

Pesticides in Streams of the Western Lake Michigan Drainages, Wisconsin and Michigan, 1993–95

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SUMMARY

During 1993–95, water samples were collected at nine sites on eight streams in the Western Lake Michigan Drainages to attempt to determine pesticide concentrations. The sampling effort was part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. Pesticides analyzed for were 58 herbicides and 30 insecticides. Pesticides are used extensively in the study area; application of herbicides to corn and soybeans accounts for most of the use.

Herbicides were detected more frequently and generally at higher concentrations than insecticides. The herbicide atrazine is applied to more acreage in Wisconsin than all other pesticides and was detected in 142 of 143 samples. The herbicides simazine, metolachlor, cyanazine, prometon, and alachlor were detected in more than half of the samples. The presence of these compounds in the sampled streams, is related to agricultural use.

Two streams in forested basins in the northern part of the study area were sampled and found to contain low concentrations of atrazine. Atmospheric deposition is the likely source; atrazine has been detected in rainfall in northeastern Wisconsin.

Herbicide concentrations in agricultural basins were highest in samples collected during storm runoff following application. Concentrations decreased over the growing season as herbicides broke down and increased ground cover reduced runoff.

The U.S. Environmental Protection Agency (USEPA) drinking-water standard for atrazine was exceeded in eight samples, and the standard for alachlor was exceeded in two samples. All exceedances occurred during brief periods of high streamflow in June and July at two streams that drain primarily agricultural basins.

Herbicide data for the Western Lake Drainages and other NAWQA study units indicate that concentrations in streams are as much as two orders of magnitude higher in areas where agricultural land contains a high percentage of row crops—especially corn and soybeans—than in areas where grazing, hay production, and other less herbicide-intensive crops are raised.

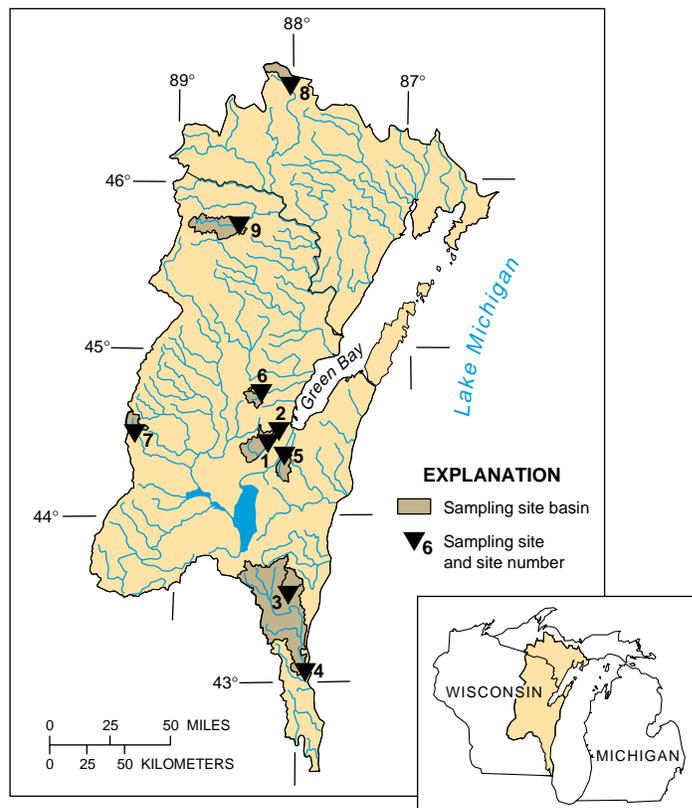


Figure 1. Location of sampling sites for pesticides in streams of the Western Lake Michigan Drainages (see table 1 for site information).

The Western Lake Michigan Drainages study unit of the National Water-Quality Assessment (NAWQA) Program encompasses a 51,540 square-kilometer area in eastern Wisconsin and the Upper Peninsula of Michigan that drains to Lake Michigan and Green Bay (fig. 1). Dairy operations and grain and vegetable crop growing are the major agricultural activities in the study unit. Crop growing and pasturing involve 37 percent of the total land area. The most intensive crop growing is in the southeastern part of the study unit.

