EVALUATION OF NONPOINT-SOURCE CONTAMINATION, WISCONSIN: SELECTED STREAMWATER-QUALITY DATA, LAND-USE AND BEST-MANAGEMENT PRACTICES INVENTORY, AND QUALITY ASSURANCE AND QUALITY CONTROL, WATER YEAR 1993

By S.R. Corsi, J.F. Walker, D.J. Graczyk, S.R. Greb, D.W. Owens, and K.F. Rappold

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	*By*	*To obtain*
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.4048	hectare
square mile (mi^2)	2.590	square kilometer
million cubic feet (Mft^3)	0.02832	million cubic meters
gallon (gal)	3.785	liter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
pound (lb)	453.6	gram

Abbreviated water-quality units used in this report: Chemical concentrations 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.

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ABSTRACT

The objective of the watershed-management evaluation monitoring program in Wisconsin is to evaluate the effectiveness of the best-management practices (BMP's) for rural streams, urban streams, and urban storm sewers. This report is an annual summary of the data collected for the program and a report of the results from several different special studies conducted within this program.

Suspended sediment and total phosphorus storm-load data are summarized for eight rural sites and suspended sediment, total phosphorus, total recoverable lead, total recoverable copper, total recoverable zinc, and total recoverable cadmium storm-load data are summarized for four urban sites. Dissolved-oxygen data is summarized and compared with Wisconsin's water-quality standards for summer 1993 for seven rural sites. The dissolved-oxygen concentrations declined to levels below these standards at least one time at all seven sites during summer 1993.

Total-recoverable hardness concentrations were compared with dissolved-hardness concentrations at two urban streams and two urban storm sewers. Least-squared linear regressions resulted in stronger relations for low-flow conditions than for high-flow conditions, indicating that most hardness during low flow is dissolved hardness. Pesticide data are summarized for four urban sites and six rural sites. Herbicides were detected at urban and rural sites; whereas insecticides were detected only at urban sites.

A land-use and best-management-practice inventory is ongoing for each evaluation monitoring project to track the different sources of nonpoint pollution in each watershed and to document implementation of best-management programs that may cause changes in water quality of streams. Updated information is gathered each year, mapped, and stored in a geographic-information-system data base.

The quality-assurance/quality-control plan for the urban watershed-management evaluation program consisted of a series of blank samples. These blank samples were used to identify and isolate contamination by inorganic and organic components throughout the collection and processing of urban streamwater samples. A dissolved trace-metal contamination problem was identified and resolved by using different laboratory-supplied sample bottles.

A special study was done to determine the effect of holding time on fecal coliform colony counts. A linear regression indicated that the mean decrease in colony counts over 72 hours was 8.2 percent per day. Results after 24 hours showed that colony counts increased in some samples and decreased in others.

INTRODUCTION

In October, 1989, the U.S. Geological Survey (USGS) began a watershed-management evaluation monitoring program in cooperation with the Wisconsin Department of Natural Resources (WDNR). The overall objective of each individual project in the program (fig. 1) is to determine if the water chemistry in the receiving stream has changed as a result of the implementation of land-management practices in the watershed. This is accomplished through monitoring of water chemistry and ancillary variables before best-management practices (BMP's) are implemented, during implementation, and after watershed-management plans have been completely implemented. The period before BMP implementation is termed "pre-BMP," the period during active implementation is termed "transitional," and the period after complete implementation is termed "post-BMP."

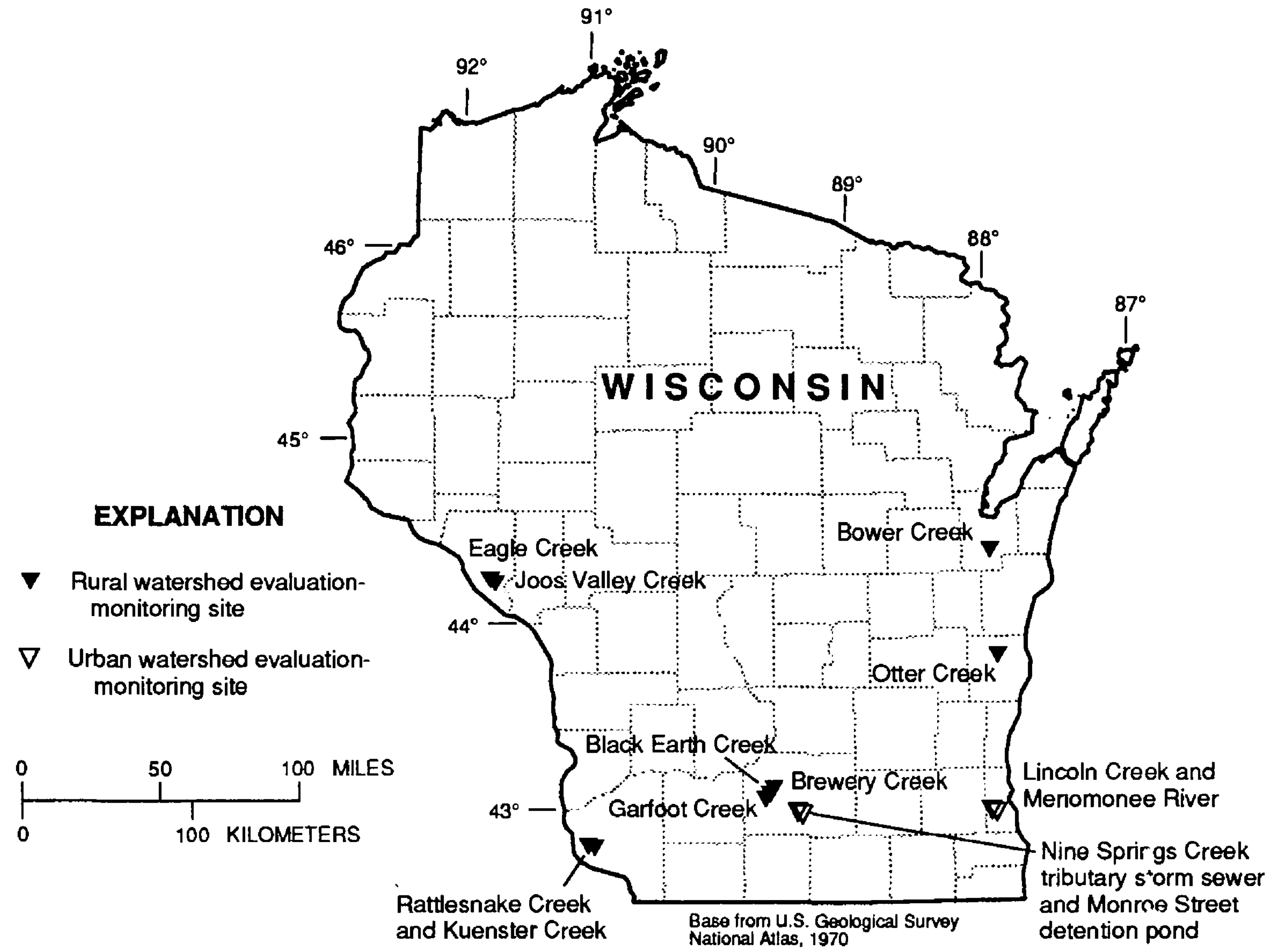

Figure 1. Map showing location of rural and urban sites in the Wisconsin watershed-management evaluation monitoring program, water year 1993.

The county Land Conservation Departments (LCD's) and the WDNR have identified sources of nonpoint pollution in each rural watershed (table 1). This information was used to select sites that are eligible for partial funding of BMP implementation. The LCD's are in the process of contacting land owners to request that they implement the appropriate BMP's for streamwater quality improvement. This is a voluntary program and, therefore, may produce variable success depending largely on the percentage of land owners that implement the recommended BMP's.

The WDNR and each city have identified sources of nonpoint contamination in the urban watersheds (table 1). Nonpoint pollution reduction goals have been set, but a specific plan identifying the type and location of BMP's needed to achieve these goals has not been defined.

This report, the second in a series of annual progress reports, is divided into three sections and includes four appendixes. The following topics are addressed: (1) streamwater-quality data, constituent loads in storm runoff, dissolved oxygen, hardness, and pesticides, (2) land-use and BMP inventory, and (3) quality assurance and quality control and effect of sample holding time on survival of fecal coliform colonies. In each section, data collected during water year (WY) 1993 (October 1, 1992 through September 30, 1993) are presented and, if appropriate, implications for future data-collection efforts are discussed. The appendixes present the storm-load data collected during WY 1985-93 and the quality-assurance/quality-control document developed during WY 1993 for sampling at the urban sites.

SELECTED STREAMWATER-QUALITY DATA

In this section, the streamwater-quality data collected during WY 1993 are summarized in four parts. The first part describes the estimated con-

Table 1. Location, site type, and principal function of sites in the watershed-management evaluation monitoring program, Wisconsin, water year[1] 1993

Site name	Latitude	Longitude	Site type	Principle site function
Black Earth Creek at County Trunk P	43°06'38"	89°38'44"	rural	dissolved oxygen
Black Earth Creek at Mills Street	43°06'48"	89°39'00"	rural	dissolved oxygen
Black Earth Creek at South Valley Road	43°07'30"	89°42'35"	rural	dissolved oxygen
Bower Creek	44°25'21"	87°56'24"	rural	water chemistry
Brewery Creek	43°07'09"	89°38'25"	rural	water chemistry
Eagle Creek	44°12'34"	91°40'42"	rural	water chemistry
Garfoot Creek	43°06'37"	89°40'46"	rural	water chemistry and dissolved oxygen
Joos Valley Creek	44°12'54"	91°39'54"	rural	water chemistry
Kuenster Creek	42°47'27"	90°57'26"	rural	water chemistry and dissolved oxygen
Lincoln Creek	43°05'49"	87°58'20"	urban	water chemistry
Menomonee River	43°02'44"	87°59'59"	urban	water chemistry
Monroe Street detention pond inlet	43°03'09"	89°26'07"	urban	water chemistry
Nine Springs Creek tributary storm sewer	43°02'03"	89°23'35"	urban	water chemistry
Otter Creek	43°47'20"	87°55'20"	rural	water chemistry and dissolved oxygen
Rattlesnake Creek	42°46'49"	90°56'32"	rural	water chemistry and dissolved oxygen

[1]Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year starting October 1, 1992 and ending September 30, 1993 is called the "1993 water year."

stituent loads and summarizes the efficiency of the sampling protocols. The second part summarizes dissolved-oxygen data. The third part presents the relation of sampling total-recoverable and dissolved-hardness data from the urban sites. The final part summarizes the pesticide data collected during WY 1993.

Constituent Loads in Storm Runoff

Streamwater quality was monitored at eight rural and four urban sites (fig. 1), at base flow and during storms. The water-quality data and discharge data were used to estimate total constituent loads for the storm periods. Eventually, the storm-load data will be used to evaluate the effect of BMP's on streamwater quality. In general, at least 20 pre-BMP and 20 post-BMP storms are needed to detect moderate differences related to implementation of the BMP's (Walker, 1993, 1994).

Summary of Data

The watershed-management evaluation monitoring sites currently have between one year

(Lincoln Creek) and 6 years (Brewery and Garfoot Creeks) of data. Precipitation, streamflow volume, and storm loads for several different water-quality constituents have been compiled (Appendixes 1 and 2).

Summary of Storm-Sampling Efficiency

Suspended-solids and total-phosphorus storm loads were calculated at the eight rural sites for all storms having a sufficient number of samples to accurately define the distribution of concentration over time. With the exception of two sites (Bower and Otter Creeks) ammonia-nitrogen loads also were calculated for all of the rural sites. The total number of storms sampled at the rural sites during WY 1993 ranged from 15 to 27, and the median was 17.5–a sufficient number of storms for the overall evaluation of the watershed-management evaluation-monitoring program.

Although a sufficient number of storms were sampled during WY 1993, additional hydrologic records were analyzed to evaluate the effectiveness of sampling procedures. For each site, the continuous streamflow record was inspected to identify all periods where a hydrograph rise and subsequent fall was significant. The hydrologist charged with maintaining each site defined each period of significant rise and fall, herein called hydrograph-rise period. The hydrograph-rise period is defined to be between the two points on the hydrograph where the storm begins and baseflow is resumed. For the purposes of this study, the beginning of the storm is the point of the first significant increase in discharge, and baseflow is resumed after the hydrograph-rise period is at a point where the hydrograph slope approaches the slope of baseflow recession. For each hydrograph-rise period, total runoff was computed, and each period was classified into one of four categories: (1) complete sampling, (2) equipment malfunction, (3) partial sampling, or (4) no sampling. Some of the equipment malfunctions during hydrograph-rise periods resulted in partial sampling and some resulted in no sampling. All hydrograph-rise periods classified with equipment malfunctions had an insufficient number of samples to define the water quality. The distinction between complete and partial sampling was determined individually by site on basis of the shape of the hydrograph and the number of samples collected. Storm events and runoff sampling categories for each of eight rural sites are shown in figures 2-9.

In general, storm-sampling protocols appear to provide a representative set of data, in terms of storm frequency and magnitude and the season of occurrence. A high percentage of large storms, which tend to carry the greatest loads, were sampled completely during WY 1993. Potential deficiencies in the sampling protocol identified previously (Graczyk and others, 1993) were modified at the beginning of WY 1993. As a result of the modifications, samples for all of the sites are more representative than those collected during previous years. One significant improvement was the adjustment of sampling thresholds during the winter to catch midwinter snowmelt. This adjustment resulted in more hydrograph-rise periods being sampled, thus greatly improving the data set available for evaluation of the nonpoint program. A potential deficiency is the exclusion of several midsized storms during May and June at most of the sites. This exclusion was the result of a shortfall in the budget for sample analysis; the decision was made jointly by the cooperator and project personnel to sample only the large storms in May and June until a new contract went into effect in July.

Monitoring activities in Water Year 1994

Although it appears that an adequate number of hydrograph-rise periods are being sampled, the efficiency of sampling protocols will continue to be monitored closely. An analysis similar to that presented above will be done periodically so that sampling protocols can be fine-tuned when necessary. In an effort to continue effective sampling of the midwinter snowmelt, sampling thresholds will be monitored and adjusted as necessary.

Dissolved Oxygen

Dissolved-oxygen data were collected continuously at seven rural sites: Garfoot Creek, Black Earth Creek at County Trunk P, Black Earth Creek at Mills Street, Black Earth Creek at South Valley Road, Otter Creek, Rattlesnake Creek, and Kuenster Creek (fig. 1). Dissolved-oxygen data were collected during open-water periods; all dissolved-oxygen meters were removed during the winter.

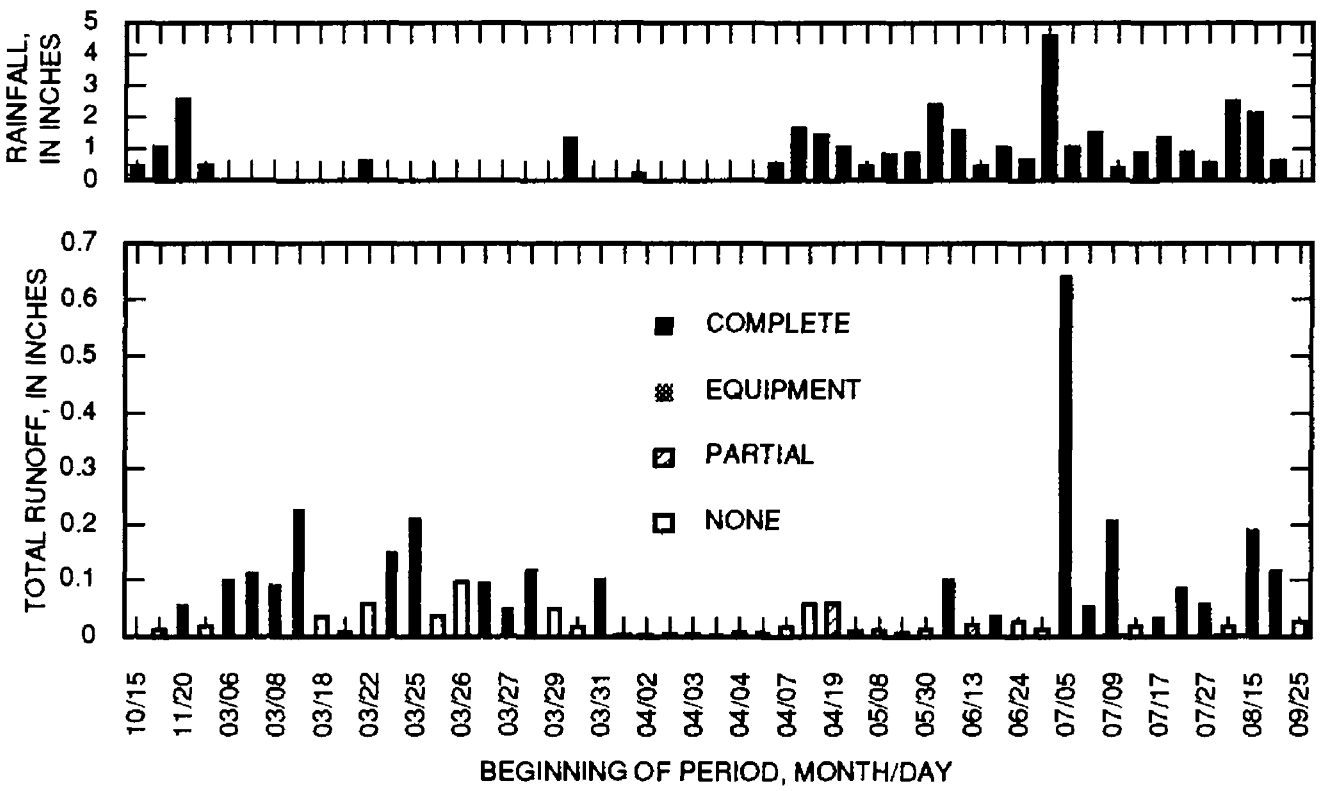

Figure 2. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Brewery Creek monitoring site, Dane County, Wis., water year 1993.

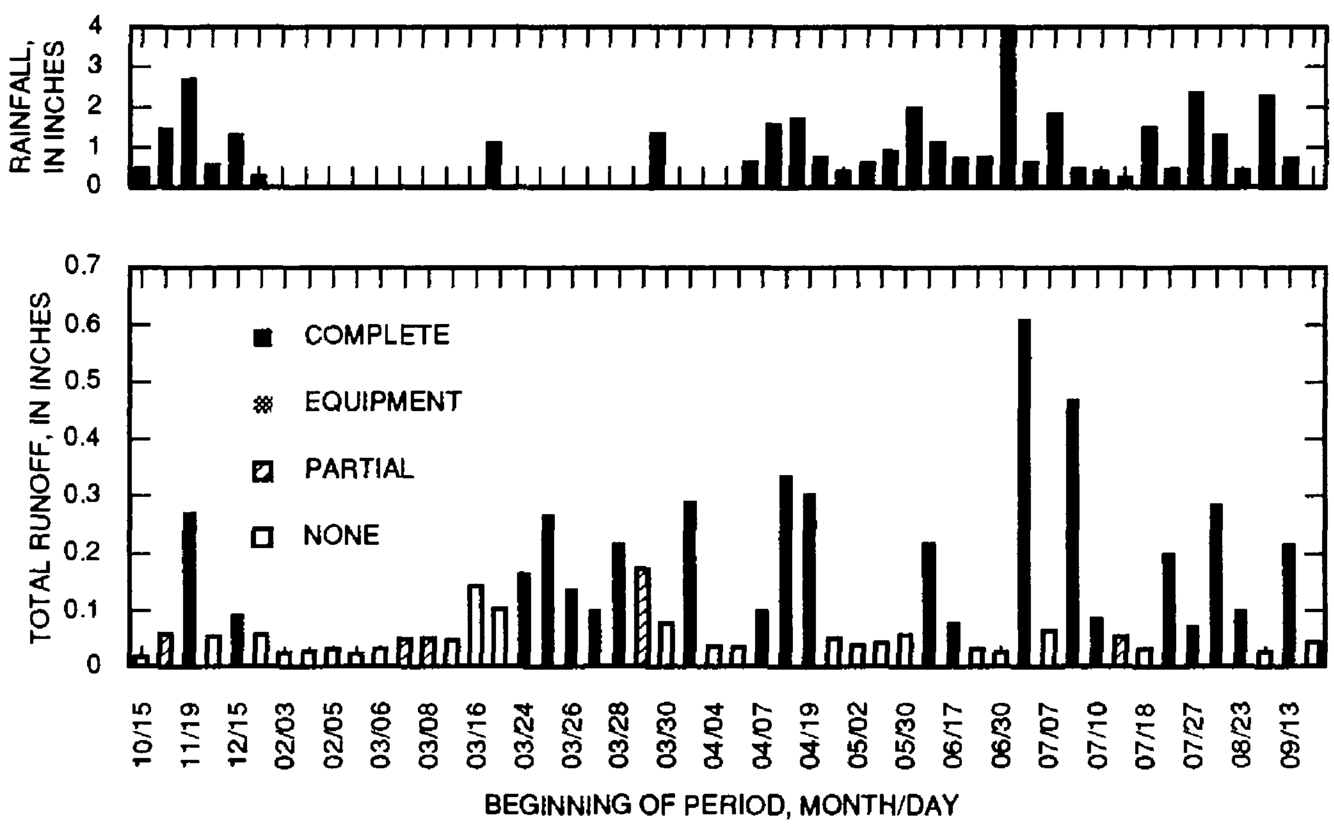

Figure 3. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Garfoot Creek monitoring site, Dane County, Wis., water year 1993.

