg/L) (34200)	Anthracene (µg/L) (34220)	Benzo[*a*] anthracene (µg/L) (34526)	Benzo[*b*] fluoranthene (µg/L) (34230)	Benzo[*k*] fluoranthene (µg/L) (34242)	Benzo [*ghi*] perylene (µg/L) (34521)
Ashland												
1	04/29/94	0754	0815	<0.5	300	<3.4	<8.2	0.13	0.41	0.58	.37	0.63
2	06/20/94	0233	0333	<.5	110	<3.4	<8.2	<.12	.36	.43	.28	.33
3	06/23/94	0535	0645	<.5	230	<3.4	<8.2	.30	.95	1.0	.71	.70
4	06/28/94	1416	1516	<.5	160	<3.4	<8.2	1.20	2.7	2.6	1.9	1.8
Median				**<.5**	**195**	**<3.4**	**<8.2**	**.22**	**.68**	**.79**	**.54**	**.67**
Equipment blank												
Ashland	04/29/94	0800	0805	<.5	<10	<3.4	<8.2	<.12	<.0030	<.0045	<.0034	<.0047
Hurley												
1	08/19/94	0556	0606	<.5	150	<3.4	<8.2	<.12	.16	.48	.33	.49
2	08/19/94	1556	1626	<.5	97	<3.4	<8.2	<.12	.14	.30	.21	.33
3	08/27/94	1214	1324	<.5	170	N/A	N/A	.60	2.1	3.0	1.6	1.5
4	09/05/94	0556	0706	<.5	160	N/A	N/A	<.12	.26	.58	.27	.53
Median				**<.5**	**155**	**<3.4**	**<8.2**	**<.12**	**.21**	**.53**	**.30**	**.51**

Site	Date	Start time	End time	Benzo[*a*] pyrene (µg/L) (34247)	Chrysene (µg/L) (34320)	Dibenz [*a,h*] anthracene (µg/L) (34556)	Fluoranthene (µg/L) (34376)	Fluorene (µg/L) (34381)	Indeno [1,2,3-*cd*] pyrene (µg/L) (34403)	Napthalene (µg/L) (34696)	Phenanthrene (µg/L) (34461)	Pyrene (µg/L) (34469)	PAH summation
Ashland													
1	04/29/94	0754	0815	.49	.78	<0.055[2]	2.0	<0.60	0.42	<10	1.5	1.4	8.71
2	06/20/94	0233	0333	.52	.63	<.070[2]	1.1	<.60	.46	<10	.53	.81	5.45
3	06/23/94	0535	0645	1.1	1.3	N/A[2]	2.6	<.60	.77	<10	1.6	2.0	13.03
4	06/28/94	1416	1516	3.1	3.3	N/A[2]	7.7	<.60	2.4	<10	6.9	5.8	39.40
Median				**.81**	**1.04**	**<.062**	**2.3**	**<.60**	**.62**	**<10**	**1.6**	**1.7**	**10.9**
Equipment blank													
Ashland	04/29/94	0800	0805	<.0023	<.023	<.0054	<.0087	<.60	<.020	<10	<.17	<.0065	N/A
Hurley													
1	08/19/94	0556	0606	.43	1.1	N/A[2]	1.3	<.60	.35	<10	.56	1.0	6.20
2	08/19/94	1556	1626	.34	.60	N/A[2]	.68	<.60	.26	<10	.29	.59	3.74
3	08/27/94	1214	1324	2.7	2.8	N/A[2]	8.6	N/A	N/A	N/A	7.5	5.9	36.3
4	09/05/94	0556	0706	.42	.33	N/A[2]	1.1	N/A	.37	N/A	.51	.86	5.23
Median				**.43**	**.85**	**N/A**	**1.2**	**<.60**	**.35**	**<10**	**.54**	**.93**	**5.72**

Table 4. Land use in monitored basins

[Land use data from Wisconsin Department of Natural Resources; numbers outside parentheses are acres; numbers in parentheses denote percentage of total basin]

Monitored basin location	Residential	Commercial	Industrial	Institutional/ miscellaneous	Open spaces	Streets	Total
Ashland, Wis.	0(0%)	3.2(48%)	0(0%)	0.9(14%)	0(0%)	2.5(3%)	6.5(100%)
Hibbing, Minn.	0(0%)	0(0%)	9.9(65%)	0(0%)	2.4(16%)	2.9(19%)	15.3(100%)
Houghton, Mich.	22.9(60%)	3.0(8%)	0(0%)	3.9(10%)	1.8(5%)	6.8(18%)	38.4(100%)
Hurley, Wis.	16.6(33%)	3.8(8%)	0(0%)	9.0(18%)	7.4(15%)	13.0(26%)	49.9(100%)
Ishpeming, Mich.	0(0%)	0(0%)	16.1(47%)	0(0%)	15.5(45%)	2.7(8%)	34.3(100%)
Negaunee, Mich.	41.2(71%)	0(0%)	0(0%)	3.3(6%)	4.8(8%)	9.0(15%)	58.2(100%)
Sault Ste. Marie, Mich.	0(0%)	0(0%)	14.0(94%)	0(0%)	.1(1%)	.8(5%)	14.9(100%)
Virginia, Minn.	1.1(9%)	5.9(47%)	0(0%)	1.6(13%)	0(0%)	3.9(31%)	12.5(100%)

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