Table 1. Selected information for pesticide-sampling sites on streams in the Western Lake Michigan Drainages [USGS, U.S. Geological Survey; km², square kilometers; N, number of samples collected; ag, agricultural; fo, forest]

Map reference number (see figure 1)	Station name	USGS station number	Drainage area (km ²)	Percent dominant land use/land cover in basin	N	Years data collected
1	Duck Creek near Oneida, Wis.	04072050	247	89 ag	44	1993–95
2	Duck Creek near Howard, Wis.	04072150	281	88 ag	10	1995
3	North Branch Milwaukee River near Random Lake, Wis.	040863075	133	88 ag	37	1993–94
4	Milwaukee River at Milwaukee, Wis.	04087000	1,800	75 ag	34	1993–94
5	East River at County Highway ZZ near Greenleaf, Wis.	04085108	117	92 ag	8	1994
6	Pensaukee River near Krakow, Wis.	04071795	92.7	86 ag	4	1994
7	Tomorrow River near Nelsonville, Wis.	04080798	114	58 ag	4	1994
8	Peshekee River near Martins Landing, Mich.	04062085	127	88 fo	1	1993
9	Popple River near Fence, Wis.	04063700	360	61 fo	1	1993

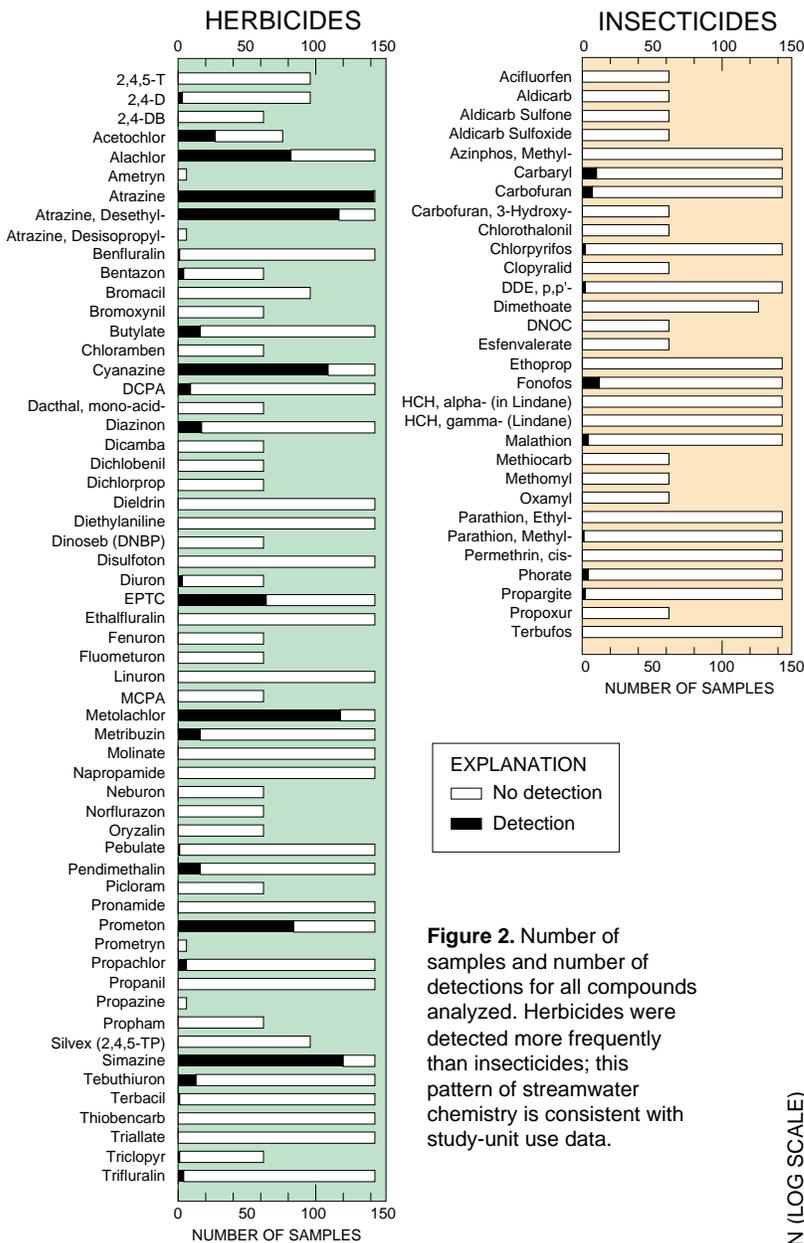


Figure 2. Number of samples and number of detections for all compounds analyzed. Herbicides were detected more frequently than insecticides; this pattern of streamwater chemistry is consistent with study-unit use data.