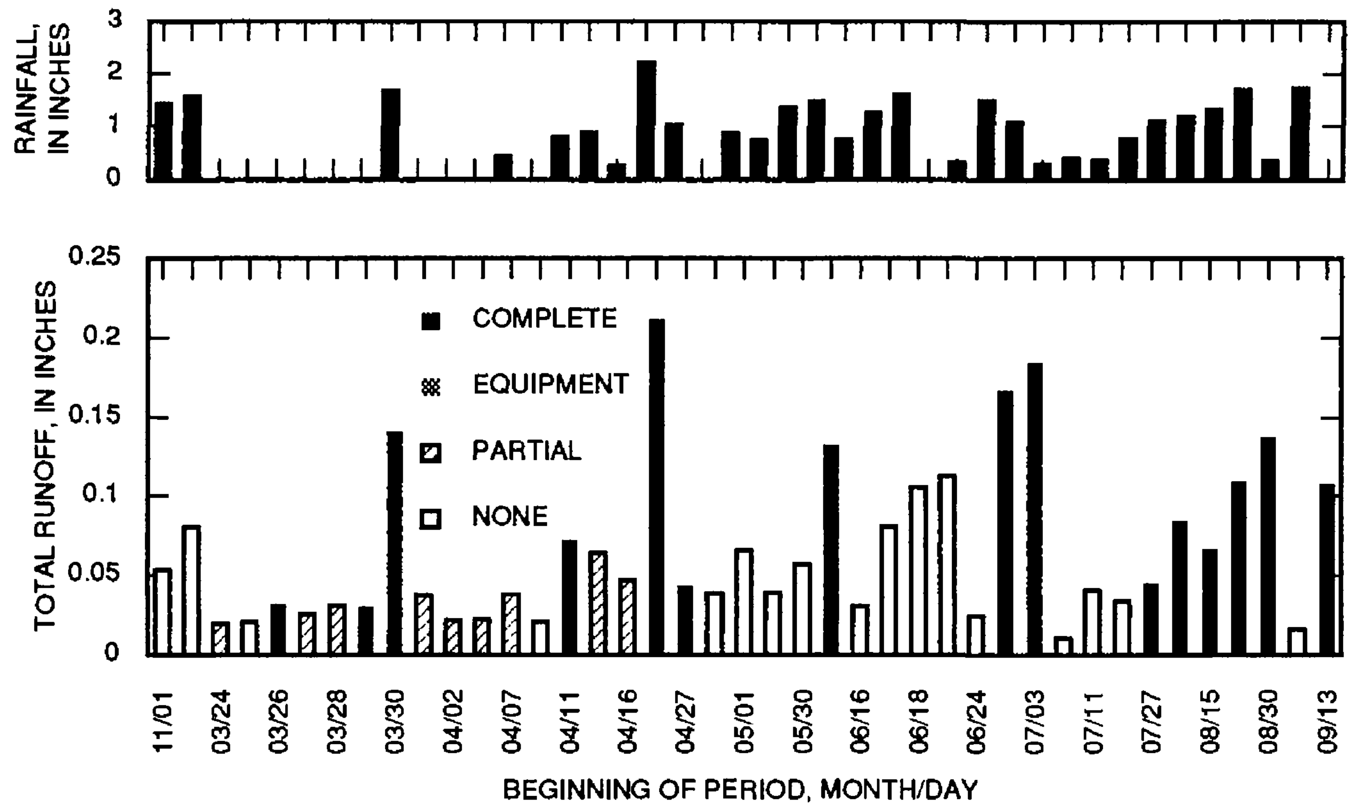

Figure 4. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Eagle Creek monitoring site, Buffalo County, Wis., water year 1993.

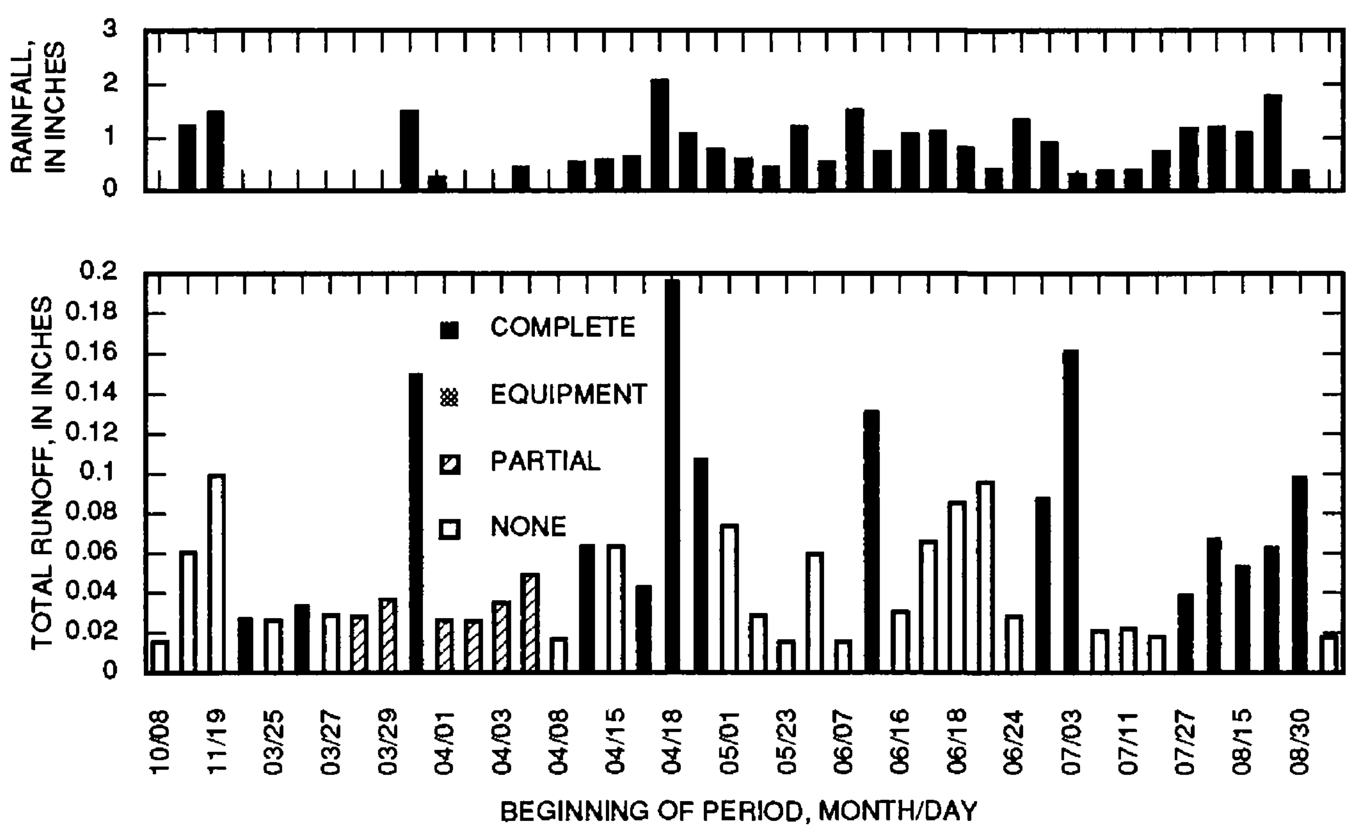

Figure 5. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Joos Valley Creek monitoring site, Buffalo County, Wis., water year 1993.

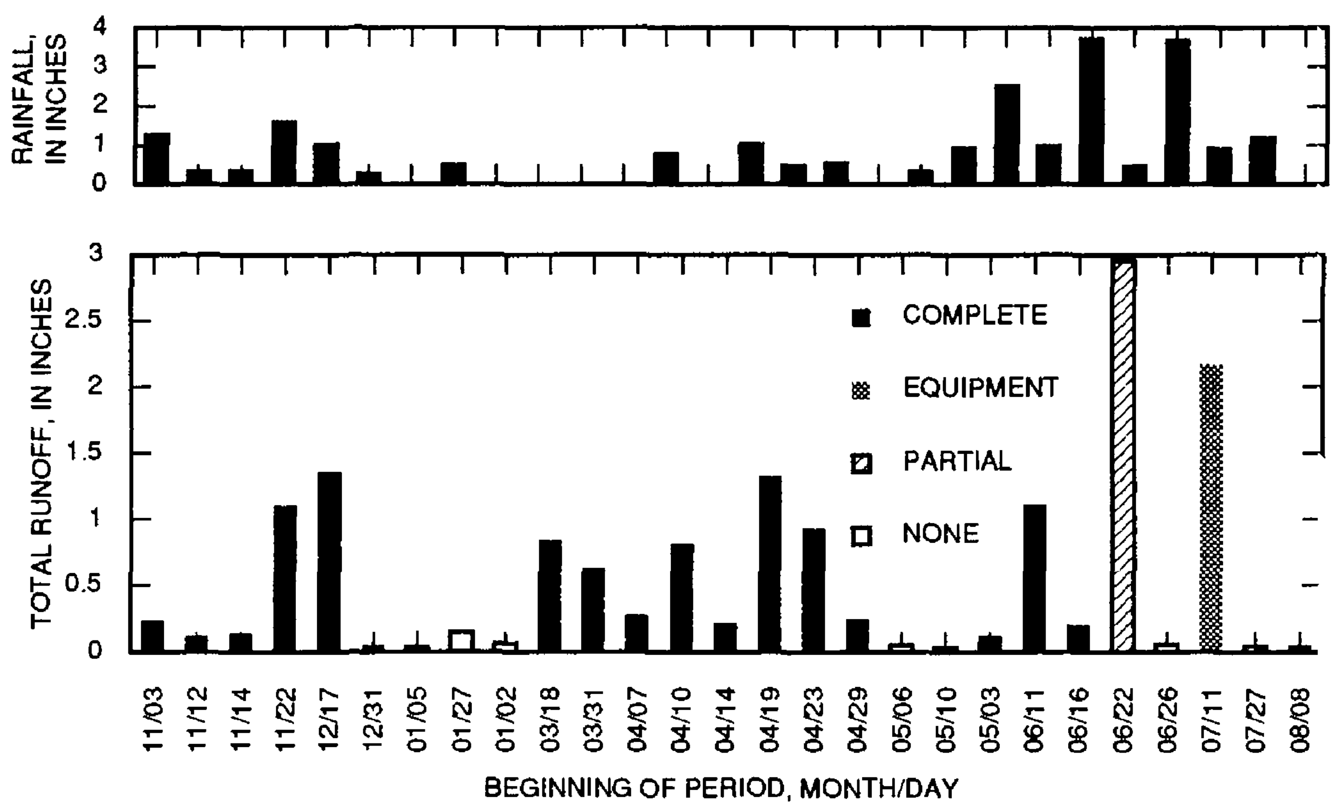

Figure 6. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Bower Creek monitoring site, Brown County, Wis., water year 1993.

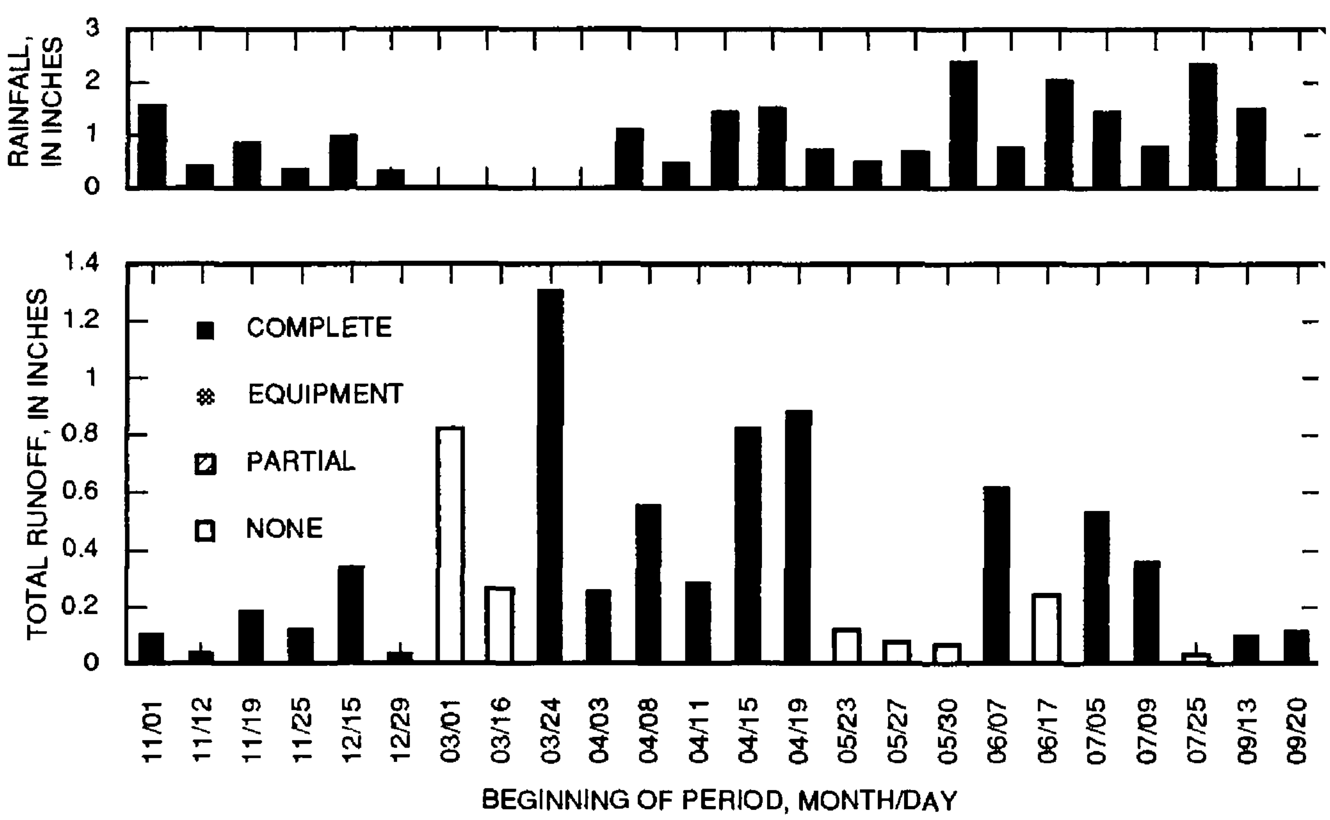

Figure 7. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Otter Creek monitoring site, Sheboygan County, Wis., water year 1993.

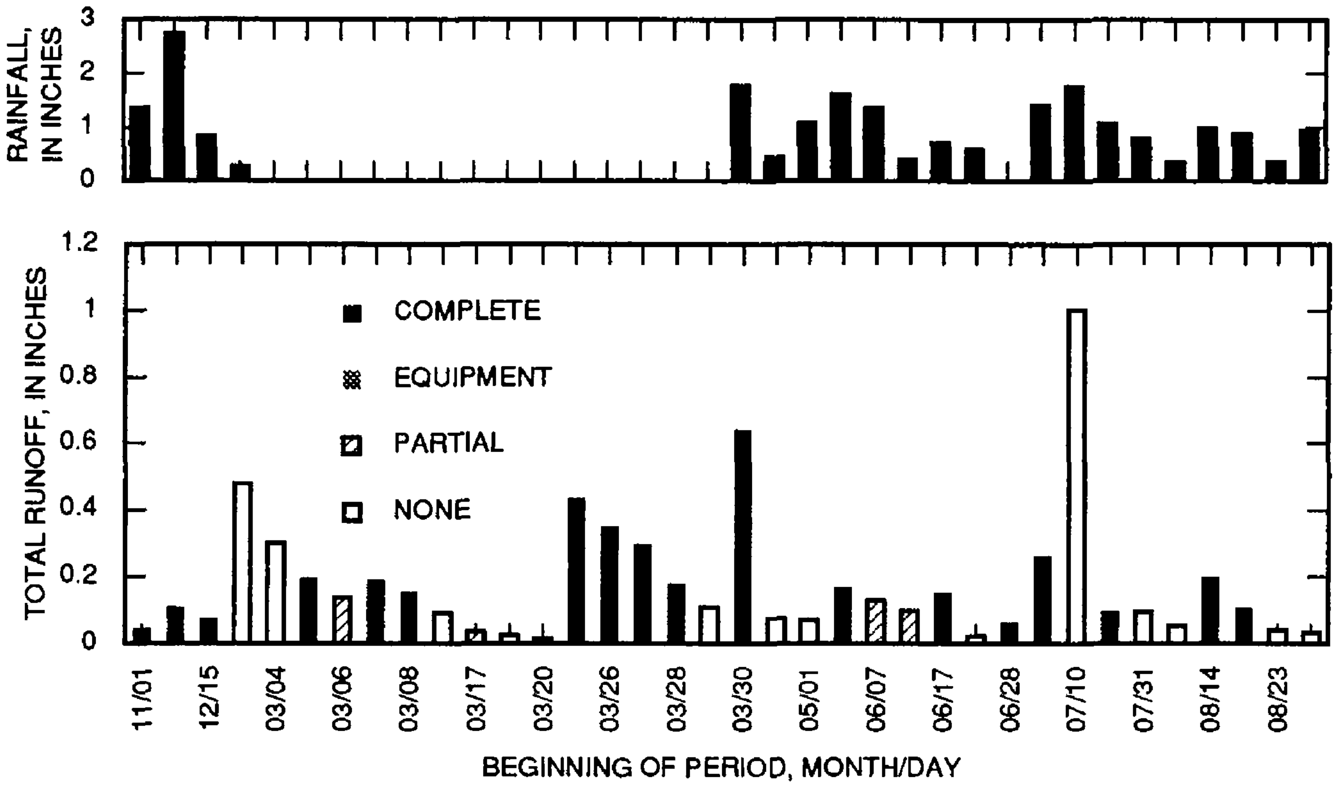

Figure 8. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Kuenster Creek monitoring site, Grant County, Wis., water year 1993.

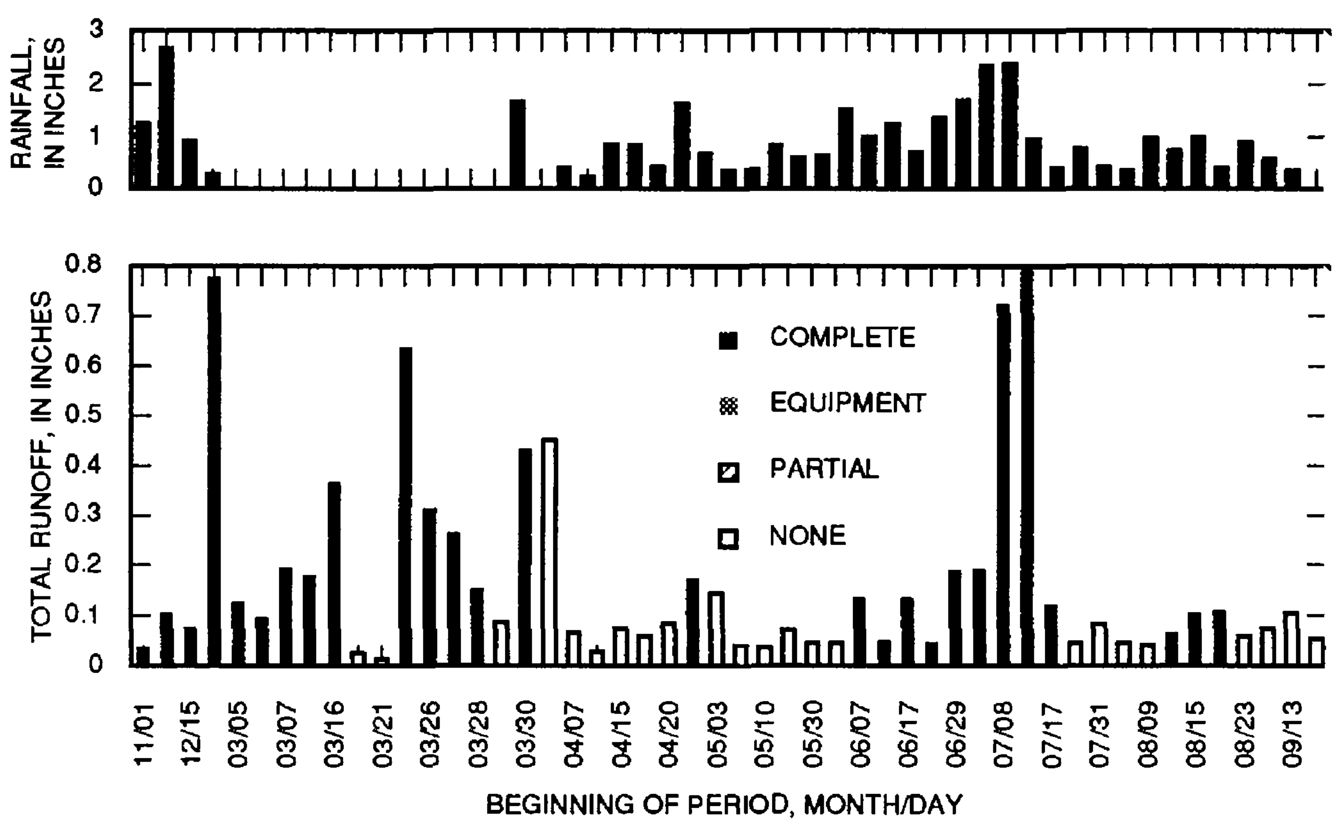

Figure 9. Graph showing total rainfall and runoff for selected hydrograph-rise periods at Rattlesnake Creek monitoring site, Grant County, Wis., water year 1993.

Summary of Data

Maximum, minimum, and mean concentrations of dissolved oxygen for each of seven sites for WY 1990-93 are listed in table 2. The maximum dissolved-oxygen concentrations during the 1993 water year ranged from 13.1 mg/L at Garfoot Creek to 16.5 mg/L at Otter Creek (table 2). The minimum dissolved-oxygen concentration ranged from 0.50 mg/L at Kuenster Creek to 5.2 mg/L at Black Earth Creek at South Valley Road. The mean dissolved-oxygen concentration in 1993 decreased from the mean in 1992 at all of the sites except for Rattlesnake Creek, Kuenster Creek, and Garfoot Creek. The mean dissolved-oxygen concentration for those three sites increased 0.7 mg/L at Rattlesnake Creek, 1.0 mg/L at Kuenster Creek, and 0.3 mg/L at Garfoot Creek.

The State of Wisconsin's water-quality standards require a minimum dissolved-oxygen concentration of 5.0 mg/L for warmwater streams (maximum water temperature is greater than 24°C) and 6.0 mg/L for coldwater streams (maximum water temperature is less than 24°C) (Wisconsin Department of Natural Resources, 1992). The number of days concentrations were below these standards and the total number of days dissolved-oxygen concentrations were monitored during WY 1991-93 are listed in table 3.

The duration that the dissolved-oxygen concentration is less than the State standards is also an important factor in the safety of aquatic organisms. A frequency analysis was done to determine the return period, in days, when the instantaneous dissolved-oxygen concentrations would be less than the State of Wisconsin standard for 1 hour. In summer 1993, the dissolved-oxygen concentration was 6.0 mg/L for 1 hour at Black Earth Creek at South Valley Road once every 75 days or about twice during the summer (May-September) (fig. 10). In comparison, during WY 1992, the dissolved-oxygen concentration was 6.0 mg/L for 1 hour once every 52 days or about three times during the summer (Graczyk and others, 1993). At Garfoot Creek in 1993, the dissolved-oxygen concentration was 6.0 mg/L for 1 hour once every 30 days on average, whereas in 1992, the dissolved-oxygen concentration was 6.0 mg/L once every 7 days on average (Graczyk and others, 1993).

In summer 1993 at Rattlesnake Creek and Kuenster Creek, the dissolved-oxygen concentration was 5.0 mg/L for 1 hour once every 155 days on average or once per summer (fig. 11). In 1992, the dissolved-oxygen concentration was 5.0 mg/L for 1 hour once every 5 days on average or about 30 times for the summer (Graczyk and others, 1993). The higher dissolved-oxygen concentrations indicate an improvement in water quality at these two sites, however, the improvement may be a result of weather and flow conditions rather than implementation of BMP's.

Monitoring activities in Water Year 1994

Dissolved-oxygen monitoring is planned to continue at the warmwater sites to investigate whether severe dissolved-oxygen reductions monitored in past years can and do still occur. Also, continued monitoring may help determine if the improvement of dissolved-oxygen concentrations at Kuenster and Rattlesnake Creeks found in WY 1993 is due to weather and flow conditions or to implementation of BMP's.

Total-Recoverable and Dissolved Hardness

Stormflow and fixed-interval water-quality samples collected at the four urban sites have been analyzed for dissolved and total-recoverable hardness since November 1992. Total-recoverable hardness is determined from a whole-water sample processed by means of a mild digestion, whereas dissolved hardness is analyzed from a filtered water sample. This comparison was done to determine whether dissolved hardness could be estimated from a linear relation with total-recoverable hardness. Linear regression models were used to determine the relation between total-recoverable hardness and dissolved hardness for fixed-interval and stormflow samples.

No relation between total-recoverable and dissolved hardness was found in stormflow samples collected at Nine Springs storm sewer, Monroe Street detention pond, and Lincoln Creek (fig. 12a and b), as indicated by the low coefficients of determination (R^2). However, a relation was found for stormflow and fixed-interval samples from Menomonee River and fixed-interval samples from Lincoln Creek (fig. 12c and d). Therefore, total-recoverable hardness could potentially be used in the future to predict dissolved

Table 2. Summary of surface water dissolved-oxygen concentration data collected at Wisconsin watershed-management evaluation monitoring sites, water years 1990-93

[Concentrations are in milligrams per liter; --, no data]

Water year	Maximum	Minimum	Mean	Maximum	Minimum	Mean
	Garfoot Creek			Otter Creek		
1990	17.4	1.5	9.4	--	--	--
1991	14.6	4.7	9.5	19.1	3.2	9.0
1992	13.7	1.3	8.8	17.6	.20	9.5
1993	13.1	4.0	9.1	16.5	3.6	8.8
	Black Earth Creek at County Trunk P			Rattlesnake Creek		
1990	16.5	4.5	9.6	16.7	.05	9.1
1991	15.5	3.6	9.1	16.8	0.0	9.6
1992	16.4	4.9	9.4	16.3	.09	8.9
1993	13.6	4.3	8.5	14.9	4.8	9.6
	Black Earth Creek at Mills Street			Kuenster Creek		
1990	17.3	3.8	9.9	--	--	--
1991	16.3	3.7	9.4	--	--	--
1992	19.0	4.1	9.4	19.9	.80	8.5
1993	15.2	2.4	8.9	16.2	.50	9.5
	Black Earth Creek at South Valley Road					
1990	17.1	4.8	9.6			
1991	18.3	3.9	9.9			
1992	18.3	4.3	9.7			
1993	13.5	5.2	9.2			

hardness in stormflow and fixed-interval samples from the Menomonee River and in fixed-interval samples from Lincoln Creek.

Linear regression results for stormflow samples collected at Nine Springs tributary storm sewer, Monroe Street detention pond, and Lincoln Creek show that the data are scattered, an indication that the solids in the stormwater contain magnesium and calcium in dissolved and particulate form (fig. 12a and b). Stormflow and fixed-interval samples collected at Menomonee River and fixed-interval samples collected at Lincoln Creek indicate that nearly all of the total-recoverable hardness is dissolved (fig. 12c and d). Stormflow samples from Menomonee River with high concentrations of solids do not contain a significant amount of particulate magnesium and calcium.

Total hardness in stormflow and fixed-interval samples from the urban river sites–Lincoln Creek and Menomonee River–tend to be higher than that of samples from the storm-sewer sites–Nine Springs tributary storm sewer and Monroe Street detention pond (fig. 12). This tendency could be attributed to the elevated concentrations of hardness in ground-water contributions to the river sites whereas the storm sewers are closed and there is minimal ground-water contribution. Fixed-interval samples have higher total hardness than stormflow samples. Stormwater runoff with lower total hardness is diluting the base flow at Lincoln Creek and Menomonee River (fig. 12b, c, and d). This finding is supported by the lower total hardness for the storm samples collected at Nine Spring tributary storm sewer and Monroe Street detention pond.

Table 3. Number of days that surface water dissolved-oxygen concentration was less than the State of Wisconsin standard at selected stream sites during water years 1991-93

Water year	No. of days dissolved oxygen concentration was less than standard	Total no. of days dissolved oxygen was monitored	No. of days dissolved oxygen concentration was less than standard	Total no. of days dissolved oxygen was monitored
	Coldwater streams[1]		Warmwater streams[2]	
	Garfoot Creek		Otter Creek	
1991	9	249	25	206
1992	22	169	23	206
1993	11	132	18	141
	Black Earth Creek at County Trunk P		Rattlesnake Creek	
1991	57	244	14	211
1992	18	155	35	161
1993	20	161	1	154
	Black Earth Creek at Mills Street		Kuenster Creek	
1991	44	223	--	--
1992	26	188	53	171
1993	27	150	4	142
	Black Earth Creek at South Valley Road			
1991	49	215		
1992	21	158		
1993	4	157		

[1]Coldwater streams typically have maximum stream-water temperatures less than 24.0°C.
[2]Warmwater streams typically have maximum stream-water temperatures greater than 24.0°C.

Pesticides

Nonfiltered water samples were analyzed for pesticides commonly used in the vicinity of six of the rural sites and four of the urban sites. Samples were collected during storms, and samples collected nearest the peak discharge were analyzed for pesticides. Automated refrigerated samplers equipped with Teflon[1]-lined tubing and glass bottles were used to collect samples at Rattlesnake, Eagle, Otter, and Bower Creeks (rural sites) and at Lincoln Creek, Menomonee River, Monroe Street detention pond, and Nine Springs tributary storm sewer (urban sites). To collect samples from Garfoot and Brewery Creeks (rural sites), investigators waded to near the center of the creek and dipped the sample bottle just below the water surface. Samples were chilled and shipped to the Wisconsin State Laboratory of Hygiene (WSLH) where they were analyzed. Generally, herbicides are less toxic to fish and other aquatic life than are most insecticides. Researchers have found increased herbicide concentrations in waterways and runoff from nonpoint sources after herbicide application and during spring and early summer rainstorms (Thurman and others, 1992).

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

Summary of Data

Rural sites

The nonfiltered samples were analyzed for the pesticides listed in table 4. These pesticides are insecticides and herbicides that are actively

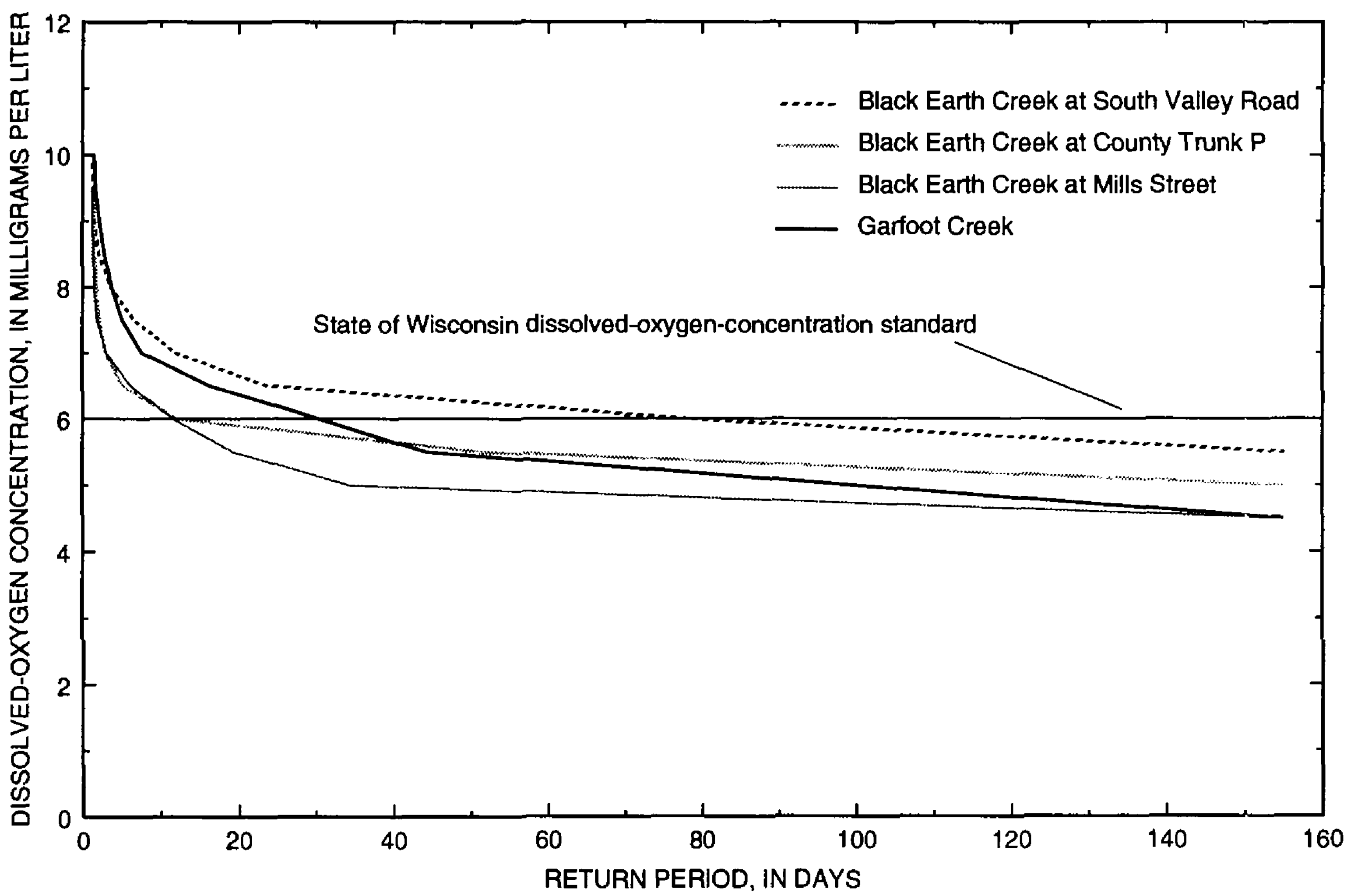

Figure 10. Return period in days that the dissolved-oxygen concentration was less than a given concentration for one continuous hour, summer 1993, at selected coldwater stream sites in Wisconsin.

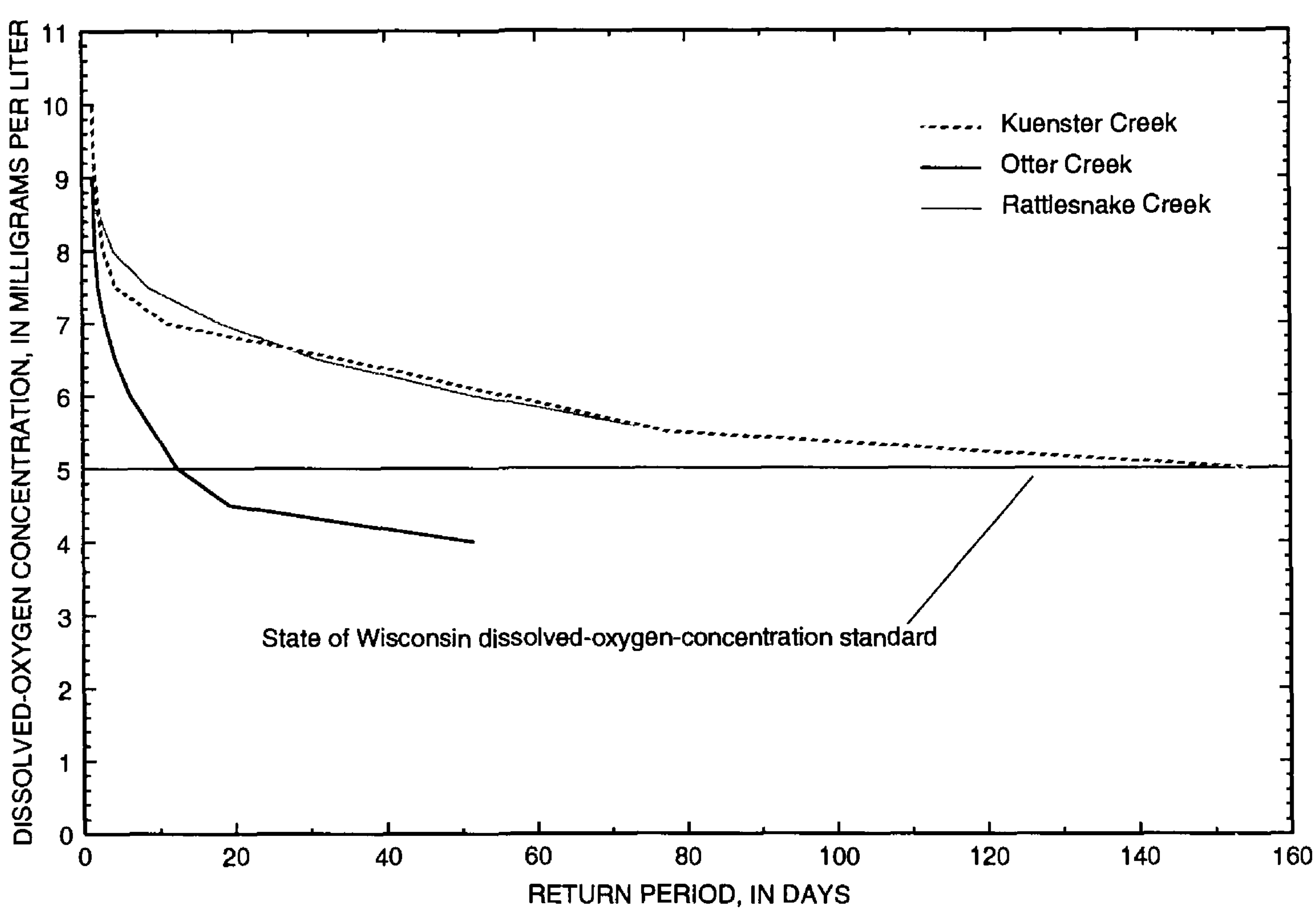

Figure 11. Return period in days that the dissolved-oxygen concentration was less than a given concentration for one continuous hour, summer 1993, at selected warmwater stream sites in Wisconsin.

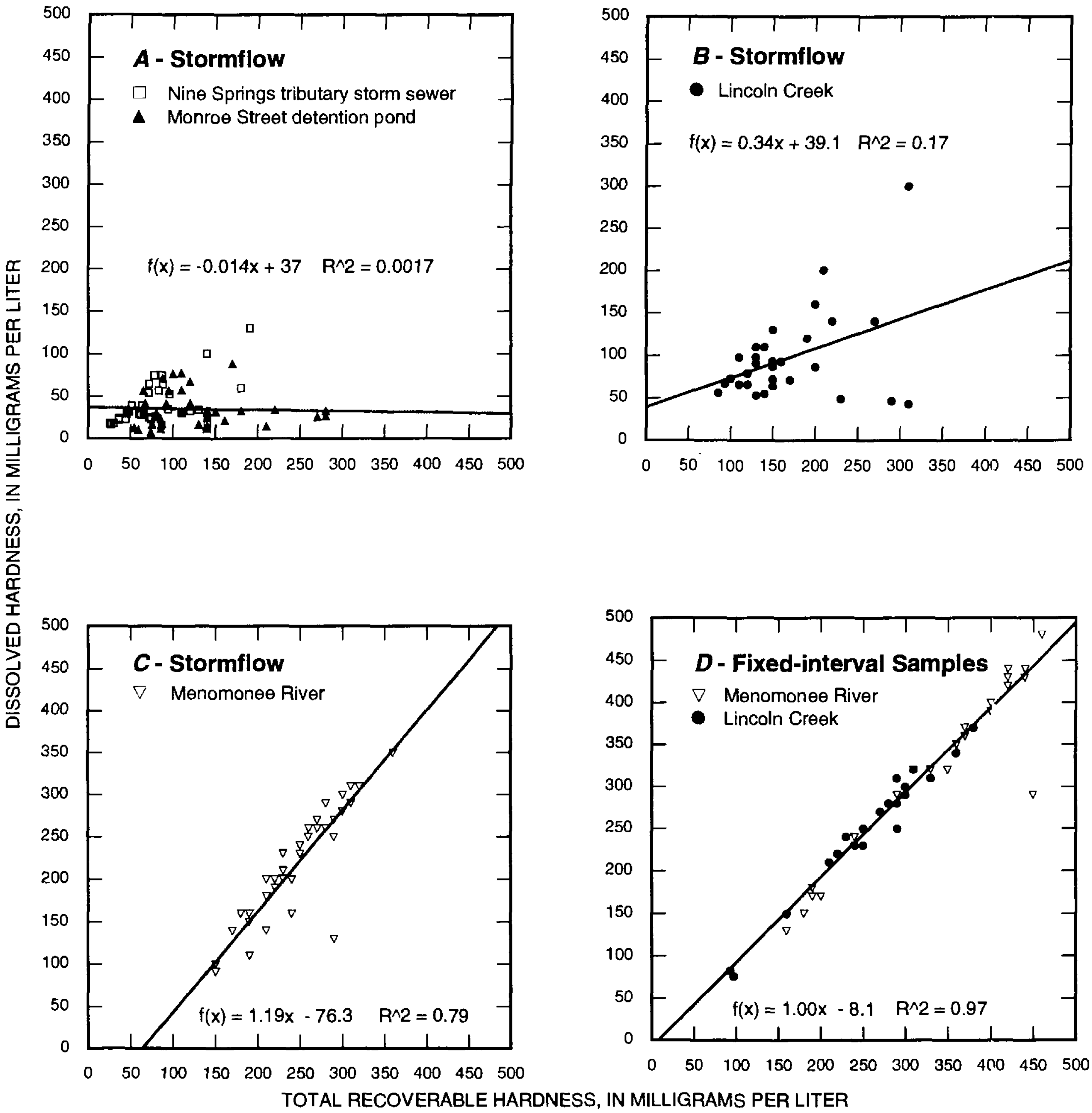

Figure 12. Graphs showing relation between total-recoverable hardness and dissolved hardness of stormflow and fixed-interval water samples from the urban watershed-management evaluation monitoring sites, Wisconsin, water years 1992 and 1993.

being applied in the watersheds. They were chosen for analysis after consultations with county agents in each basin.

Detectable concentrations of herbicides were found in the water-sediment samples collected at all of the sampling sites. The highest concentrations of cyanazine and metolachlor were found in Garfoot Creek at concentrations of 72 µg/L and 57 µg/L, respectively (table 4 and fig. 13). The highest concentration of alachlor was found at Brewery Creek, at 32 µg/L. Concentrations of atrazine were highest in Eagle Creek and Bower Creek, at 22 µg/L and 13 µg/L, respectively (table 4 and fig. 13). At Otter Creek, concentrations of atrazine were found at or near the limit of detection of 0.10 µg/L (table 4 and fig. 13). Concentrations of atrazine at Garfoot Creek were

Table 4. Summary of pesticide data in nonfiltered surface water samples from the six rural watershed-management evaluation monitoring sites in Wisconsin, water year 1993

[Units are micrograms per liter; <, less than limit of detection]

Pesticide	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum
	Eagle Creek			Garfoot Creek			Brewery Creek		
2,4-D[1]	4	.57	<.91	4	.54	<.50	4	3.9	<.50
Atrazine[1]	4	22	0.73	4	0.86	<0.10	4	3.6	0.25
Alachlor[1]	4	1.2	<.10	4	5.2	<.10	4	32	<.10
Cyanazine[1]	4	.37	<.30	4	72	1.3	4	28	.40
Dicamba[1]	4	.74	<.20	4	<.20	<.20	4	5.8	<.20
Metolachlor[1]	4	9.5	.22	4	57	1.3	4	16	<.20
Pendimethalin[1]	4	<1.0	<1.0	4	<1.0	<1.0	4	<2.4	<1.0
Trifluralin[1]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0
Carbofuran[2]	4	<1.9	<.20	4	<1.9	<.30	4	<1.9	<.30
Chlorpyrifos[2]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0
Cis-Permethrin[2]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0
Dimethoate[2]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0
Fonofos[2]	4	<.20	<.20	4	<1.0	<1.0	4	<.20	<.20
Methomyl[2]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0
Parathion[2]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0
Phorate[2]	4	<.20	<.20	4	<.20	<.20	4	<.32	<.20
Terbufos[2]	4	<.20	<.20	4	<.20	<.20	4	<.20	<.20
Trans-Permethrin[2]	4	<1.0	<1.0	4	<1.0	<1.0	4	<1.0	<1.0

Table 4. Summary of pesticide data in nonfiltered surface water samples from the six rural watershed-management evaluation monitoring sites in Wisconsin, water year 1993--Continued

Pesticide	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum
	Rattlesnake Creek			Otter Creek			Bower Creek		
2,4-D[1]	5	.87	<.50	3	<.50	<.50	4	.71	<.50
Atrazine[1]	5	3.3	0.30	3	0.11	<0.10	4	13.0	2.1
Alachlor[1]	5	0.79	<.10	3	.10	<.10	4	3.7	<.10
Cyanazine[1]	5	2.8	<.30	3	.72	<.30	4	4.4	1.0
Dicamba[1]	5	1.8	<.20	3	1.7	<.20	4	17.0	<.20
Metolachlor[1]	5	7.2	.63	3	<.20	<.20	4	.73	<.20
Pendimethalin[1]	5	<1.0	<1.0	3	<1.0	<1.0	4	<1.0	<1.0
Trifluralin[1]	5	<1.0	<1.0	3	<1.0	<1.0	3	<1.0	<1.0
Carbofuran[2]	5	<1.9	<.30	3	<1.9	<.34	4	<1.0	<.34
Chlorpyrifos[2]	5	<1.0	<1.0	3	<1.0	<1.0	4	<1.0	<1.0
Cis-Permethrin[2]	5	<1.0	<1.0	3	<1.0	<1.0	3	<1.0	<1.0
Dimethoate[2]	5	<1.0	<1.0	3	<1.0	<1.0	3	<1.2	<1.0
Fonofos[2]	5	<.20	<.20	3	3.2	<.20	3	.23	<.20
Methomyl[2]	5	<1.0	<1.0	3	<1.0	<1.0	3	<1.0	<1.0
Parathion[2]	5	<1.0	<1.0	3	<1.0	<1.0	4	<1.0	<1.0
Phorate[2]	5	<.20	<.20	3	<.20	<.20	3	<.20	<.20
Terbufos[2]	5	<.20	<.20	3	<.20	<.20	3	<.20	<.20
Trans-Permethrin[2]	5	<1.0	<1.0	3	<1.0	<1.0	3	<1.0	<1.0