Data on agricultural pesticides in streamwater in the study unit had been limited to analyses for a few common compounds in samples collected by the U.S. Geological Survey (USGS) and several cooperating agencies. To expand this data set, the Western Lake Michigan Drainages NAWQA team collected streamwater samples during low flows at selected sites to determine concentrations of pesticides in streams in a variety of land-use settings (table 1) prior to the planting and application period of about mid-May through June. In addition, samples were collected during high flows at sites 1–5 in an attempt to determine the magnitude and timing of maximum concentrations and to identify and describe other factors that affect concentrations in representative streams of the study unit.

The selection of sampling sites for the collection of pesticide data was based on land-use patterns within the basins of established sampling sites. Sites were sampled at least monthly during 1993–95. Additional information on water-quality monitoring sites in the Western Lake Michigan Drainages NAWQA study unit is given in Sullivan and others (1995). Additional information on site selection is given in Robertson and Saad (1995). Samples were collected, handled, and analyzed according to protocols developed for the NAWQA Program (Shelton, 1994). Pesticides analyzed for were 58 herbicides and 30 insecticides.

Streamwater samples were collected at all sites during low-flow conditions. Followup sampling at agricultural sites 1–4 targeted the preapplication period, postapplication storm runoff, and the growing season. Runoff from a single large storm was sampled at site 5 in conjunction with other NAWQA (nonpesticide) sampling.

Results of the initial low-flow sampling indicated that atrazine was present in streamwater at every site. However, the atrazine concentration was very low at the primarily forested sites (0.005 parts per billion at site 8; 0.004 parts per billion at site 9). Atmospheric deposition may be the source of atrazine at these sites. Rainwater samples with atrazine concentrations as high as 0.6 parts per billion have been collected in northeastern Wisconsin (Goolsby and others, 1994).

The data for all samples indicate that herbicides were detected more frequently than insecticides (fig. 2). Atrazine was detected in 142 of 143 samples. In all, 14 herbicides were detected more frequently than the most commonly detected insecticide. This pattern of streamwater chemistry is consistent with patterns of use of these compounds in the study unit. In 1994, herbicides were applied to 97 percent of all corn acreage in Wisconsin, whereas insecticides were applied to only about 25 percent of all corn acreage in Wisconsin (Wisconsin Department of Agriculture, 1995). Herbicides were applied to similar percentages of soybeans; however, insecticides are generally applied on less than five percent of soybean acreage.

Six herbicides were detected in more than half of all samples (fig. 3). This finding corresponds well with herbicide-use data for agriculture in the study unit. Atrazine was applied to more corn acreage than all other herbicides; metolachlor was applied to