[1]Herbicide
[2]Insecticide

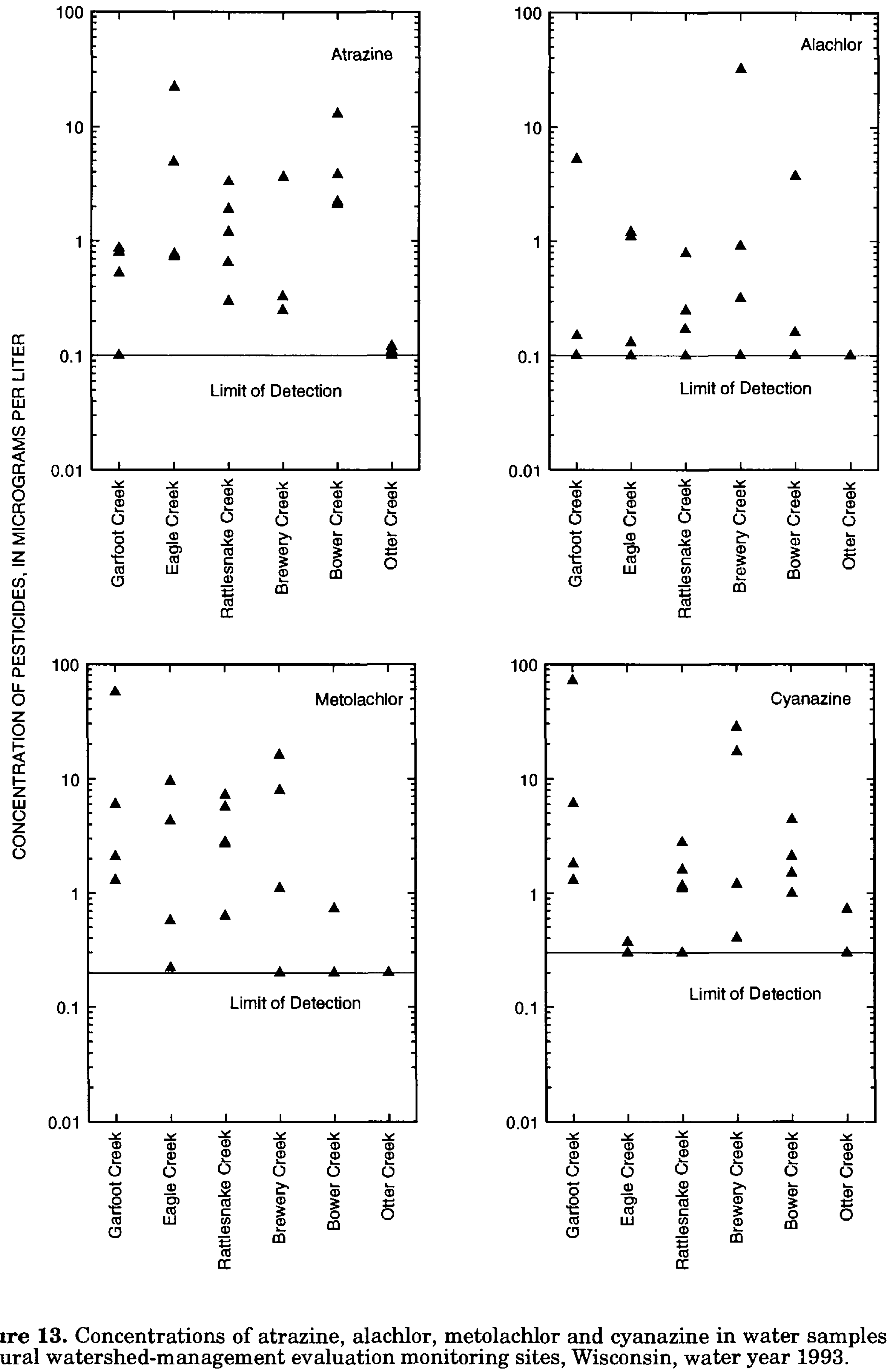

Figure 13. Concentrations of atrazine, alachlor, metolachlor and cyanazine in water samples at the six rural watershed-management evaluation monitoring sites, Wisconsin, water year 1993.

also low; maximum concentration was 0.86 µg/L. Atrazine concentrations at Brewery Creek were higher than concentrations at Garfoot Creek; maximum was 3.6 µg/L. (Garfoot Creek and Brewery Creek watersheds are adjacent to each other and both are tributary to Black Earth Creek. The land uses in both watersheds are similar; however, atrazine is banned in the Garfoot Creek watershed (Wisconsin Department of Agriculture, Trade, and Consumer Protection, written commun., 1993).) Samples from Otter Creek had relatively low concentrations of pesticides compared to the other rural sites (table 4). Concentrations may be low because Otter Creek flows through two lakes that may dilute the pesticide concentrations.

Two other herbicides were detected in samples from the rural sites. Detectable concentrations of dicamba and 2,4-D were found at all of the sites with two exceptions. At Garfoot Creek, no dicamba was found above the limit of detection (0.20 µg/L) and at Otter Creek, 2,4-D was not found above the limit of detection (0.50 µg/L). At Brewery Creek, maximum concentrations of dicamba and 2,4-D were 5.8 µg/L and 3.9 µg/L, respectively. The highest concentration of dicamba was 17 µg/L, detected in a sample collected from Bower Creek.

All samples contained insecticide concentrations below the analytical reporting limit at all of the sampling sites (table 4).

Urban sites

Nonfiltered samples were analyzed for the pesticides listed in table 5. These pesticides are insecticides and herbicides commonly used in urban areas. They were chosen for analysis after consultations with lawn-care companies, lawn and garden stores, and hardware stores.

Herbicides were detected more frequently and at higher concentrations than insecticides. Atrazine, alachlor, and 2,4-D were detected above limits of detection at all four urban sites (fig. 14), cyanazine was detected at Nine Springs Creek tributary and the Menomonee River, and dicamba was detected at the Menomonee River. The maximum atrazine, 2,4-D, cyanazine, and dicamba concentrations were 0.42 µg/L, 1.8 µg/L, 1.7 µg/L, and 0.49 µg/L, respectively, at Menomonee River. The maximum alachlor concentration was 0.62 µg/L at the Monroe Street detention pond. The difference in magnitude of concentrations from site to site was not substantial, but concentrations of herbicides at the urban sites were noticeably less than concentrations of herbicides at the rural sites. This difference between urban sites and rural sites is most likely due to the heavier application of the herbicides in agricultural areas.

At the Monroe Street detention pond, three insecticides (diazinon, lindane, and chlordane) were detected. Maximum concentrations of diazinon, lindane, and chlordane in samples collected at the four urban sites were 0.49, 0.018, and 0.25 µg/L, respectively, all in samples from the Monroe Street detention pond. At Nine Springs Creek tributary and Menomonee River, P,P'-DDT was the only insecticide detected. The maximum concentration of P,P'-DDT was 0.05 µg/L at Menomonee River, which is between the limit of detection and the limit of quantification. P,P'-DDT was banned from general use on January 1, 1973. Its presence in one sample at the Menomonee River and one sample at Nine Springs Creek tributary indicates that P,P'-DDT is still being used or that residuals from before 1973 are still present in some places. At Lincoln Creek, no insecticides were detected (table 5).

Monitoring activities in Water Year 1994

At all rural sites, samples for herbicides are planned to be collected for another year. The number of analytes, however, probably will be reduced. Analyses for insecticides are likely to be discontinued because none of the insecticides were detected in these samples. Most of the samples were collected in early June and July, a time that coincided with crop planting and pesticide application. Herbicide concentrations were low (near the limit of detection) after a major storm in early July at all of the sites; therefore, sampling beyond early July probably will be discontinued, especially if several substantial storms have occurred before July.

At urban sites, samples for pesticides are planned to be collected at all of the sites for another year. The suite of analytes, however, probably will be reconsidered. Pesticides that have not been found above the limit of detection may be discontinued unless the limits of detec-

Table 5. Summary of pesticide data in nonfiltered surface water samples from four urban watershed-management evaluation monitoring sites in Wisconsin, water year 1993

[Units in micrograms per liter; <, less than the limit of detection]

Pesticide	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum	Number of samples	Maximum	Minimum
	Monroe Street detention pond			Nine Springs Creek tributary			Lincoln Creek			Menomonee River		
2,4-D[1]	12	1.6	<.33	6	1.6	<.33	9	2	<.33	8	1.8	<.33
Alachlor[1]	12	.62	<.1	7	.54	<.1	9	.54	<.1	8	.29	<.1
Atrazine[1]	12	.24	<.1	7	.34	.14	9	.32	<.1	8	.42	<.1
Captan[1]	12	<1.0	<1.0	7	<1.0	<1.0	9	<1.0	<1.0	8	<1.0	<1.0
Cyanazine[1]	12	<.3	<.3	7	.37	<.30	9	<.3	<.3	8	1.7	<.3
Dacthal (DCPA)[1]	10	<.85	<.091	5	<.91	<.1	8	<.12	<.091	7	<.55	<.091
Dicamba (Mediben, Banvel D)[1]	12	<.56	<.22	6	<.22	<.22	9	<.22	<.22	8	.49	<.22
Pendimethalin[1]	12	<1.0	<1.0	7	<1.0	<1.0	9	<1.0	<1.0	8	<1.0	<1.0
Trifluralin[1]	12	<1.0	<1.0	7	<1.0	<1.0	9	<1.0	<1.0	8	<1.0	<1.0
Chlordane[2]	13	.25	<.05	7	<.05	<.05	10	<.05	<.05	8	<.05	<.05
Chlorpyrifos[2]	12	<1.0	<1.0	7	<1.0	<1.0	9	<1.0	<1.0	8	<1.0	<1.0
Diazinon[2]	12	0.49	<0.1	7	<0.13	<0.1	10	<0.1	<0.1	8	<0.1	<0.1
Dimethoate[2]	12	<1.0	<1.0	7	<1.0	<1.0	9	<1.0	<1.0	8	<1.0	<1.0
Disulfoton[2]	12	<1.0	<1.0	7	<1.0	<1.0	9	<1.0	<1.0	8	<1.0	<1.0
Lindane[2]	12	.018	<.01	7	<.01	<.01	10	<.01	<.01	8	<.01	<.01
Malathion[2]	12	<.2	<.2	7	<.2	<.2	10	<.2	<.2	8	<.2	<.2
Methoxychlor[2]	12	<.04	<.04	7	<.04	<.04	10	<.04	<.04	8	<.04	<.04
P,P' DDT[2]	13	<.02	<.02	7	.038	<.02	10	<.02	<.02	8	.05	<.02
Sevin[2]	12	<1.7	<1.0	7	<1.7	<1.0	10	<1.0	<1.0	8	<1.0	<1.0

[1]Herbicide

[2]Pesticide

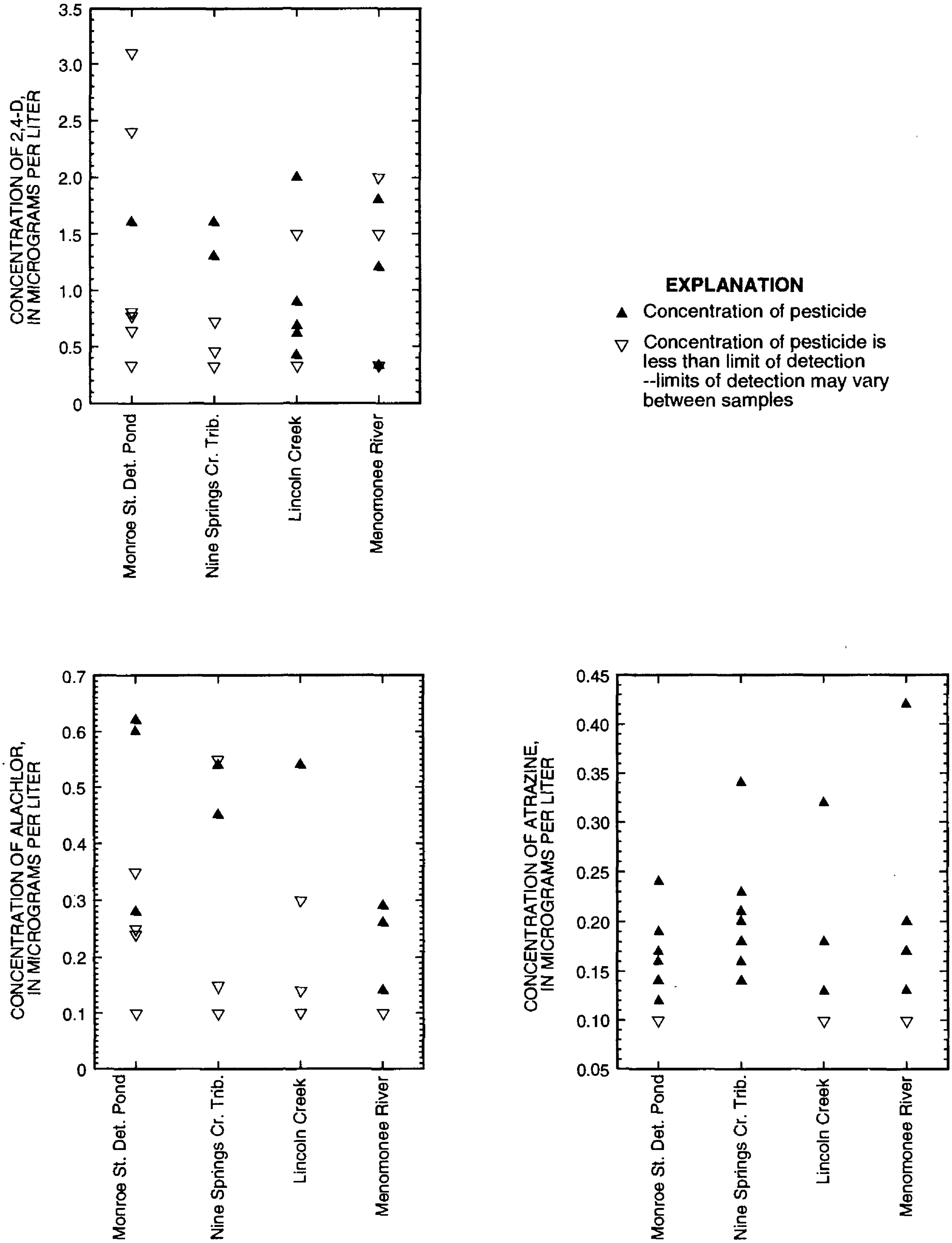

Figure 14. Concentrations of alachlor, atrazine and 2,4-D in water samples at the four urban watershed-management evaluation monitoring sites, Wisconsin, water year 1993.

tion are lowered. Samples were collected from May through August 1993. The data include some pesticide detections through August, when pesticide sampling was discontinued. Also, according to lawn-care companies, pesticides are applied on lawns from April through September. Therefore, in future years, an effort probably will be made to collect at least one event sample per month for pesticides from April through September.

LAND USE AND BEST-MANAGEMENT-PRACTICE INVENTORY

The Priority Watershed Program is administered by the WDNR and the Wisconsin Department of Agriculture, Trade and Consumer Protection to improve streamwater quality in Wisconsin. Designation of a priority watershed is based on severity of pollution, sources of nonpoint pollution contributing to degradation of the water-body, cooperation of local governments to provide support in the planning and BMP implementation phase, and support of local communities.

After priority watersheds are chosen and priority watershed plans are written (Wisconsin Department of Natural Resources, 1989, 1990, 1991, 1993; Wisconsin Department of Natural Resources, written commun., 1990), the county Land Conservation Departments (LCD's) follow several steps to implement these plans. First, the stream is inventoried to determine its condition and to determine what land uses currently exist in the basin. Next, the inventory is broken down into sites that are eligible for BMP implementation based on the contribution of contamination to the stream from each site. Then the LCD contacts the land owners of eligible sites for a voluntary sign-up. If the land owner volunteers for the program, cost share agreement and design of BMP's are made with contingency for the practice to be installed by a certain date.

The WDNR and the USGS implemented the watershed-management evaluation monitoring program in 1984 to test if the BMP's change streamwater quality. Eight rural sites and four urban sites from the Priority Watershed Program were chosen as test sites. Each of the test sites is a smaller watershed that is monitored within one of the priority watersheds. Eight rural sites were chosen with land characteristics similar to the eight rural test sites for use as reference sites. BMP's will not be implemented in the reference sites because they are not in a priority watershed. These sites are to be used as a parallel comparison to the test sites to help describe anomalies found in streamwater quality data from the test sites.

Progress in BMP implementation, changes in land use, and other watershed characteristics are being tracked for each watershed throughout the course of water-quality sampling. This information, along with the results from water-quality analyses, will help to determine the cause of changes in water quality and to what extent BMP's should be implemented in order to achieve specified levels of water-quality improvement.

Data Collection

Updates on eligible and implemented BMP's, priority-watershed-plan inventory data, and some information on other land uses were obtained from the LCD's for the individual test sites within each priority watershed. Some additional land-use information was obtained from the appropriate county LCD's for the individual reference sites.

Road and bridge construction, along with general maintenance information for the test and reference sites, was requested from the appropriate county highway commissions and the Wisconsin Department of Transportation. This information will be used to augment the priority-watershed-plan inventory data on nonpoint-pollution sources.

In preparation for a spring 1994 ephemeral gully inventory, county-soil-survey maps from the U.S. Soil Conservation Service (SCS) were used to locate possible sources of gully erosion and areas where the occurrence of ephemeral gullies are likely. U.S. Agriculture Stabilization and Conservation Service annual aerial photographs of the test sites were also used to facilitate the identification of ephemeral gullies.

Agricultural Land Use

Table 6 summarizes agricultural land uses listed in the priority-watershed-plan inventories for the watershed-management evaluation monitoring watersheds. Cover types for cropland are, by nature, subject to change; future uses of the

Table 6. Agricultural land use in selected rural watersheds in Wisconsin

["Other" may include residential, commercial, non-farm natural resources (such as lakes and woods), and any missing watershed data; --, cover type not found]

Cover type	Total acreage of cover type/percentage of total area			
	Bower Creek (1988-89)	Otter Creek (1987)	Rattlesnake Creek (1989)	Eagle Creek (1988)
Corn	6,275/66	1,420/24	15,802/58	1,674/25
Hay	--	1,062/18	107/0	2,031/31
Oats	--	--	--	273/4
Corn (no rotation)	--	--	3,887/14	110/2
Small grains	--	1,404/24	--	--
Grassland	163/2	578/10	--	34/0
Grazed woodlot	--	--	2,056/8	337/5
Pasture	97/1	11/0	3,061/11	944/14
Woodlot	512/5	748/13	422/2	--
Wetland	44/0	345/6	--	--
Farmstead	235/3	154/3	657/3	110/2
Other	2,146/23	121/2	1,105/4	1,149/17
Total	9,472/100	5,843/100	27,097/100	6,662/100

fields must be ascertained from the rotation codes listed for the individual fields (Wisconsin Department of Natural Resources, 1989, 1990, 1991, 1993; Wisconsin Department of Natural Resources, written commun., 1990). For example, for fields listed as corn, oats, or hay, corn may be grown 1-3 years, oats, 1 year, and hay, 1-4 years. Thus, the cover-type data for cropland account only for the year in which the inventory was completed.

Development of Geographic-Information-System Data Base

A geographic-information-system (GIS) data base is being developed for test and reference sites as follows:

A. Base-map data are entered into the GIS data base by digitizing the mapped data directly from USGS 7.5-minute quadrangles. The base maps include the basin outline, the drainage system, the major roads, and the locations of stream and rain gages.

B. Information on eligible and implemented BMP's, land uses, and other changing watershed characteristics is obtained from the county LCD or the SCS for each individual site.

C. The eligible and implemented BMP's, land uses, and other changing watershed characteristics are then digitized and incorporated onto the base maps.

D. The maps are updated each year to incorporate changes in any of the mapped information.

The eight rural reference sites were digitized and development of base maps was started. The two urban test sites and the eight rural test sites were digitized, and base maps were completed. Land-use and priority-watershed-plan inventory data were digitized and displayed on the Otter Creek base map.

Activities in Water Year 1994

All pertinent land-use data will be entered into a computer data base at the WDNR by a

USGS employee. An updated contaminant source evaluation of the test sites will be developed. This evaluation will account for changes that have occurred since the original priority-watershed-plan inventory and will be accomplished by use of data supplied by the LCD's, by completion of new field inventories of nonpoint-source contaminants (for example, gully and streambank erosion), and by generation of new nonpoint-source-contaminant loads from computer models. Control and development of the GIS data base will be transferred from the USGS to the Bureau of Information Management (BIM) within the WDNR. The BIM is expected to assume the primary responsibility for future development of the GIS data base.

QUALITY ASSURANCE AND QUALITY CONTROL

The quality-assurance/quality-control (QA/QC) plan for the rural watershed-management evaluation monitoring sites was defined previously (Graczyk and others, 1993), and the QA/QC plan for the urban watershed-management evaluation monitoring sites beginning in the spring of 1994 is outlined in Appendix 3. Before the spring of 1994, the QA/QC plan for the urban sites is not formally defined.

The field procedures, sample processing, and equipment cleaning procedures during 1993 were the same as outlined in Appendix 3. Blank samples were treated somewhat differently. Before the spring of 1994, each project chief took several blank samples per year to determine if contamination existed in the samples. When contamination was found, blanks were taken for each individual component of the sampling process defined on page 54.

Inorganic and Organic Constituents at Urban Sites

The QA/QC plan for the urban watershed-management evaluation monitoring project during WY 1993 consisted of a series of blank samples collected from Milli-Q (analyte-free) water passed through different components used in sample collection and processing of streamwater samples from urban sites. These blank samples are used to attempt to isolate inorganic and organic contamination from five components: the sample bottle, the filtering apparatus, the automatic sampler, the filtering pump tube, and the splitter. Blank samples are analyzed for the same constituents as those analyzed for in the streamwater samples.

Inorganic Constituents

Sample bottles

Only one bottle blank was collected during WY 1993. In general, all concentrations were below the limits of detection. The few exceptions were specific conductance (3 µS/cm), alkalinity (3 mg/L), and dissolved zinc (31 µg/L). The blank concentrations should be similar to the concentration of Milli-Q water, which generally has a specific conductance less than 2 µS/cm and alkalinity less than 1 mg/L. The high concentration of dissolved zinc was found to be a result of contamination in the 60-mL sample bottles supplied by the WSLH, as described below.

Filter-blank samples

Most of the blank samples collected were filter blanks (n=21) because early results indicated that the filters may be a source of contamination. The four constituents that were found as contaminants in the filter blanks were dissolved cadmium (Cd), dissolved copper (Cu), dissolved zinc (Zn), and dissolved phosphorus (P) (fig. 15). Beginning in August 1993, dissolved metal samples were filtered into 250-mL metals bottles, whereas earlier samples were filtered into 60-mL sample bottles. This change in bottles dropped the degree of metal contamination noted in the filter blanks, with one exception. Dissolved cadmium was detected in two samples after sample bottles were changed. (The laboratory limit of detection decreased during this sampling period, and the appearance of a decline in filter blanks' metal concentrations (fig. 15) should not be attributed to improved QA/QC procedures.) A discussion of the details of this contamination problem is contained in the following section on Significance of Sample Contamination.

Concentrations of dissolved phosphorus were at or above the limits of detection in 10 samples. In only 2 out of the 10 contaminated samples, however, were concentrations greater than the limits of quantification (Appendix 4). The source of this contamination is unknown.

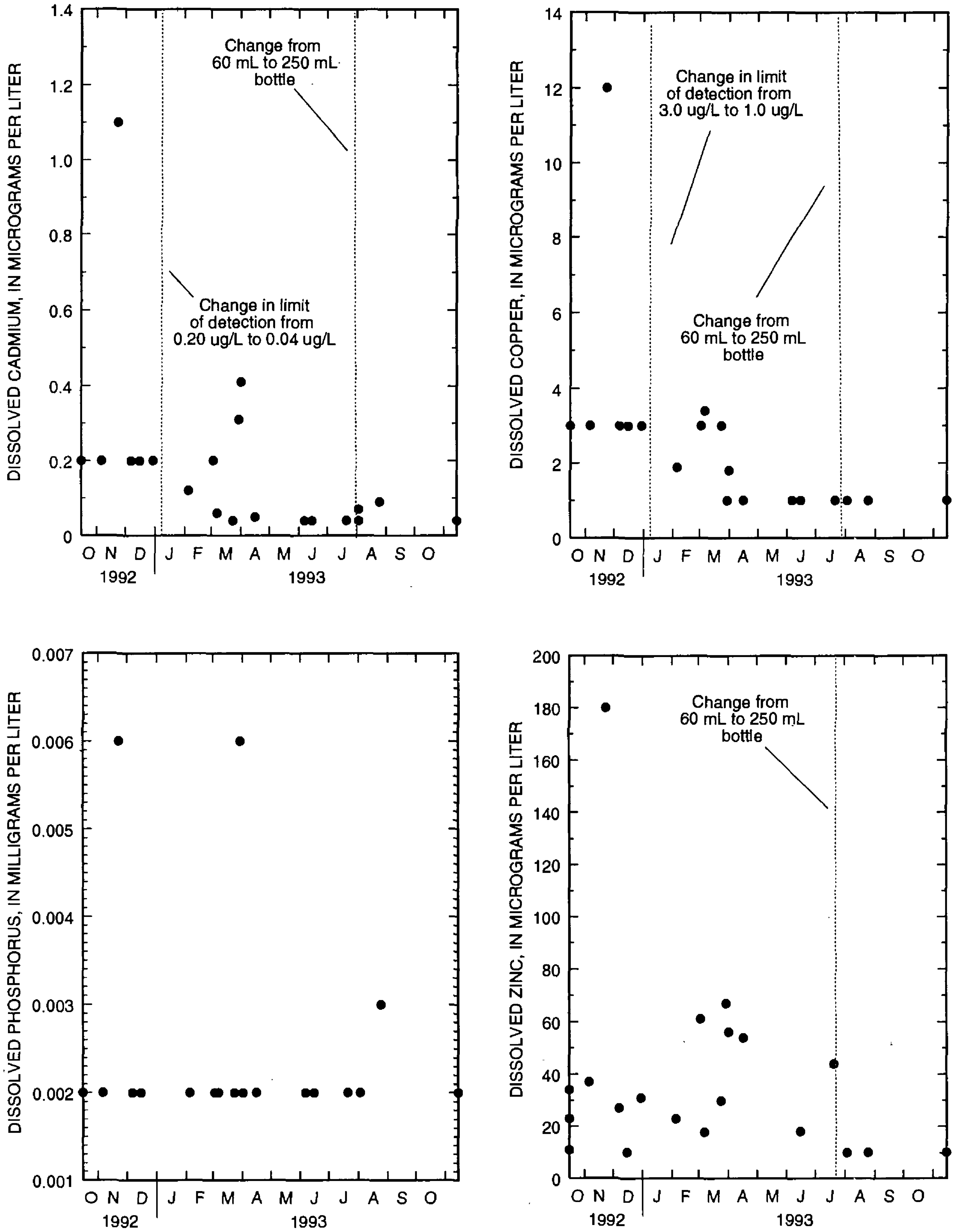

Figure 15. Filter-blank concentrations for selected dissolved constituents for the urban watershed--management evaluation monitoring program, Wisconsin, water year 1993.

Splitter-blank samples

Two blanks were collected by splitting Milli-Q water through the Teflon-lined churn splitter. Inorganic contamination problems in both samples were similar to those found for the bottle and filter blanks (for example, dissolved copper, dissolved zinc, alkalinity). The relative contribution of contamination from the churn splitter could not be determined because of the bottle contamination.

Pump-tube blank samples

Two pump-tube blanks were collected by pumping Milli-Q water through the filter pump tubing and collecting the sample directly into 60-mL bottles. Contamination by dissolved cadmium and zinc was found in both samples, presumably originating from the 60-mL bottles. Consequently, contamination from the pump tubing itself could not be determined.

Sampler-blank samples

A total of six sampler blanks were reported. Because sampler blanks are a measure of the cumulative contamination throughout the entire sampling process, the contamination observed in any of the component blanks discussed above would also be detected in the sampler blanks. In addition to the contaminants previously found in association with the 60-mL bottles, various additional contaminants (calcium, chloride, nitrate, sulfate, suspended solids, and total solids) were observed in the sampler blanks. This contamination appeared to be random and not associated with any particular site or time period.

Organic Constituents

One splitter blank and one sampler blank were collected for analysis of 37 organic constituents sampled at the urban sites, including a number of polycyclic aromatic hydrocarbons (PAH's) not included in this report. Four PAH's (benzo(a)pyrene, benzo(b)fluoranthene, fluoranthene, and pyrene) were found in the sampler blanks at concentrations greater than the limits of detection but less than the limits of quantification. Only fluoranthene and pyrene were detected in the splitter blank. The concentrations of these two constituents were similar in the two blanks: fluoranthene, 0.0093 and 0.0092 µg/L; and pyrene, 0.0084 and 0.0080 µg/L.)

Significance of Sample Contamination

The 60-mL bottles were clearly a source of the systematic dissolved-metal contamination in samples collected before August 1993. Because of the variation in this contamination, there is no simple way to correct for this error. Dissolved zinc analyses before this date are unreliable but concentrations of other dissolved-metals in the blank samples were near the limit of detection, therefore analyses before this date are not necessarily unreliable. Unfortunately, dissolved cadmium contamination was still observed after the bottle problem was corrected in August; therefore, this problem still needs to be closely watched. Since dissolved cadmium is detected at levels near the limit of detection in stream samples, even low levels of contamination are significant. Even though half of the filter blanks indicated some degree of dissolved-phosphorus contamination, the extent of this contamination relative to the concentration of dissolved-phosphorus in streamwater was generally low. Two exceptions are filter-blank samples that had dissolved-phosphorus concentrations of 0.006 mg/L. Use of additional bottle and filter blanks in the future may help to define the extent of this phosphorous contamination.

The source of the high alkalinity of the bottle blank (3 mg/L) is still unknown. This blank was simply Milli-Q water poured directly in the sample bottles and the contamination problem must lie either with the alkalinity bottles, with the Milli-Q water, with the field technique, or with the lab analysis. Because only one sample was collected, it is difficult to determine how serious a problem this may be. Given the fact that the Menomonee River typically has alkalinity concentrations that range from 100 to 200 mg/L, the low level of sample contamination is probably acceptable.

Possible contamination from the churn splitter and the pump tubes could not be determined because of the few samples collected and the overshadowing bottle contamination.

The source of the seemingly random contamination by constituents such as calcium, alkalinity, suspended solids, and chloride in the sampler blanks was impossible to determine; however, this contamination is probably due to residue particulate matter and streamwater in the samplers. Contamination by these constituents is not a serious concern because the level of contamination is generally one or two orders of magnitude less than the instream concentrations.

Although the organic contamination was between the limits of detection and quantification, findings indicate a systematic contamination somewhere in the sampling process. Most streamwater samples had concentrations that were considerably greater than the contamination levels found in the two blank samples, but a few streamwater samples had concentrations quite similar to the blank concentrations. The organic-concentration data available for streamwater to date can be used for interpretive purposes, but future QA/QC work would be needed to isolate the source of this contamination.

Contamination by either inorganic or organic constituents during the collection and processing of water-quality samples for the 1993 urban sampling program are not significant. On the other hand, the frequency of blank sample collection, especially collection of bottle blanks, must be increased if tenuous interpretations based on one or two blanks are to be avoided. If sampling personnel closely follow a more regimented schedule for collecting sample blanks, then it may be possible to determine when and where the contamination is occurring.

Because the QA/QC efforts are extremely important in verifying the integrity of the water-quality data, results from blanks need to be obtained from the WSLH as soon as possible, and the staff from WDNR and USGS need to work collectively to correct situations such as the dissolved-metal-bottle contamination problems when they occur. The current mechanism of the annual review of blank results is inadequate in responding to quality-control problems. Given the large investment of time and money that goes into this sampling program, periodic staff meetings (maybe every month during the sampling season) are warranted to review, discuss, and take the necessary corrective measures to prevent future losses of data.

The QA/QC plan outlined in Appendix 3 is scheduled to be implemented in spring 1994.

Fecal Coliform Bacteria

The work described in this section of the report is a continuation of a study began in late fall 1993. The objective of this study was to determine the effect of holding time on survival of fecal coliform colonies because field personnel sometimes found it difficult to deliver samples to the WSLH within the required 24-hour holding time. In August and September 1993, 20 samples were collected by USGS personnel during runoff events at Brewery Creek and Garfoot Creek (fig. 1). All of these samples were received at the WSLH within 24 hours of collection time (WSLH recommended maximum holding time). Samples were set up in triplicate at four different holding times: 0, 24, 48, and 72 hours, where 0 hours is the time when the sample was received at the laboratory. Sample bottles were refrigerated between setup times. Each plate count was obtained by setting up a three-to-four serial dilution sequence and choosing the optimal plate (preferably 20-60 colonies per plate). The total number of analyses was 240 (20 samples x 4 holding times x 3 replicates). Ten percent of the plates were reported as “too numerous to count” and could not be used in the data analysis. All of these plates were from the 0-hour holding time.

Fecal coliform counts ranged from 100,000 to 4,400,000 colonies per 100 mL of sample and were considerably higher than counts determined in November 1992 (table 7). In both years, all samples far exceeded the State recommended limit of 200 colonies per 100 mL for full-body contact in recreational waters (data are on file at the U.S. Geological Survey in Madison, Wis.). Illustrated in figure 16 are examples of colony counts in the 1994 data. As was the case in the previous year (Graczyk and others, 1993), large variation was seen within each replicate (fig. 16). The mean coefficient of variation within a replicate was 14.5 percent and replicates differed by as much as 43 percent. This variation did not exhibit a consistent pattern with holding time. This inconsistency is seen in the Brewery Creek sample (fig. 16), where the variability and the mean concentration appeared to be decreasing, but on the third day, the concentration substantially increased.

As was the case in November and December 1992, fecal coliform counts generally decreased during the 4-day investigation. Plotted in fig-

Table 7. Fecal coliform summary statistics, Brewery and Garfoot Creeks, Wisconsin, water years 1993-94

[Concentrations are in colonies per 100 milliliters]

Site	Dates	Observations	Mean	Minimum	Maximum	Median
Brewery Creek	*92/11-92/12	20	41,000	8,300	160,000	25,000
	93/8-93/9	96	780,000	110,000	2,800,000	615,000
Garfoot Creek	92/11-92/12	24	130,000	28,000	310,000	97,000
	93/8-93/9	144	640,000	100,000	4,400,000	420,000

*Samples were collected in November and December, 1992 and August and September, 1993.

ures 17 and 18 are the replicate means against holding times for all samples. Linear regression models of the log-concentration values (dependent variable) with respect to time (independent variable) were calculated for all curves. Negative slopes were found for all 20 samples. The mean slope (rate of coliform die off) was -8.2 percent per day. The mean slope for samples from November and December 1992 was slightly higher, -12.6 percent.

Data Analysis

In an attempt to explain the inconsistent patterns observed in means and variances such as those seen at Brewery Creek (fig. 18a), the counts and dilution factors were obtained from the laboratory and examined (table 8).

The serial dilution used during this 3-day time series was not consistent (as mentioned previously, a number of plates of differing dilutions were set up for each replicate, and the optimum plates were chosen). The dilution factor for the Brewery Creek sample was initially 10,000:1 and was changed to 1,000:1 for one of the replicates after 24 hours, and all of the replicates after 48 hours. After 72 hours, a dilution factor of 10,000:1 was used for all three replicates. Increasing the dilution factor on the fourth day explains the increased variability seen on the fourth day. In this case, the change to the dilution factor also resulted in an apparent increase in the mean fecal coliform concentration, but this increase is actually an anomaly due to the large variability on the fourth day.

Application of t-test

A t-test was applied to the data to determine whether significant differences in fecal coliform counts exist with respect to holding times. Because the t-test compares only two treatments, it was run three times, 0- against 24-hour holding time, 0- against 48-hour holding time, and 0- against 72-hour holding time. The level of significance was set at $p < 0.10$, and variances were assumed to be unequal. Differences in fecal coliform counts were significant for 35 percent of the samples concentration at 24 hours, 45 percent at 48 hours, and 50 percent at 72 hours. In the 0- against 24-hour holding time runs, two increases and two decreases in concentrations were significant. All of the significant differences in comparisons of 0 against 48 hours and 0 against 72 hours were decreases.

The equal number of increases and decreases in the 0- against 24-hour comparison indicates that fecal coliform concentrations may have increased in the bottle. Gordon and Fliermans (1978) have demonstrated that fecal coliform colonies can grow in the aquatic environment, outside of the host animal. The samples from Brewery and Garfoot Creeks may be especially susceptible to fecal coliform growth given the relatively high concentrations of nutrients found in these samples.

Clearly, the longer holding periods of 48 and 72 hours resulted in a fecal coliform die-off in the sample bottles. Unfortunately, conclusions regarding the 24-hour additional holding time results are somewhat unclear, and most sample rejections due to holding-time problems are from samples that were held for only one additional day, not two or three. The 24-hour results indicate that either fecal coliform can die off or they can grow during this period, especially during warm weather. Therefore, in order to obtain

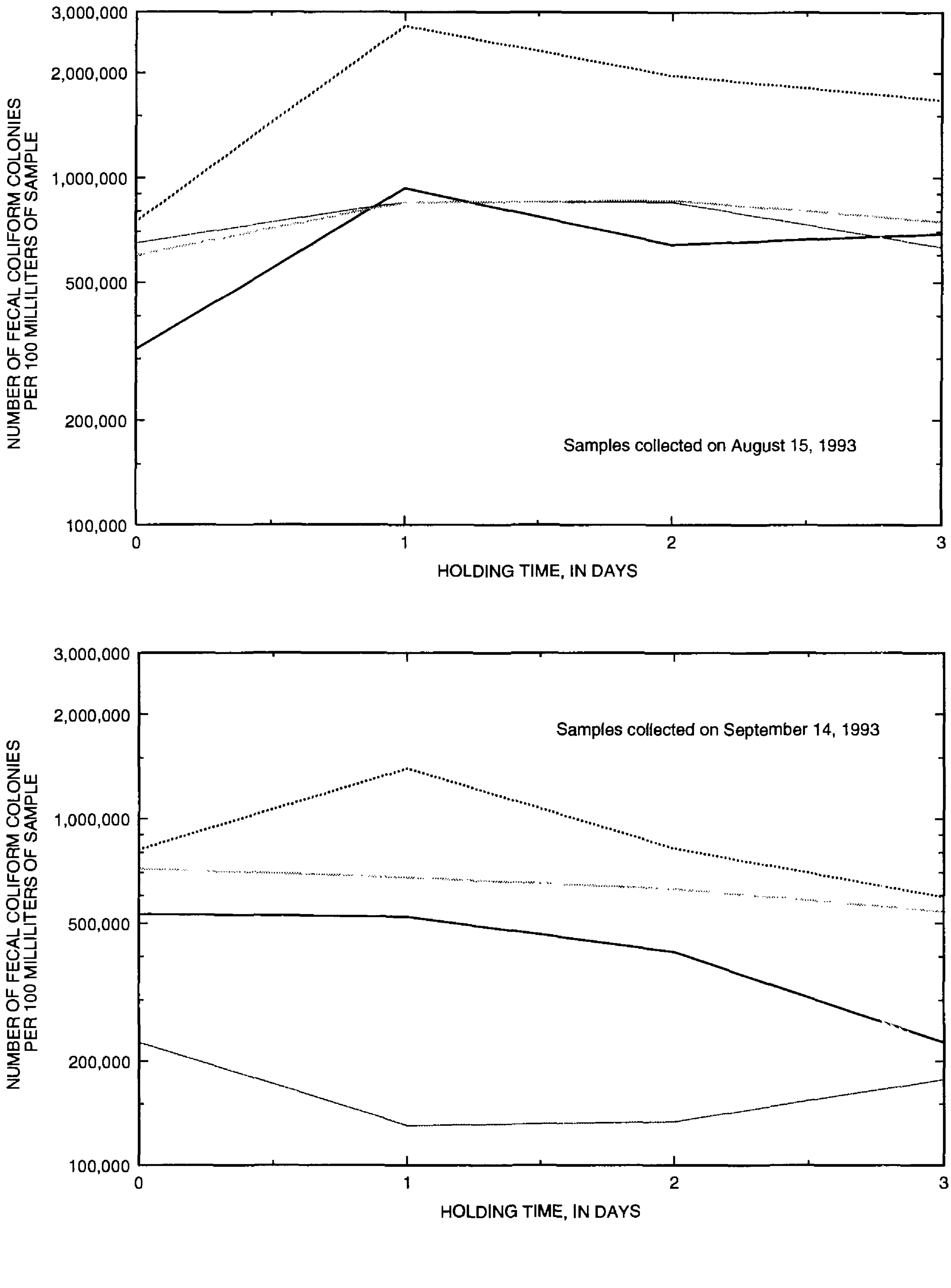

Figure 16. Mean fecal coliform colony counts for different holding times of replicate water samples from Brewery Creek, Wisconsin, for two storms in 1993. Each line represents a different sample within the same storm.

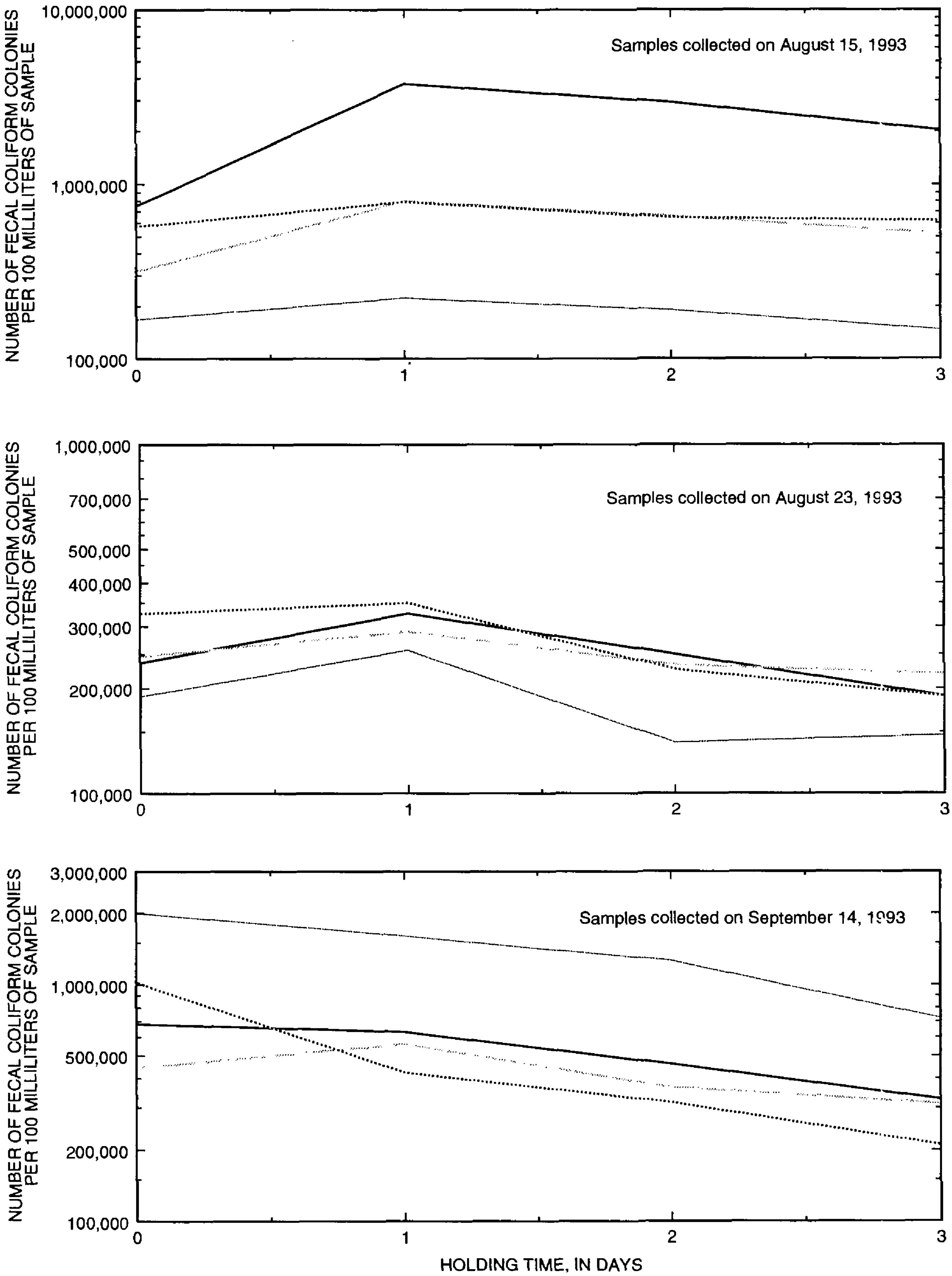

Figure 17. Mean fecal coliform colony counts for different holding times of replicate water samples from Garfoot Creek, Wisconsin, for three storms in 1993. Each line represents a different sample within the same storm.