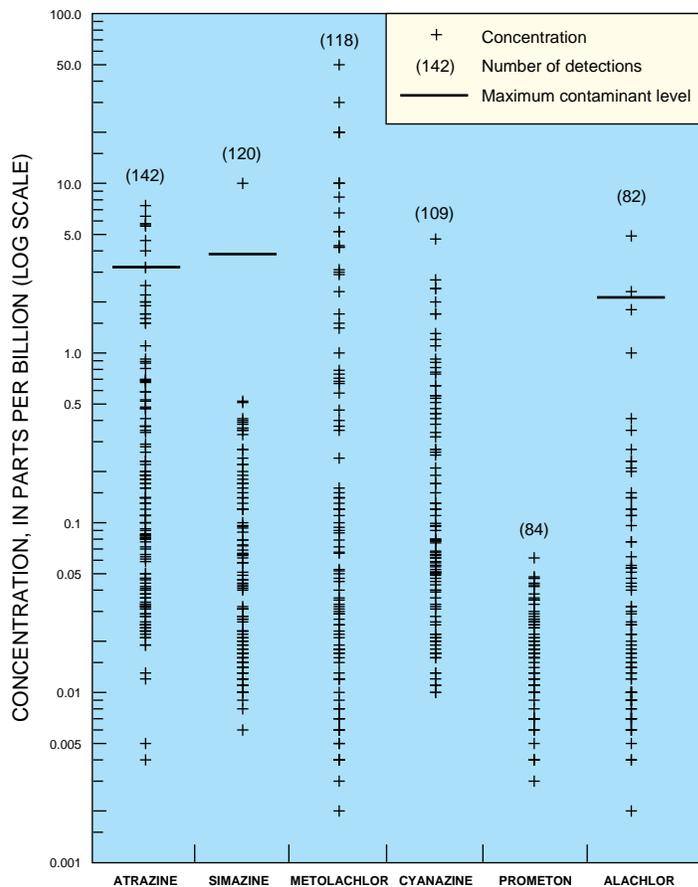


Figure 3. Concentrations of six herbicides detected in more than half of all samples. These data correspond well with patterns of herbicide use for agriculture.