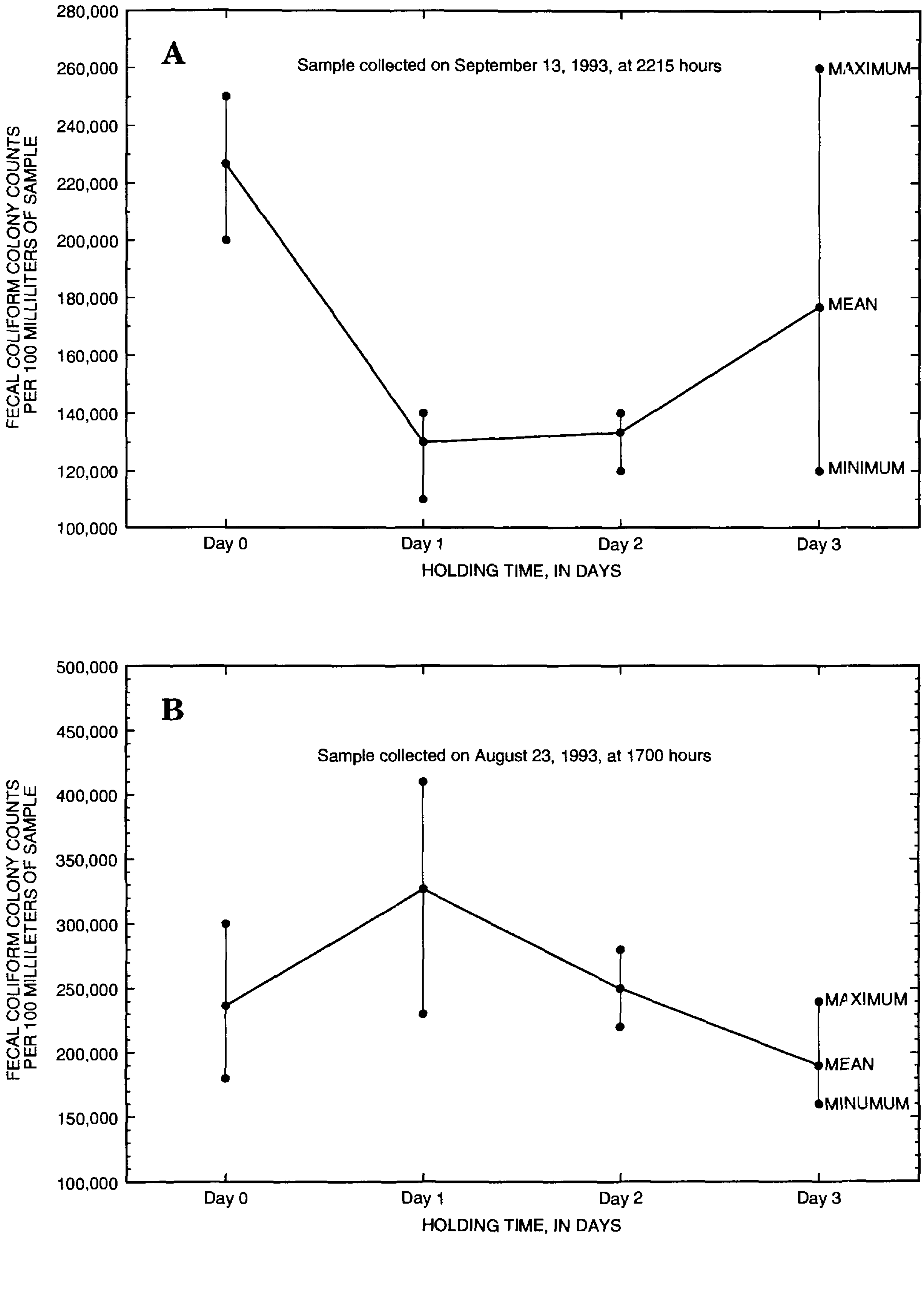

Figure 18. Examples of the effect of holding time on maximum, mean and minimum fecal coliform colony counts in water samples from (A) Brewery Creek and (B) Garfoot Creek, Wisconsin.

Table 8. Fecal coliform counts in, and dilutions used for, the water sample collected from Brewery Creek, Wisconsin, on September 13, 1994

[Concentrations are in colonies per 100 milliliters]

	Holding times							
	0 hours		24 hours		48 hours		72 hours	
Replicate	Count	Dilution	Count	Dilution	Count	Dilution	Count	Dilution
1	25	10,000	14	10,000	130	1,000	15	10,000
2	23	1,000	14	10,000	130	1,000	26	10,000
3	20	10,000	110	1,000	140	1,000	12	10,000

accurate fecal coliform data, it may be even more important to get the samples to the laboratory within the first 24-hour period and avoid not only attrition of the fecal coliform sample but potential growth and increase in fecal coliform concentrations. Conversely, for the small sample size tested here the numbers of increases and decreases were equal, and it is possible that these opposing factors will somewhat cancel each other out when pooled together over the course of the monitoring program. In addition, rejection of 24-hour-old samples may result in the substantial decrease in the number of samples, which will decrease the statistical power for detecting changes in long-term fecal coliform concentrations.

Variance-component analysis

The variability of fecal coliform concentrations due to the effect of holding time was examined in the context of the other sources of variability, namely the analytical (determined from the replicates) and sampling (time within a storm that samples were collected) variability, by use of a variance component analysis on the data set. The holding time and analytical variabilities are possible sources of error, whereas the sampling-time variability represents the natural variability of fecal coliform counts at different times during an event. The variability due to all three factors is listed in table 9. In all but one case, the variability of fecal coliform concentrations resulting from time of sampling within a given storm was the largest source of variability. In no instance was holding time the largest source of variability.

Correlation of fecal-coliform concentrations with other water-quality variables

Concentrations of fecal-coliform and other water-quality characteristics that were measured at the time of the fecal-coliform sampling were correlated to determine which factors are associated with fecal coliform concentrations. The Pearson correlation coefficients are listed in table 10.

Water temperature had the highest correlation with fecal coliform concentrations. The fact that water temperature has a strong effect on fecal coliform has been observed by others (Gordon and Fliermans, 1978; Hunter and McDonald, 1991; Hirotani and Matsui, 1992). The significant correlations with total phosphorus, suspended solids, and volatile suspended solids suggest that fecal coliform concentrations may be associated with runoff or resuspension materials.

Possible Methods to Improve Analytical Results

Statistical differences were observed in fecal coliform concentrations when sample bottles were held longer than the required maximum holding time (24 hours). These differences were apparent despite large variability among replicates. Use of different dilutions for samples within the same time series resulted in misleading anomalies in fecal coliform concentrations over time. Use of consistent dilutions is warranted for any future time-series testing. These data provide some evidence of fecal coliform growth in the sample bottles at least during the first 24 hours (WSLH recommended maximum holding time). In order to obtain as many observations as possible for future statistical analyses, laboratory personnel could analyze samples

Table 9. Values of the three major components of variance in fecal coliform concentrations in water samples from Brewery and Garfoot Creeks, Wisconsin, water year[1] 1993

[Variances in billions of colonies squared]

Site and date		Source of variability		
		Sampling time	Holding time	Analytical
Brewery Creek:	August 15	310	8.3	0.94
	September 14	65	33	8.7
Garfoot Creek:	August 15	1,000	170	46
	August 23	.033	.24	.25
	September 14	130	110	8.8

[1]Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year starting October 1, 1992 and ending September 30, 1993 is called the "1993 water year."

Table 10. Pearson correlation coefficients between fecal coliform concentrations in, and selected characteristics of, water samples from Brewery and Garfoot Creeks, Wisconsin, water year 1993

[*, significant at 0.05 level]

Variable	Correlation coefficient
Water temperature	0.76*
Biochemical oxygen demand (BOD)	-.39
Ammonia (NH_4)	-.46
Total phosphorus	.50*
Suspended solids	.46*
Volatile suspended solids	.47*

between 24 and 48 hours old and flag the results. Samples that have been delayed more than 48 hours could be discarded.

SUMMARY

The objective of the watershed-management evaluation monitoring program in Wisconsin is to evaluate the effectiveness of BMP's for rural streams, urban streams, and urban storm sewers. This report is an annual summary of the data collected for the program and a report of the results from several different special studies conducted within this program.

Water-quality data from eight rural sites and four urban sites are summarized. Storm loads for suspended sediment and total phosphorus were computed for the rural sites, and storm loads for suspended sediment, total phosphorus, total recoverable lead, total recoverable copper, total recoverable zinc, and total recoverable cadmium were computed for the urban sites. All storm load data are summarized in tables.

Continuous dissolved-oxygen data were collected during the summer of 1993 at seven rural sites. Resulting data are summarized in tables. Recurrence intervals are plotted and compared with Wisconsin's water-quality standards. The dissolved-oxygen concentrations declined to levels below these standards at least one time at all seven sites during WY 1993.

Total-recoverable-hardness concentrations were compared with dissolved-hardness concentrations at two urban streams (Lincoln Creek and Menomonee River) and two urban storm sewers (Nine Springs Creek tributary storm sewer and Monroe Street detention pond inlet). Least-squared linear regressions were computed for samples collected during storm-flow and low flow. The storm sample regressions for the storm sewers and Lincoln Creek indicate very weak linear relations (coefficients of determination were less than 0.2) whereas the storm-sample regression for the Menomonee River indicates a fairly strong relation (coefficient of determination was 0.79). The low-flow sample regression for Lincoln Creek and Menomonee River was relatively strong (coefficient of determination was 0.97). The regression equation indicates that most of the hardness during low flow is dissolved hardness.

Pesticide data were collected at four urban sites and six rural sites during WY 1993. Some herbicides were detected at the rural sites, but insecticides were not found above analytical reporting limits. Although herbicides were more prevalent, both herbicides and insecticides were found at the urban sites. Maximum and minimum concentrations of all pesticides are summarized in tables.

A land-use and best-management-practice inventory is ongoing for each evaluation monitoring project to track the different sources of nonpoint pollution in each watershed. Information is being gathered from the county Land Conservation Departments, the county highway commissions, the Wisconsin Department of Transportation, and the U.S. Soil Conservation Service. This information is mapped and stored in a geographic-information-system data base. Each year the information for each watershed is reviewed and updated.

The quality-assurance/quality-control plan for the urban nonpoint monitoring project during WY 1993 consisted of a series of blank samples collected from Milli-Q water passed through different components used in the sample collection and processing of urban stream samples. These blank samples were used to isolate inorganic and organic contamination from the different components of the sampling routine. Constituent concentrations in these blank samples indicated that some dissolved metal contamination in the early part of the water year was corrected during the later months of WY 1993. Some low level organic contamination was found.

A special study was done to determine the effect of holding time on fecal-coliform colony counts. Samples were analyzed at 0 hours, 24 hours, 48 hours, and 72 hours. By use of the t-test and a level of significance of 0.10, a significant decrease in concentrations was found in 33 percent of the samples at 24 hours, 45 percent at 48 hours, and 50 percent at 72 hours. A linear regression shows the mean slope of concentration from 0 hours to 72 hours to be -8.2 percent per day.

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APPENDIXES 1-4

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93

[yr, year; mo, month; d, day; h, hour; in., inches; Mft^3, million cubic feet; lb, pounds; s/m, snowmelt; --, no data]

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids load (tons)	Total-phosphorus load (lb)
Brewery Creek							
84/10/18	1745	84/10/19	1700	2.78	1.5	35	140
84/11/01	0015	84/11/01	2245	.93	.48	7.4	28
84/12/28	0045	84/12/28	2145	s/m	1.3	22	180
85/02/21	0430	85/02/25	0700	s/m	9.6	120	1,500
85/07/24	1930	85/07/26	2230	6.85	14	500	2,000
85/08/12	2145	85/08/13	1800	.94	.25	1.2	13
85/08/25	0200	85/08/26	1000	1.70	.53	2.6	--
85/09/04	2330	85/09/05	2115	1.53	.56	2.3	38
85/09/09	0015	85/09/09	2345	1.40	1.3	25	130
85/10/12	0315	85/10/13	0200	.80	.76	3.3	--
85/10/23	1515	85/10/24	1400	.59	.39	2.3	20
85/10/31	1800	85/11/02	1100	2.77	2.4	20	190
85/11/17	2245	85/11/19	0800	.63	.85	3.5	55
86/03/09	2200	86/03/10	2300	s/m	.67	8.1	--
86/03/17	1200	86/03/20	0100	s/m	3.1	60	330
86/05/15	1500	86/05/16	0200	.58	.28	1.2	18
86/05/17	0100	86/05/18	0600	1.09	.96	8.1	78
86/06/22	0100	86/06/22	2300	1.16	.77	1.1	24
89/10/05	0745	89/10/05	1500	--	.020	.040	1.1
90/03/08	0930	90/03/09	0500	.67	1.8	590	750
90/03/11	0600	90/03/12	0200	.50	2.5	160	820
90/03/13	1815	90/03/14	0600	.84	.89	48	250
90/06/02	1315	90/06/03	1000	1.54	.59	35	140
90/06/28	2330	90/06/29	1900	2.14	4.1	250	1,100
91/04/12	1230	91/04/13	1230	1.17	.75	8.3	85
91/04/14	0600	91/04/14	2400	.80	.61	4.1	54
91/04/28	2045	91/04/29	1100	1.24	.29	7.1	47
91/05/05	0900	91/05/05	2400	1.08	.24	3.4	25
91/07/01	1415	91/07/02	1500	1.29	.34	1.7	27
91/07/07	1430	91/07/08	1315	1.11	.52	3.1	56
91/08/08	0130	91/08/08	0900	2.24	.14	.97	9.9
91/10/24	2000	91/10/26	0100	3.55	2.9	120	740
91/11/01	0030	91/11/02	1330	.81	.88	5.4	90
91/11/29	1900	91/11/30	1800	.61	.44	2.3	32
92/02/27	1030	92/02/28	0500	s/m	.87	6.7	130
92/02/28	0845	92/02/29	0300	s/m	.98	14	160
92/03/01	1200	92/03/02	0700	s/m	.66	20	120
92/07/13	1500	92/07/15	0300	1.49	.34	--	36

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids load (tons)	Total-phosphorus load (lb)
Brewery Creek--Continued							
92/08/29	0330	92/08/29	1100	1.21	.037	.13	.78
92/09/16	1100	92/09/17	1800	1.19	.25	.51	27
92/09/18	0330	92/09/19	1700	.73	.33	.47	18
92/10/15	1800	92/10/15	2300	.45	.019	.020	.28
92/11/20	0300	92/11/22	0600	2.55	1.4	7.5	100
93/03/06	1000	93/03/07	0815	s/m	.60	13	440
93/03/07	1200	93/03/08	0800	s/m	1.2	9.3	490
93/03/08	1300	93/03/09	0400	s/m	.83	7.8	380
93/03/16	0700	93/03/17	0800	s/m	1.7	73	640
93/03/24	1000	93/03/25	0700	s/m	2.1	36	330
93/03/25	1000	93/03/26	0800	s/m	2.3	67	460
93/03/26	1200	93/03/27	0800	s/m	2.3	--	160
93/03/27	1200	93/03/28	0800	s/m	1.2	16	98
93/03/28	1100	93/03/29	0700	s/m	2.9	210	590
93/03/31	0300	93/04/01	0300	s/m	2.5	55	250
93/06/07	1035	93/06/08	1000	2.39	2.5	110	470
93/06/17	1000	93/06/18	1200	.43	.93	18	67
93/07/05	0430	93/07/07	0900	4.58	16	1,300	4,000
93/07/07	1800	93/07/08	0900	1.03	1.3	130	460
93/07/09	0100	93/07/10	0400	1.47	5.1	250	570
93/07/17	1100	93/07/18	0400	.86	.84	42	87
93/07/25	0100	93/07/26	0400	1.35	2.1	83	300
93/07/27	2200	93/07/28	1900	.88	1.4	25.8	120
93/08/15	0500	93/08/16	2000	2.48	4.7	88.6	470
93/09/13	0800	93/09/15	1500	2.12	2.9	12.1	130
Garfoot Creek							
84/10/18	1200	84/10/19	2200	2.64	3.1	37	210
84/10/31	2400	84/11/01	1800	1.13	1.1	16	76
84/12/27	2200	84/12/29	0900	s/m	2.4	45	140
85/02/21	0200	85/02/25	0100	s/m	6.3	62	470
85/07/24	1915	85/07/26	0500	6.56	7.5	65	710
85/09/04	2400	85/09/05	1300	1.38	.49	1.7	22
85/09/09	0015	85/09/09	2100	1.63	2.2	17	130
85/09/23	0300	85/09/24	0300	1.20	.57	1.9	--
85/10/11	2345	85/10/12	2100	.85	1.1	14	--
85/10/23	1600	85/10/24	0700	.70	.62	9.8	46
85/10/31	1626	85/11/02	1400	2.79	5.3	34	370
85/11/18	0300	85/11/19	0900	.73	1.6	17	98

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids load (tons)	Total-phosphorus load (lb)
Garfoot Creek--Continued							
86/03/09	1600	86/03/11	0600	s/m	1.7	26	110
86/03/16	1200	86/03/20	0200	s/m	7.7	59	610
86/05/15	1400	86/05/16	0500	.72	.53	14	27
86/05/17	0100	86/05/18	0400	1.15	1.2	15	75
89/10/05	0930	89/10/06	0600	--	.21	.27	6.4
90/01/16	1845	90/01/17	2200	s/m	1.4	13	190
90/03/11	0600	90/03/12	0400	.48	2.9	53	330
90/03/13	0600	90/03/14	1300	.76	1.3	30	160
90/03/14	1600	90/03/15	1500	1.12	2.0	31	230
90/06/02	1300	90/06/03	0100	1.48	.42	23	100
90/06/28	2330	90/06/29	2300	2.45	3.0	77	530
90/08/19	1630	90/08/20	1200	--	.81	4.6	61
91/03/01	0945	91/03/02	2200	1.51	3.2	53	370
91/03/22	2130	91/03/23	0700	.74	.33	4.2	28
91/04/12	1500	91/04/13	1400	1.74	2.2	74	210
91/04/14	0600	91/04/14	2400	.99	1.9	58	200
91/08/08	0200	91/08/08	1500	2.34	.30	--	12
91/11/01	0900	91/11/02	0100	1.40	1.3	15	150
91/11/29	2000	91/11/30	1300	.87	.98	13	76
92/02/26	1400	92/02/27	0100	s/m	.30	--	11
92/02/27	1045	92/02/28	0100	s/m	.68	9.0	54
92/02/28	1130	92/02/28	2400	s/m	.44	1.5	21
92/09/16	1200	92/09/17	0330	1.34	.69	7.4	46
92/09/18	0330	92/09/18	1800	.89	.70	5.2	48
92/11/19	2000	92/11/21	2300	2.68	3.4	43	420
92/12/15	1600	92/12/16	1200	1.30	1.2	7.4	400
93/03/24	1300	93/03/25	0830	s/m	2.1	24	240
93/03/25	1030	93/03/26	1000	s/m	3.4	41	300
93/03/26	1300	93/03/27	0500	s/m	1.7	14	130
93/03/27	1240	93/03/28	0400	s/m	1.3	9.1	100
93/03/28	1000	93/03/29	0300	s/m	2.7	44	290
93/03/31	0400	93/04/01	0400	s/m	3.7	28	210
93/04/07	2300	93/04/08	1700	.62	1.3	13	60
93/04/15	0100	93/04/16	1200	1.55	4.2	35	240
93/04/19	1300	93/04/20	2300	1.69	3.8	37	180
93/06/07	1045	93/06/08	2000	1.97	2.8	31	180
93/06/17	1800	93/06/18	1200	1.09	.99	13	54
93/07/05	0500	93/07/07	0200	3.98	7.7	130	730

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids load (tons)	Total-phosphorus load (lb)
			Garfoot Creek--Continued				
93/07/08	1300	93/07/10	0400	1.81	5.9	110	490
93/07/10	1800	93/07/11	0500	.45	1.1	12	63
93/07/25	0300	93/07/25	2400	1.48	2.5	43	220
93/07/27	2200	93/07/28	1500	.44	.92	5.92	38
93/08/15	0500	93/08/16	1300	2.35	3.6	30.8	230
93/08/23	1600	93/08/24	0700	1.26	1.3	14.2	65
93/09/13	1000	93/09/15	0500	2.27	2.7	18.6	140
			Eagle Creek				
91/04/29	0200	91/04/29	2200	1.81	5.1	2,100	3,800
91/05/05	0800	91/05/05	2230	1.29	1.7	61	210
91/05/15	2130	91/05/17	0200	.85	6.9	3,200	4,700
91/05/31	0900	91/05/31	2000	.50	1.2	250	280
91/07/21	1715	91/07/21	2400	1.99	1.6	220	430
91/08/07	1540	91/08/08	1500	1.88	1.6	62	140
91/10/23	2325	91/10/24	1200	1.21	.88	52	200
91/11/01	0050	91/11/01	2300	2.75	7.0	620	1,400
91/11/17	1900	91/11/18	1200	1.15	1.9	120	250
92/03/01	1100	92/03/02	0400	s/m	1.3	140	220
92/03/03	2000	92/03/04	0900	.41	.92	48	130
92/03/09	0100	92/03/09	1300	.82	1.1	72	170
92/04/20	1500	92/04/21	0900	1.24	1.8	210	300
92/05/16	1645	92/05/16	2400	1.54	.66	83.6	160
92/05/21	1730	92/05/21	2200	.51	.24	6.3	22
92/05/22	1815	92/05/23	0300	.44	.47	26	84
92/07/13	1400	92/07/13	2400	1.27	.73	43	80
92/08/01	1900	92/08/02	0200	1.03	.49	16	31
92/09/16	0200	92/09/16	2400	3.99	1.2	1,700	3,300
93/03/26	1200	93/03/27	0200	s/m	1.1	35	87
93/03/29	1100	93/03/29	2400	s/m	9.9	27	42
93/03/30	1300	93/03/31	2100	1.67	4.7	420	610
93/04/11	0200	93/04/12	0600	.79	2.4	50	100
93/04/18	2100	93/04/20	0600	2.22	7.0	450	960
93/04/27	0100	93/04/27	1400	1.02	1.4	74	180
93/06/08	1500	93/06/09	0400	1.47	4.4	950	2,000
93/07/02	0010	93/07/02	1100	1.47	5.5	420	1,100
93/07/03	1400	93/07/04	0600	1.06	6.1	1,500	3,000
93/07/27	1715	93/07/28	0400	.76	1.5	120	220
93/08/09	0600	93/08/09	2000	1.09	2.8	310	540

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft³)	Suspended-solids load (tons)	Total-phosphorus load (lb)
			Eagle Creek--Continued				
93/08/15	0400	93/08/15	1800	1.18	2.2	73	160
93/08/18	0900	93/08/18	2100	1.30	3.6	290	640
93/08/30	0400	93/08/30	2000	1.69	4.6	410	1,000
93/09/13	1000	93/09/14	1100	1.72	3.6	120	300
			Joos Valley Creek				
90/08/17	1850	90/08/18	0200	1.37	.96	170	420
90/08/26	0545	90/08/26	1500	1.75	2.8	750	1,600
91/04/29	0200	91/04/29	1600	2.11	1.7	840	1,500
91/05/05	0730	91/05/05	2000	1.25	.64	26	57
91/05/15	2000	91/05/17	0200	1.21	1.8	390	850
91/05/31	0850	91/05/31	1900	.57	.40	36	78
91/07/21	1710	91/07/22	1100	1.24	.68	27	70
91/08/07	1500	91/08/08	1100	2.27	.63	11	34
91/10/23	2250	91/10/24	1300	.83	.34	3.4	12
91/10/31	2200	91/11/01	2200	2.87	2.1	110	330
91/11/17	1800	91/11/18	1400	1.21	.96	14	62
92/03/01	1000	92/03/02	0400	s/m	.63	16	68
92/03/03	1400	92/03/04	0800	.37	.47	1.5	11
92/03/08	2400	92/03/09	1100	.86	.45	20	49
92/04/20	1300	92/04/21	0700	1.24	.77	56	120
92/05/16	1500	92/05/16	2200	1.62	.34	54	110
92/05/21	1700	92/05/21	2400	.74	.22	13	35
92/05/22	1800	92/05/23	0300	.49	.27	12	31
92/06/17	0400	92/06/17	1800	.57	.25	2.8	7.7
92/07/02	0500	92/07/02	1500	.72	.23	4.2	9.2
92/07/13	1300	92/07/14	0200	1.32	.40	7.1	21
92/07/22	1000	92/07/23	0300	1.19	.37	1.4	5.7
92/08/01	1800	92/08/02	1300	1.24	.57	24	73
92/09/16	0100	92/09/16	2200	4.19	5.4	910	1,700
93/03/24	1100	93/03/25	0500	s/m	.38	1.4	14
93/03/26	1300	93/03/27	0200	s/m	.47	8.3	56
93/03/30	1100	93/03/31	2000	1.50	2.1	86	25
93/04/11	0100	93/04/12	0200	.53	.87	4.0	15
93/04/16	1200	93/04/17	0100	.64	.60	4.2	16
93/04/18	2200	93/04/20	0300	2.07	2.7	130	320
93/04/27	0100	93/04/28	0200	1.07	1.5	22	63
93/06/08	1500	93/06/08	2310	1.50	1.8	630	900

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft³)	Suspended-solids load (tons)	Total-phosphorus load (lb)
			Joos Valley Creek--Continued				
93/07/01	2400	93/07/02	0940	1.33	1.2	180	410
93/07/03	1400	93/07/03	2100	.90	2.2	880	1,600
93/07/27	1700	93/07/27	2300	.75	.54	64	130
93/08/09	0600	93/08/09	1400	1.17	.92	110	220
93/08/15	0300	93/08/15	1500	1.19	.73	12	330
93/08/18	0900	93/08/18	0900	1.08	.87	53	140
93/08/30	0300	93/08/30	1300	1.78	1.4	130	290
			Bower Creek				
90/10/17	2040	90/10/20	0925	.38	3.6	12	280
91/03/01	1500	91/03/04	1100	1.05	100	100	--
91/03/05	1700	91/03/08	1500	s/m	12	13	520
91/03/18	1300	91/03/25	0900	s/m	160	160	1,800
91/04/09	1100	91/04/12	2000	s/m	48	48	460
91/04/12	2400	91/04/17	2400	.71	260	260	1,500
91/06/14	0500	91/06/15	1545	1.40	1.2	9.7	70
91/10/29	1000	91/10/31	1400	1.02	1.00	1.8	58
91/11/01	1325	91/11/04	0600	.35	.91	.55	77
91/11/18	0700	91/11/20	0905	.23	.90	.24	32
91/11/29	1805	91/12/02	1610	.78	10	64	590
91/12/12	0825	91/12/14	0700	.61	14	64	700
92/03/29	1500	92/03/31	0940	.28	3.9	5.9	120
92/03/31	1200	92/04/02	1100	.12	3.9	11	150
92/04/10	1700	92/04/13	1535	.43	12	75	440
92/04/15	1200	92/04/18	0935	2.07	34	710	2,900
92/04/19	1355	92/04/20	1815	.19	3.4	11	110
92/04/20	1945	92/04/22	0910	.36	7.2	72	430
92/07/13	1820	92/07/16	0500	.71	.48	.24	13
92/09/16	0725	92/09/17	0520	1.39	.95	2.9	110
92/09/18	0240	92/09/20	0800	1.48	13	97	950
92/09/26	1000	92/09/30	0510	1.11	3.3	2.7	120
92/11/01	1900	92/11/03	2300	1.27	8.1	40	550
92/11/08	2300	92/11/12	0401	.34	4.1	3.7	130
92/11/12	1200	92/11/14	1001	.34	4.7	6.3	170
92/11/20	0005	92/11/22	0530	1.60	38	270	2,500
92/12/15	0715	92/12/17	2216	1.02	47	180	1,900
92/12/29	0600	92/12/31	2301	s/m	1.6	.77	58
93/03/02	1140	93/03/18	1801	s/m	29	30	1,600

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft³)	Suspended-solids load (tons)	Total-phosphorus load (lb)
			Bower Creek--Continued				
93/03/24	0859	93/03/31	1501	s/m	22	26	1,100
93/04/04	1130	93/04/07	1101	s/m	9.5	22	350
93/04/07	1345	93/04/10	0101	.76	28	290	1,700
93/04/11	1459	93/04/14	0801	s/m	7.4	8.0	230
93/04/15	0559	93/04/19	0301	1.01	46	420	2,400
93/04/19	0900	93/04/23	0801	.49	32	140	1,300
93/04/27	1729	93/04/29	1401	.55	8.5	27	340
93/05/30	1245	93/06/03	0531	.92	4.0	2.5	110
93/06/08	0300	93/06/11	1201	2.51	38	1,100	3,600
93/06/14	0225	93/06/16	0021	.96	6.9	110	480
93/08/05	2300	93/08/08	1700	1.18	1.6	5.1	--
			Otter Creek				
90/09/06	1940	90/09/08	1845	1.53	1.5	7.1	63
90/09/14	0540	90/09/18	2335	1.67	6.5	26	190
90/11/05	0610	90/11/06	1030	.79	1.2	1.2	20
91/02/03	0300	91/02/08	1400	s/m	10	11	180
91/03/01	1100	91/03/04	1600	s/m	5.3	27	--
91/06/14	1735	91/06/18	0300	2.24	5.2	35	230
91/10/24	1200	91/10/26	1245	1.85	2.0	8.3	57
91/10/26	1245	91/10/27	2300	.46	1.4	1.6	23
91/10/29	0225	91/10/30	1910	--	2.6	11	83
91/11/01	1200	91/11/03	0005	.53	2.2	8.1	70
91/11/14	1535	91/11/17	0155	.46	2.0	3.0	24
91/11/18	0140	91/11/20	1810	.39	2.7	7.6	45
91/11/29	2015	91/12/02	2235	1.38	6.7	19	150
92/02/27	1200	92/03/01	0900	s/m	4.1	12	110
92/03/01	0900	92/03/03	0900	s/m	4.1	14	130
92/03/05	2100	92/03/08	1100	.37	5.8	15	100
92/03/09	0335	92/03/10	1930	.55	4.8	24	98
92/03/24	1200	92/03/28	0700	s/m	6.0	8.3	82
92/04/10	1800	92/04/13	0500	.81	4.1	19	82
92/04/16	0500	92/04/18	0540	.80	4.5	25	110
92/09/14	1230	92/09/15	0600	1.01	.24	.27	2.8
92/09/16	0950	92/09/17	0640	1.00	.41	1.1	13
92/09/18	0440	92/09/19	0735	1.09	.82	3.1	25
92/09/26	2110	92/09/28	1700	.74	.63	.52	5.2
92/11/01	1600	92/11/03	1600	1.55	2.4	6.5	57
92/11/12	0800	92/11/13	1901	.39	.92	.62	9.3

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft³)	Suspended-solids load (tons)	Total-phosphorus load (lb)
Otter Creek--Continued							
92/11/19	2300	92/11/22	1701	.84	4.2	16	120
92/11/25	1900	92/11/27	1901	.35	2.7	3.0	53
92/12/15	0520	92/12/17	1301	.97	7.6	32	220
92/12/29	0744	92/12/30	0731	.30	.83	.44	7.8
93/03/24	1050	93/04/01	1201	s/m	29	39	450
93/04/03	1400	93/04/06	0900	s/m	5.7	4.8	58
93/04/08	0035	93/04/09	1833	1.10	12	45	270
93/04/11	1100	93/04/13	1001	.45	6.4	5.3	69
93/04/15	0335	93/04/17	0713	1.43	18	74	420
93/04/19	1505	93/04/21	2152	1.50	20	67	440
93/06/07	1230	93/06/09	2045	2.39	14	140	510
93/07/05	1700	93/07/07	2100	2.04	12	160	580
93/07/09	0300	93/07/10	2200	1.42	8.0	120	410
93/09/13	1045	93/09/16	0700	2.34	2.3	3.7	37
93/09/20	1435	93/09/22	0900	1.49	2.6	12	78
Kuenster Creek							
92/11/01	1900	92/11/04	0100	1.38	1.0	1.8	36
92/11/19	1600	92/11/22	0100	2.73	2.4	19	300
92/12/15	0200	92/12/17	0400	s/m	1.7	8.2	220
93/03/05	1100	93/03/06	0400	s/m	1.7	85	440
93/03/07	1400	93/03/08	0700	s/m	4.2	2.70	1,200
93/03/08	1400	93/03/09	0800	s/m	3.4	83	560
93/03/15	2300	93/03/17	0900	s/m	6.5	290	920
93/03/25	1200	93/03/26	0900	s/m	9.7	1,100	3,600
93/03/26	1200	93/03/27	0700	s/m	7.8	430	1,400
93/03/27	1200	93/03/28	0500	s/m	6.6	210	1,190
93/03/28	1300	93/03/29	0600	s/m	4.1	91	540
93/03/30	1200	93/03/31	1900	1.78	14	3,000	6,700
93/05/02	1900	93/05/03	1000	1.63	3.8	340	1,400
93/06/17	1800	93/06/18	2000	.72	3.4	100	730
93/06/28	1600	93/06/29	0600	--	1.4	20	80
93/06/29	2300	93/06/30	2200	1.42	5.8	470	1,600
93/07/17	1000	93/07/17	1900	1.07	2.2	170	470
93/08/14	1715	93/08/16	0500	1.00	4.4	120	455
93/08/18	1100	93/08/19	1100	.88	2.4	36	190
Rattlesnake Creek							
90/01/16	1700	90/01/18	0800	s/m	9.4	150	1,600
90/03/08	0600	90/03/08	1200	s/m	16	1,300	3,600

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids load (tons)	Total-phosphorus load (lb)
Rattlesnake Creek--Continued							
90/03/11	0500	90/03/12	0200	s/m	4.1	57	480
90/05/09	0115	90/05/10	0100	--	3.2	170	360
90/05/19	0500	90/05/20	2100	--	5.8	83	530
90/06/22	0315	90/06/22	1800	--	3.3	55	180
90/08/24	2000	90/08/25	2300	--	7.9	230	1,600
90/08/26	0900	90/08/27	0400	--	5.6	190	940
91/04/12	1100	91/04/13	1900	1.64	14	98	1,000
91/08/07	2000	91/08/08	2300	2.50	8.3	200	4,600
91/11/01	0045	91/11/02	0330	1.55	5.9	59	650
91/11/29	1100	91/11/30	1700	.80	6.2	29	230
92/02/03	1300	92/02/04	0900	s/m	3.7	69	290
92/02/20	1445	92/02/21	0800	s/m	19	2,800	7,600
92/02/22	1400	92/02/23	1635	s/m	14	1,600	4,400
92/02/24	1500	92/02/25	0900	.24	8.6	420	1,700
92/04/20	1300	92/04/21	0900	.91	4.4	34	520
92/06/16	1000	92/06/17	0300	.66	1.3	.44	14
92/09/07	2230	92/09/08	1800	.90	2.3	4.1	180
92/09/14	1400	92/09/15	1800	.84	2.3	2.9	130
92/11/01	1600	92/11/03	1000	1.25	3.7	3.3	64
92/11/19	2000	92/11/21	2200	2.68	10	68	1,300
92/12/15	0100	92/12/17	0400	.91	7.6	27	510
93/03/03	0300	93/03/05	0600	.27	16	2,100	4,000
93/03/05	1400	93/03/06	0800	s/m	7.7	330	1,700
93/03/06	1500	93/03/07	0800	s/m	4.8	120	1,500
93/03/07	1400	93/03/08	1000	s/m	19	610	4,700
93/03/08	1300	93/03/09	0900	s/m	18	380	3,600
93/03/16	0030	93/03/17	0600	s/m	31	1,400	4,200
93/03/24	1600	93/03/26	1100	s/m	63	4,300	14,000
93/03/26	1101	93/03/27	1000	s/m	31	420	3,000
93/03/27	1200	93/03/28	0800	s/m	26	840	4,300
93/03/28	1300	93/03/29	0900	s/m	15	240	1,700
93/03/30	1300	93/03/31	2000	1.67	43	4,400	14,000
93/05/02	2100	93/05/03	1500	1.64	17	500	2,600
93/06/07	1000	93/06/08	1900	1.53	13	260	1,100
93/06/13	2100	93/06/14	2100	1.01	5.0	29	170
93/06/17	1900	93/06/18	1500	1.25	13	690	2,700
93/06/28	0600	93/06/28	1500	.71	4.7	160	570
93/06/29	2300	93/06/30	1800	1.36	19	1,300	4,400

Appendix 1. Storm-load data for rural watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1985-93--Continued

Start of storm		End of storm				Loads	
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids load (tons)	Total-phosphorus load (lb)
Rattlesnake Creek--Continued							
93/07/05	1200	93/07/06	1500	1.69	19	470	3,000
93/07/08	2330	93/07/09	2000	2.35	71	8,700	25,000
93/07/10	1600	93/07/12	0400	2.39	78	8,500	24,000
93/07/17	0900	93/07/18	0200	.97	12	480	1,700
93/08/14	1700	93/08/15	0545	.97	6.5	130	590
93/08/15	0900	93/08/16	0100	.74	10	150	810
93/08/18	1300	93/08/19	0600	1.00	11	220	1,200

[1]Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year starting October 1, 1992 and ending September 30, 1993 is called the "1993 water year."

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93

[yr, year; mo, month; d, day; h, hour; in., inches; Mft^3, million cubic feet; lb, pounds; s/m, snowmelt; --, no data]

Start of storm		End of storm				Loads						
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Lincoln Creek											
93/03/22	2235	93/03/24	0800	s/m	14	120	350	0.62	22	42	140
93/03/24	1030	93/03/26	1800	s/m	4.5	1.7	25	<.056	2.2	1.1	13
93/03/31	0800	93/04/02	0700	s/m	15	71	200	.58	20	29	120
93/04/02	0844	93/04/05	0730	s/m	6.5	3.6	20	.12	3.2	2.8	18
93/04/19	1220	93/04/21	0400	1.94	36	400	880	1.8	47	180	360
93/04/29	0300	93/04/29	1645	.55	3.7	12	56	.12	4	6.1	23
93/05/22	2200	93/05/24	0845	.35	3.1	21	57	.078	3.7	4.7	17
93/05/30	0800	93/05/31	0745	.53	3.4	12	44	<.042	3.3	4.2	17
93/06/04	1910	93/06/05	1500	.26	1.6	1.7	12	.04	.9	.9	4.3
93/06/07	1215	93/06/08	0215	1.98	19	12	190	.35	16	9.3	52
93/06/08	0215	93/06/08	0615	.32	3.2	11	.018	.03	1.3	1.9	6.6
93/06/14	0150	93/06/14	1930	.69	5.2	24	72	.13	4.6	5.9	28
93/06/17	1950	93/06/18	1245	.73	5.6	38	100	.21	7.3	15	45
93/06/19	1755	93/06/20	1040	.89	7.9	40	130	.15	6.9	14	46
93/06/30	0250	93/06/30	1745	.38	2	4.4	22	.025	1.2	1.5	7.8
93/07/03	2035	93/07/04	0330	.52	4.1	54	110	.20	7.9	18	61
93/07/05	2125	93/07/06	1145	.55	3.9	18	51	.12	3.6	6.8	23
93/07/08	1440	93/07/09	2400	1.06	8.5	25	96	.16	5.9	9.1	41
93/07/13	1900	93/07/14	1030	.50	3.5	9	41	--	2.8	3.7	18
93/07/25	0110	93/07/25	1245	.41	2.7	20	57	.12	4.5	7.2	25
93/08/09	1140	93/08/09	2000	.25	1.1	2.5	16	.021	1.1	1.3	5.9
93/08/15	0825	93/08/16	0400	.57	3.4	22	86	.13	5.6	8.4	32
93/08/30	1600	93/08/31	0215	2.29	17	8.5	64	<.21	11	4.3	30
93/09/13	0900	93/09/15	0655	1.62	13	58	180	.21	12	20	84
93/09/20	0900	93/09/21	1045	.72	5.6	28	81	.14	5.6	8.8	35

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Menomonee River											
91/06/14	1500	91/06/15	0550	1.49	23	240	630	--	--	---	--
91/06/22	0300	91/06/22	2000	--	5.5	13	62	--	--	--	--
91/07/01	1600	91/07/01	1840	--	11	240	530	--	--	--	--
91/07/07	1615	91/07/07	2300	--	8.8	74	190	--	--	--	--
91/07/12	0730	91/07/12	1320	--	20	240	630	--	--	--	--
91/07/18	1720	91/07/18	2055	--	2	9.4	45	--	--	--	--
91/07/21	0520	91/07/21	1920	.56	18	100	310	--	--	--	--
91/07/29	0500	91/07/29	1200	--	2.4	1.7	14	--	--	--	--
91/08/08	0550	91/08/08	1420	1.61	24	210	560	--	--	--	--
91/09/09	1830	91/09/10	0500	--	9.7	57	210	--	--	--	--
91/09/11	2325	91/09/12	1205	1.29	24	130	390	.45	24	47	140
91/09/14	0100	91/09/14	2345	.56	23	110	330	.43	19	27	110
91/10/04	0215	91/10/07	0430	2.6	93	290	1,400	1.2	81	92	450
91/10/14	0030	91/10/14	1515	--	4.5	1.7	20	<.057	7.1	2.5	8.8
91/10/28	2010	91/11/06	1145	.62	170	210	1,400	< 2.1	74	84	360
92/03/16	1910	92/03/20	1400	s/m	71	66	310	<.88	31	35	140
92/03/23	1330	92/03/25	0955	s/m	33	18	100	<.41	20	10	41
92/03/25	0955	92/03/27	0900	s/m	45	8.4	110	2.2	14	14	330
92/03/27	0900	92/03/29	2105	s/m	44	1.4	55	<.55	16	11	36
92/03/30	0930	92/04/02	0420	s/m	40	3.8	50	<.5	< 7.5	7.5	35
92/04/15	0720	92/04/16	1500	s/m	42	250	650	1.3	< 7.8	78	290
92/04/16	1500	92/04/17	1330	s/m	43	120	380	.81	19	30	140
92/04/17	1330	92/04/18	1445	s/m	28	17	100	<.35	< 5.2	8.7	26
92/04/18	1445	92/04/21	0015	s/m	43	11	110	<.54	< 8.1	< 8.1	< 27
92/05/11	2115	92/05/13	1000	--	15	16	100	<.18	9.1	9.1	30

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Menomonee River--Continued											
92/06/14	0300	92/06/14	1515	--	3.8	12	80	<.047	3.1	2.8	12
92/06/17	1350	92/06/18	1230	.74	25	270	810	1.6	43	86	250
92/07/08	0935	92/07/09	1235	--	18	140	540	.91	29	44	160
92/07/12	1140	92/07/13	2230	.74	46	350	950	1.7	55	95	320
92/07/13	2230	92/07/16	0830	1.36	38	86	380	<.47	16	14	96
92/08/12	1000	92/08/13	0745	.89	11	38	130	--	11	11	46
92/08/25	2210	92/08/27	1030	.71	26	130	530	--	30	43	150
92/08/27	1030	92/08/30	0405	--	22	25	150	--	8.2	8.2	40
92/09/09	0725	92/09/10	0925	.88	22	140	570	--	33	62	180
92/09/14	1320	92/09/16	1355	.56	23	140	470	--	22	52	150
92/09/16	1355	92/09/18	1235	--	45	210	610	--	33	61	200
92/11/01	0810	92/11/05	1140	2.59	150	440	2,300	--	110	100	480
92/11/19	0630	92/11/23	0800	.64	110	150	870	--	47	53	270
92/11/23	0800	92/11/24	1510	.41	36	23	180	--	14	< 6.8	36
92/12/15	0700	92/12/16	1155	.93	50	170	720	--	50	62	250
93/03/01	1155	93/03/02	1820	s/m	13	6.6	55	--	7.8	4.7	34
93/03/02	1820	93/03/04	1555	s/m	22	26	150	--	17	12	65
93/03/04	1555	93/03/05	1115	s/m	7.6	2.4	28	--	4.3	1.9	13
93/03/05	1315	93/03/07	1300	s/m	33	46	310	--	17	13	73
93/03/16	0405	93/03/17	0635	s/m	25	44	250	--	22	19	97
93/03/22	1115	93/03/23	1440	s/m	49	310	930	--	74	100	400
93/03/23	1440	93/03/25	0905	s/m	100	330	1,300	--	52	72	330
93/03/25	0905	93/03/27	1550	s/m	100	66	880	--	44	< 19	150
93/03/27	1550	93/03/29	1240	s/m	82	51	510	--	21	15	110
93/03/29	1240	93/03/31	0650	s/m	73	46	410	--	18	< 14	100

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Menomonee River--Continued											
93/03/31	0650	93/04/01	1905	s/m	100	400	1,500	--	90	110	430
93/04/14	1525	93/04/19	0610	1.77	410	980	3,300	--	170	260	810
93/04/19	1310	93/04/23	2315	2.36	580	2,400	7,000	--	320	620	1,600
93/04/29	0435	93/05/01	1900	.58	62	48	310	--	23	23	93
93/05/22	2150	93/05/24	1240	.26	21	35	170	--	10	12	32
93/05/30	1115	93/06/01	1225	.44	30	54	260	--	17	17	70
93/06/04	1910	93/06/13	2245	2.49	340	1,200	5,800	--	180	320	1,000
93/06/19	1805	93/06/21	1230	1.82	110	420	1,500	--	67	94	380
93/06/30	0250	93/07/01	1400	.51	17	36	170	--	9.4	11	48
93/07/05	2130	93/07/06	1710	.41	24	130	430	--	24	41	140
93/07/08	1445	93/07/13	1900	2.36	240	1,000	4,000	--	160	250	980
93/08/30	0300	93/08/30	1225	.28	15	150	450	.77	28	52	190
93/08/30	1225	93/08/30	1815	.63	5.5	33	110	.17	4.5	7.6	30
93/08/31	1905	93/09/03	1220	.95	29	19	270	<.36	9.1	9.1	40
93/09/13	1025	93/09/14	1635	1.28	49	250	770	1.2	49	71	1,000
Monroe Street detention pond											
92/03/16	1755	92/03/16	2221	.31	.029	.74	1.8	.0039	.085	.2	.68
92/03/22	1300	92/03/22	1830	s/m	.015	.088	.27	.00094	.019	.035	.13
92/03/28	2200	92/03/29	0615	.26	.021	.062	.39	.00052	.023	.036	.14
92/04/08	2000	92/04/09	0015	.32	.043	1.7	3.3	.0037	.13	.29	.91
92/04/15	0500	92/04/15	0550	.43	.019	.79	1.5	.0023	.074	.19	.49
92/05/11	1645	92/05/11	1755	.21	.016	.58	2.6	.0016	<.003	.13	.44
92/06/17	1158	92/06/17	1448	.56	.088	5.1	11	.0088	.24	.77	2.5
92/07/02	0809	92/07/02	1421	1.09	.11	4.4	7.7	.007	.19	.69	1.6