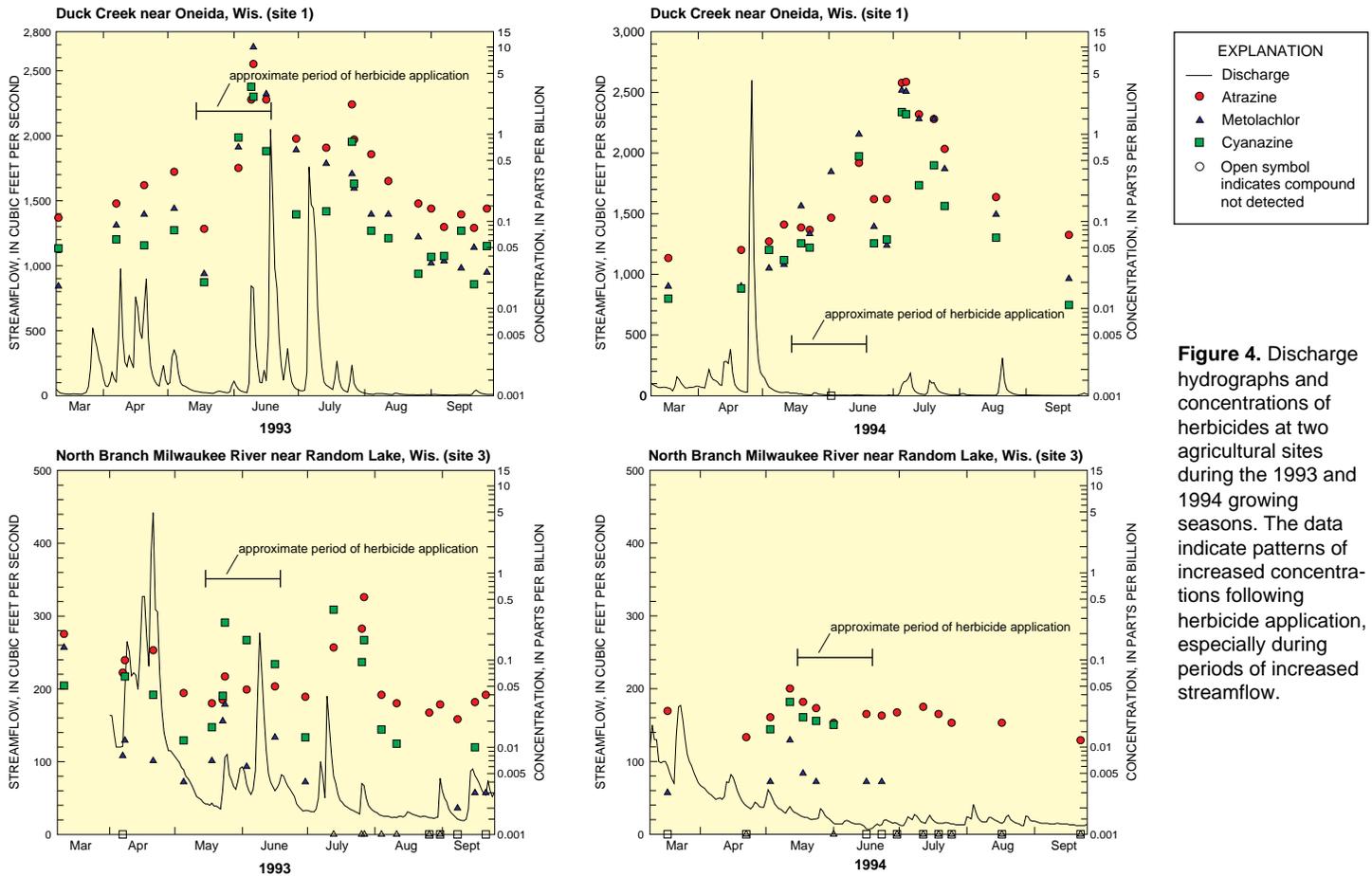


Figure 4. Discharge hydrographs and concentrations of herbicides at two agricultural sites during the 1993 and 1994 growing seasons. The data indicate patterns of increased concentrations following herbicide application, especially during periods of increased streamflow.

fewer acres but at about double the rate per acre (Wisconsin Department of Agriculture, 1995).

Simazine use for agriculture was negligible during the sampling period, and most detections of simazine indicated small concentrations. Simazine is relatively long-lived in the environment; thus, the small concentrations found during the sampling may be residuals from applications in previous years. Nonagricultural use of simazine for general weed control also may be a source. The highest concentration of simazine (10 parts per billion) was in a sample collected at site 2 and may have resulted from nonagricultural use.

Comparisons of herbicide concentrations to flow data at sites 1 and 3 (fig. 4) illustrates the relation of streamflow and time of pesticide application to concentrations of these compounds in streamwater. Low concentrations were evident in early spring (March through mid-May) prior to the planting/application period. Periods of increased streamflow after application in May and early June correspond to increased pesticide concentrations in streams. The progressively lower concentrations in streamwater over the duration of the growing season reflect herbicide breakdown and increased ground cover, which reduces runoff from fields.

The effects that herbicides in streams may have on humans and aquatic biota are difficult to quantify. Drinking-water standards developed for some commonly used compounds, such as atrazine and alachlor, can be useful as a reference point (even though the streams of interest may not be drinking-water sources). Atrazine and alachlor concentrations briefly exceeded the maximum contaminant levels (MCL's) established by the U.S. Environmental Protection Agency, levels based on continuous lifetime exposure (Nowell and Resek, 1994). Atrazine concentrations exceeded the MCL of 3 parts per billion in four samples each from sites 1 and 5. Alachlor concentrations exceeded the MCL of 2 parts per billion in two samples from site 1. All

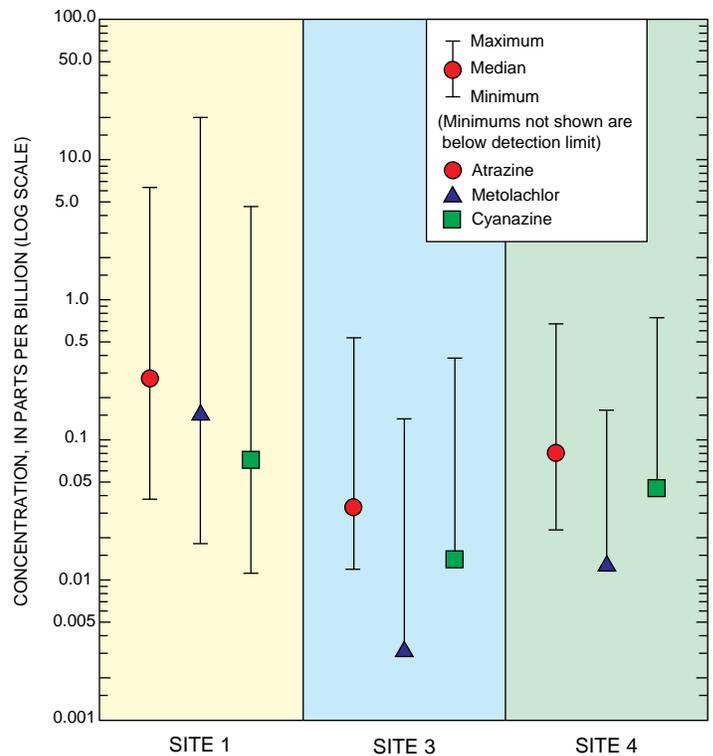


Figure 5. Concentrations of atrazine, metolachlor, and cyanazine at three primary stream sampling sites. Higher concentrations at site 1 may be related to texture of surficial deposits, herbicide application rates, and drainage basin size.