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Monroe Street detention pond--Continued											
92/07/08	0800	92/07/08	0913	1.11	.16	7.3	8.8	.011	.3	.94	2.3
92/12/30	0645	92/12/30	1258	.37	.025	.059	.68	--	--	--	.16
93/03/03	1224	93/03/03	2346	s/m	.035	.16	.52	--	--	--	.26
93/03/05	1327	93/03/05	2011	s/m	.015	.038	.61	--	--	--	.069
93/03/06	1100	93/03/07	0255	s/m	.041	.14	2.1	--	--	--	.2
93/03/07	1304	93/03/07	2157	s/m	.035	.071	2.4	--	--	--	.15
93/03/08	1333	93/03/08	1927	s/m	.02	.022	1.3	--	--	--	.091
93/03/22	2329	93/03/23	2327	s/m	.22	.89	3.9	--	--	--	1.8
93/04/14	1034	93/04/16	1008	2.33	.41	3.4	7.3	.013	.25	.76	2.3
93/05/01	2112	93/05/02	1116	.62	.061	.27	1.8	--	--	--	.35
93/05/22	1922	93/05/24	1133	.65	.061	.51	2.1	--	--	--	.45
93/05/30	0408	93/05/30	1539	.90	.096	.51	2.9	--	--	--	.66
93/06/02	1226	93/06/03	1134	.46	.037	.065	.75	--	--	--	.18
93/06/07	1058	93/06/07	2137	2.63	.38	9	19	--	--	--	4
93/06/24	1949	93/06/25	0830	.87	.1	1.4	4.2	--	--	--	.75
93/06/30	0022	93/06/30	0355	.63	.073	.44	1.7	--	--	--	.5
93/07/05	0524	93/07/05	2245	3.61	.64	13	23	--	--	--	5.5
93/07/09	0113	93/07/09	0609	1.71	.28	6.1	8.9	--	--	--	2.7
93/07/25	0249	93/07/25	0448	1.59	.21	3.3	6.7	.0052	.13	.54	1.4
93/08/15	0527	93/08/15	2255	2.15	.31	2.4	8.2	.0058	.077	.46	1.4
93/09/13	0920	93/09/14	0947	2.84	.28	3.1	6.8	.0061	.23	.5	1.6
Nine Springs tributary storm sewer											
90/11/21	0225	90/11/21	0349	.24	.0065	.022	.11	--	--	--	--
90/11/27	0515	90/11/27	0630	.28	.02	.36	.78	--	--	--	--
90/11/27	1531	90/11/27	1639	.14	.0048	.025	.11	--	--	--	--

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Nine Springs tributary storm sewer--Continued											
90/12/12	1338	90/12/12	1501	s/m	.00043	.0017	.0092	--	--	--	--
91/02/04	1400	91/02/04	1553	s/m	.0027	.021	.095	--	--	--	--
91/03/01	0939	91/03/02	0918	1.56	.23	1.1	6.6	--	--	--	--
91/03/17	1406	91/03/18	0157	.35	.089	.19	1.4	--	--	--	--
91/03/22	1837	91/03/22	2251	.52	.11	3.1	7	--	--	--	--
91/03/26	0309	91/03/26	0650	.14	.031	.082	.36	--	--	--	--
91/03/26	2320	91/03/27	1523	.94	.31	3.1	8.2	--	--	--	--
91/04/08	1327	91/04/09	1500	1.22	.33	.8	3.5	--	--	--	--
91/04/12	0933	91/04/12	2253	1.27	.48	1.5	5.7	--	--	--	--
91/04/13	1840	91/04/14	1159	.89	.32	.49	2.4	--	--	--	--
91/05/05	0717	91/05/05	1333	.73	.15	.23	1.4	--	--	--	--
91/05/17	1908	91/05/17	2000	--	.0078	.029	.36	.00058	.025	.011	.22
91/05/18	1051	91/05/18	1518	.71	.19	.7	2.8	.0048	.22	.17	1.3
91/05/21	1608	91/05/21	1723	.15	.039	.37	1	.0029	.063	.078	.85
91/05/25	1529	91/05/25	1538	--	.0011	.0028	.021	.000085	.0022	.0014	.019
91/06/10	1541	91/06/10	1739	.34	.064	.56	2.2	.0044	.14	.14	1.6
91/06/12	0253	91/06/12	0450	.40	.082	.4	1.4	.0041	.087	.11	.82
91/06/13	2257	91/06/14	0128	.28	.063	.26	1	.0024	.059	.075	.75
91/07/01	1702	91/07/01	1738	.17	.023	.24	.68	.0027	.079	.068	.64
91/07/21	0503	91/07/21	0625	2.31	.21	2.1	4.4	.012	.29	.46	3.4
91/08/07	0622	91/08/07	0651	2.00	.012	.14	.53	--	--	--	--
91/08/16	2233	91/08/17	0021	.15	.028	.099	.65	--	--	--	--
91/09/03	0947	91/09/03	1101	.10	.022	.19	.89	--	--	--	--
91/09/09	2303	91/09/10	0027	.45	.039	.051	.68	.0046	.054	.029	.75

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Nine Springs tributary storm sewer--Continued											
91/09/11	1853	91/09/12	0733	1.05	.28	.47	4.7	<.0035	.07	.12	.95
91/09/14	0551	91/09/14	2227	.46	.36	1.4	5.4	.011	.25	.36	2.3
91/09/15	2340	91/09/16	0300	1.48	.063	.039	.36	<.00079	.02	.016	.18
91/09/17	2017	91/09/18	0337	.46	.13	.097	.84	.0025	.042	.042	.79
91/09/24	1214	91/09/24	1536	.15	.027	.1	.56	.002	.039	.042	.45
91/10/03	2241	91/10/04	0015	.14	.021	.14	.61	.00066	.024	.019	.27
91/10/04	0923	91/10/05	0941	.92	.34	.84	5.3	.011	.38	.32	2.5
91/10/13	1925	91/10/13	2128	.16	.024	.039	.7	.0003	.028	.016	.21
91/10/26	0902	91/10/26	1402	.52	.16	.13	1.2	.0029	.37	.11	<.098
91/10/28	1549	91/10/29	1146	.53	.2	.29	1.7	.0062	.12	.14	1.5
91/10/31	1335	91/11/01	1432	.25	.42	.79	5.8	.013	.37	.52	3.9
91/11/14	1252	91/11/15	0308	.66	.19	.46	2.7	.012	.35	.33	2.1
91/11/17	1940	91/11/18	0349	.63	.18	.23	1.4	.0056	.13	.26	1.2
91/12/12	0235	91/12/12	1620	.58	.19	.77	3.7	.013	.41	.51	2.3
92/01/08	2131	92/01/09	0102	.20	.056	.38	1.4	.0053	.14	.21	1
92/03/09	0147	92/03/09	0805	.26	.04	.55	1.3	.007	.14	.21	1.1
92/03/28	2217	92/03/29	0404	.28	.042	.09	.42	.0016	.037	.058	.37
92/04/08	1945	92/04/09	0104	.31	.058	.14	.62	.0018	.066	.08	.58
92/04/15	0456	92/04/15	0651	.40	.068	.68	1.6	.0068	.17	.25	1.6
92/04/15	2046	92/04/15	2154	.13	.03	.37	.85	.004	.066	.13	.77
92/04/16	0621	92/04/16	1044	.23	.066	.18	.87	.0029	.062	.087	.7
92/04/18	2317	92/04/19	0325	.93	.15	1.9	4.4	.013	.28	.57	2.8
92/04/23	1216	92/04/23	1702	.24	.058	.21	.8	.0029	.073	.087	.69
92/05/11	1644	92/05/11	1730	.16	.022	.3	1.2	.0043	.1	.094	1.1

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Nine Springs tributary storm sewer--Continued											
92/06/17	1200	92/06/17	1248	.36	.049	.8	1.9	.0052	.15	.24	1.3
92/06/24	0644	92/06/24	0730	--	.015	.16	.45	.0013	.043	.061	.39
92/07/02	0810	92/07/02	1545	--	.12	.57	2.1	.007	.16	.2	1.9
92/07/08	0757	92/07/08	1054	.97	.22	2.5	5.1	.014	.42	.6	2.8
92/07/13	0709	92/07/13	2158	1.26	.4	.84	3.7	.0076	.25	.31	2
92/07/16	0221	92/07/16	0415	.16	.029	.027	.31	.00037	.026	.024	.2
92/08/29	0400	92/08/29	0825	.98	.26	.65	2.9	--	.13	.21	1.6
92/09/06	0213	92/09/06	0730	.64	.15	.25	1.6	--	.067	.11	1.1
92/09/09	0531	92/09/09	0910	.48	.11	.3	1.3	--	.077	.098	.98
92/09/16	1221	92/09/16	1656	.94	.27	.44	8	--	.22	.4	2
92/09/17	0419	92/09/17	0906	.62	.23	.85	4.1	--	.3	.28	1.4
92/09/18	0332	92/09/18	0803	.44	.13	.3	1.8	--	.098	.098	.77
92/10/15	1756	92/10/16	0041	.47	.13	.26	1.7	--	.067	.092	1
92/11/01	2225	92/11/02	0432	1.26	.062	.035	.39	--	.027	.015	.34
92/11/12	0600	92/11/12	1444	.20	.057	.28	1.2	--	.085	.13	1.1
92/11/19	1515	92/11/20	2346	2.45	.73	2.4	10	--	.51	.74	7.3
92/11/22	1412	92/11/22	2300	.53	.21	.29	1.7	--	.1	.12	1.1
92/12/15	0259	92/12/16	0141	1.28	.43	1.7	6.7	--	.86	.83	5.4
92/12/29	0126	92/12/29	0833	.36	.11	.16	1.4	--	.13	.11	1.2
92/12/30	0454	92/12/30	1113	.22	.06	.13	1.3	--	.082	.082	.63
93/01/23	1121	93/01/23	2014	s/m	.059	.077	.77	--	.1	.048	.55
93/03/02	1146	93/03/02	1646	s/m	.023	.11	.68	--	.07	.063	.45
93/03/03	1116	93/03/03	2138	s/m	.071	.24	1.7	--	.14	.098	.8
93/03/05	1219	93/03/05	1810	s/m	.036	.076	1	--	.042	.027	.27

Appendix 2. Storm-load data for urban watershed-management evaluation monitoring sites, Wisconsin, water years[1] 1991-93--Continued

Start of storm		End of storm				Loads					
Date (yr/mo/d)	Time (24 h)	Date (yr/mo/d)	Time (24 h)	Precipitation (in.)	Streamflow volume (Mft^3)	Suspended-solids (tons)	Phosphorus (lb)	Total cadmium (lb)	Total copper (lb)	Total lead (lb)	Total zinc (lb)
Nine Springs tributary storm sewer--Continued											
93/03/06	1126	93/03/06	1804	s/m	.057	.087	1.7	--	.053	.025	.27
93/03/07	1209	93/03/07	1938	s/m	.05	.037	1.7	--	.043	.012	.2
93/03/08	1127	93/03/08	1817	s/m	.036	.053	1.1	--	.029	.018	.17
93/03/16	0039	93/03/16	1809	s/m	.13	.48	3	--	.24	.18	1.3
93/03/22	0948	93/03/23	2231	.83	.39	1.6	7.1	--	.63	.91	5.3
93/03/31	0237	93/03/31	2049	1.55	.59	4.5	12	--	1.2	1.4	8.8
93/04/19	1035	93/04/20	1424	1.50	.57	1.8	6	--	.42	.64	4.2
93/05/01	1913	93/05/02	0605	.75	.21	.8	3.8	--	.21	.3	2.1
93/05/30	0315	93/05/30	2148	.96	.29	.43	2.7	--	.18	.16	2
93/06/02	1049	93/06/03	0215	.40	.13	.26	1.3	--	.11	.12	1.4
93/06/07	1107	93/06/07	1355	1.71	.45	4.1	17	--	.54	.79	4.5
93/06/24	1908	93/06/25	0336	.89	.22	.7	2.4	--	.14	.13	1.4
93/06/30	0043	93/06/30	0509	.65	.17	.33	1.5	--	.083	.052	1

[1]Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year starting October 1, 1992 and ending September 30, 1993 is called the "1993 water year."

Appendix 3. Quality-assurance/quality-control plan for urban watershed-management evaluation monitoring program, Wisconsin

INTRODUCTION

The following are quality-assurance/quality-control (QA/QC) procedures that apply to the data-collection projects associated with the urban watershed management evaluation. The purpose of these guidelines is to provide consistent procedures to be used by all field personnel collecting data for the projects.

The QA/QC procedures are divided into field procedures and laboratory procedures. All samples are processed in a consistent manner as described in the following sections. All chemical analyses are done by the Wisconsin State Laboratory of Hygiene (WSLH). The WSLH has its own QA/QC procedures (Wisconsin State Laboratory of Hygiene, 1993) which are not discussed herein. The USGS does an inter-laboratory evaluation program semiannually. The WSLH participates in this program, which furnishes a variety of reference samples to accomplish quality-assurance testing of laboratories and to provide an adequate supply of samples that contribute to quality-control programs of participating laboratories. Reports of the results of the standard- reference-sample program and a more detailed description of the program are on file at the USGS office in Madison, Wis.

FIELD PROCEDURES

Water samples are collected from streams during periods of low flow and high flow and from storm sewers during periods of high flow. Periods of low-flow are at times when the discharge in the stream is not directly affected by precipitation or snowmelt, whereas periods of high flow are at times when the discharge in the stream is increased due to precipitation or snowmelt. Low-flow samples are collected every 2 weeks from April through November and monthly from December through March.

Low-flow samples are collected with a DH-81 TMS (trace metal sampler). The outer shell of the sampler is constructed of polypropylene plastic, and the inside of the sampler and the nozzle are made of Teflon. The DH-81 TMS, which can be used with 1/8-, 3/16-, 1/4-, or 5/16-in. nozzles, is suspended from a plastic-coated rod. The 5/16-in. nozzle typically is used to collect samples during low flow. This sampler is used with a 1-L glass mason jar.

An equal-width-increment (EWI) sample consists of collecting water at 5 to 10 verticals across the stream. The mason jar, the sampling apparatus, and the collection jar are rinsed twice with stream water. The mason jar is then filled approximately 10 times and emptied into a 10-L glass collection jar. The sample is transported in an iced cooler to the Madison field office for processing.

A refrigerated automatic sampler is used to collect samples at high flow. Teflon-lined 3/8-in. sample tubing connects the stream to a peristaltic pump, which pumps water through approximately 3 ft of polyethylene tubing into one of four 10-L glass bottles stored in the refrigerator. The samples are collected on a flow-composite basis, resulting in an event mean concentration. After each runoff period, the samples are capped and transported in an iced cooler to the Madison field office for processing.

SAMPLE PROCESSING

Low-flow and high-flow samples are processed identically. The 10-L glass collection bottles are agitated and emptied into a Teflon-lined churn splitter. The sample is split into several bottles that have been rinsed with sample water. The sample is then filtered through Gelman capsule filters with a peristaltic pump. The filtered water is collected into two different WSLH sample bottles; sample bottles are rinsed with filtered water before they are filled. One bottle of sample to be analyzed for organic constituents and the bottle of sample to be analyzed for nutrients are preserved with sulfuric acid. The samples for determination of total recoverable and dissolved metals are preserved with nitric acid. The sulfuric and nitric acid are acquired from the WSLH. All of these bottles are then transported to the WSLH in an iced cooler.

EQUIPMENT CLEANING PROCEDURES

The DH-81 TMS sampler, glass mason jar, 10-L glass collection jars, and the churn splitter are all cleaned in the same manner. They are initially washed with a nonphosphate soap and tap water. They are then rinsed once with tap water, once with a 10-percent trace-metal-grade hydrochloric acid solution, twice with Milli-Q water (deionized water passed through a carbon filter and a membrane filter), once with methanol, and finally three times with Milli-Q water.

Each of the four glass collection bottles in the refrigerated sampler holds 10 to 20 subsamples, depending on the individual site. Before each subsample is collected, the sampler runs through a rinsing procedure. To begin with, the sample tubing is purged. Next, the pump draws streamwater into the point just before the pump head and the sample tubing is purged again. At this point, the rinse cycle is complete and the subsample is collected.

USE OF BLANK SAMPLES

QA/QC procedures include regular analysis of blank samples to investigate the sampling process for possible sources of contamination.

Blank-Sample Processing

Sampler blanks are used to evaluate contamination of the entire storm-sampling process, which includes all equipment (automatic sampler, 10-L sample-collection bottles, and churn splitter) and filtering procedures. Milli-Q water is collected into 5-gal glass carboys from the WSLH and is used as reagent water. The blank samples are collected as follows:

1. A set of WSLH sample bottles is first rinsed and then filled directly with Milli-Q water from the carboy. Each bottle in this set is referred to as a "bottle blank before." The samples are preserved with acid as outlined above and refrigerated for possible future use.

2. A 3.8-in.-Teflon-lined extension tube is connected to the end of the sample tubing at the site. The sample tubing is purged. The extension tube is inserted into the carboy, and the Milli-Q water is pumped through the tubing to the point just before it reaches the pump head. The extension tube is taken out of the carboy, and the sample tubing is purged again. The extension tube is inserted back into the carboy, and Milli-Q water is pulled through the sampling system until it fills two 10-L collection bottles. The two bottles are taken out of the sampler. The water from these two bottles is used to rinse a set of WSLH sample bottles and then to fill them. Half of the sample is from one of the 10-L bottles and the other half is from the second of the 10-L bottles. Each bottle in this set is referred to as an "ISCO blank." The samples are preserved with acid as outlined above and refrigerated for possible future use.

3. Again, a set of WSLH bottles is rinsed and filled with Milli-Q water directly from the carboy. Each bottle in this set is referred to as a "bottle blank after." The samples are preserved with acid as outlined above and refrigerated for possible future use.

4. The remaining sample is transported in an iced cooler to the Madison field office. At the office, the sample is emptied into a Teflon-lined churn splitter from which a set of WSLH sample bottles (referred to as "cumulative splitter blanks") are rinsed and filled for analysis of total an total-recoverable constituents. Some of the water in the churn splitter is filtered and then used to rinse and fill a set of WSLH bottles (referred to as "cumulative filter blanks") for analysis of filtered constituents. The cumulative splitter blanks and the cumulative filter blanks are preserved with acid as outlined above, chilled, and taken to the WSLH for analysis.

If results from the cumulative splitter blanks and cumulative filter blanks are indicative of contamination, then the ISCO blank will be analyzed. If results from the ISCO blanks are indicative of contamination, then the bottle blanks after will be analyzed. If results from the bottle blanks after are indicative of contamination, then the bottle blanks before will be analyzed. If contamination persists with the bottle blanks before, further investigation is needed.

Evaluation of Blank Samples

The field blanks described above are designed to evaluate whether or not samples have been contaminated, and, if so, at what level, through the course of collection, processing, preservation, or transportation. Contamination can be either systematic or erratic. Regardless of the source of contamination or whether the contamination is systematic or erratic, it is useful to define the point where contamination levels are unacceptable. At this point, further investigation is needed to identify and eliminate the sources of contamination. Appendix 4 contains a list of the constituents being monitored, the limit of detection (LOD) and limit of quantification (LOQ) for each constituent, the minimum concentration detected in a water sample during water year 1993 at any of the urban sites, and the concentration where blank sample contamination is suspected and further investigation is warranted.

The LOD and LOQ are used for samples analyzed by the WSLH. The LOD is defined as the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. Near this limit, results are estimated to have an uncertainty in the range of ± 100 percent. The LOQ is defined as the concentration of a substance above which quantitative results may be obtained with a 99 percent degree of confidence. Test results that fall between the LOD and the LOQ are much more uncertain than those that are equal to or greater than the LOQ. A detailed description of the quality assurance program used by the WSLH is on file at the WSLH and the USGS office located in Madison, Wis.

The concentration where blank sample contamination is suspected is defined in this report as twice the LOD. Sample concentrations near the LOD are very uncertain, so it is estimated that the range where concentrations are at the LOD ± the LOD are too uncertain to support any type of sampling decisions. Above this level, there is an adequate degree of confidence that enough contamination is present to effect stream-sample concentrations. If blank-sample concentrations are consistently found to be greater than twice the LOD, investigation is needed to identify the source(s) of contamination, and after the source(s) is identified, whether and how the source of contamination can be eliminated.

Appendix 4. Summary of constituent concentrations indicative of contamination in sample blanks for urban watershed-management evaluation monitoring sites, Wisconsin

[mg/L, milligrams per liter; µg/L, micrograms per liter; --, undefined]

Constituent	Limit of detection	Limit of quantification	Lowest water sample concentration, water year 1993	Concentration where contamination is suspected
BOD_5, total	0.3 mg/L	--	<1.0 mg/L	0.6 mg/L
COD, low level	5.0 mg/L	16. mg/L	<5.0 mg/L	10. mg/L
Calcium, dissolved	.02 mg/L	.05 mg/L	13. mg/L	.04 mg/L
Magnesium, dissolved	.02 mg/L	.07 mg/L	2. mg/L	.04 mg/L
Hardness as $CaCO_3$, dissolved	6.0 mg/L	--	43. mg/L	12. mg/L
Alkalinity	1.0 mg/L	--	51 mg/L	2. mg/L
Chloride, dissolved, high range	.1 mg/L	.4 mg/L	5.0 mg/L	.2 mg/L
Solids, suspended	2.0 mg/L	--	2. mg/L	4.0 mg/L
Solids, total	10. mg/L	--	160. mg/L	20. mg/L
Nitrate + nitrite	.007 mg/L	.03 mg/L	.22 mg/L	.014 mg/L
Nitrogen ammonia	.005 mg/L	.019 mg/L	.017 mg/L	.010 mg/L
Phosphorus, total	.008 mg/L	.031 mg/L	.03 mg/L	.016 mg/L
Phosphorus, dissolved, low range	2.0 µg/L	5.0 µg/L	2.0 µg/L	4.0 µg/L
Cadmium, dissolved	.04 µg/L	.15 µg/L	<.04 µg/L	.08 µg/L
Cadmium, total recoverable	.16 µg/L	.52 µg/L	<.2 µg/L	.32 µg/L
Copper, dissolved	1.0 µg/L	3.0 µg/L	1.8 µg/L	2.0 µg/L
Copper, total recoverable	1.0 µg/L	3.0 µg/L	4.0 µg/L	2.0 µg/L
Zinc, dissolved	10. µg/L	40. µg/L	<10. µg/L	20. µg/L
Zinc, total recoverable	10. µg/L	40. µg/L	<10. µg/L	20. µg/L
Lead, dissolved	1.0 µg/L	3.0 µg/L	<1.0 µg/L	2.0 µg/L
Lead, total recoverable	1.2 µg/L	4.0 µg/L	<3.0 µg/L	2.4 µg/L