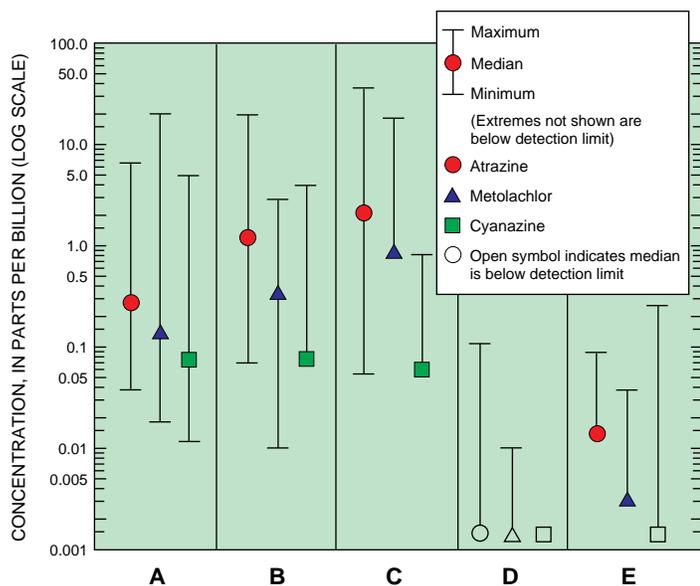


Figure 6. Concentrations of herbicides in selected streams in NAWQA study units in the Midwest. Concentrations were highest in streams in corn and soybean-growing areas, and lower in areas where grazing and small grains predominate.

[A = Duck Creek near Oneida, Wis.; B = Clifty Creek near Hartsville, Ind.; C = Prairie Creek near Ovina, Nebr.; D = Dousinbury Creek near Wall Street, Mo.; E = Snake River near Alvarado, Minn.]

samples in which the MCL was exceeded were collected during high flows in June and early July. The effect of short-term exposure to high concentrations on humans and stream biota is uncertain.

The observed concentrations of commonly detected herbicides were significantly higher (at the 95-percent confidence level) at Duck Creek (sites 1 and 2) than at North Branch Milwaukee River (site 3), by an order of magnitude at some times (fig. 5). Numerous factors may explain the higher concentrations in water from Duck Creek. Both basins have similar percentages of acreage in corn, but surficial deposits differ: soils in the Duck Creek Basin are underlain by poorly permeable clays, whereas soils in the North Branch Milwaukee River Basin are underlain by highly permeable sands. Thus, more infiltration of precipitation and thus less runoff would be expected in the North Branch Milwaukee River Basin. In addition, the state of Wisconsin imposed atrazine-application restrictions of 0.75 pound per acre on all coarse soils in the North Branch Milwaukee River Basin during 1993 and 1994. In contrast, farmers were allowed to apply as much as 1.5 pounds of atrazine per acre in the Duck Creek Basin during this period. Finally, although the percent of acreage in corn grown in each basin is approximately equal, the ratio of grain corn to sweet corn in the Duck Creek Basin was about 20 to 1, whereas the ratio in the North Branch Milwaukee River Basin was about 5 to 1. Grain corn typically receives heavier herbicide applications than sweet corn does, another factor that may explain higher concentrations in Duck Creek.

The drainage area of Milwaukee River at Milwaukee (site 4) is a mixture of land use/land cover (primarily agriculture but also urban) and surficial deposits (predominantly sand with clay in the lower part of the basin), and is about 7 times the drainage areas of the Duck Creek sites. Concentrations at Milwaukee were also significantly lower than at the Duck Creek sites (at the 95-percent confidence level). In addition to the factors mentioned for the North Branch Milwaukee River, previous studies have shown that pesticide concentrations in areas of similar land use are generally lowest at sites that drain the largest areas (Baker, 1988).

Concentrations of commonly detected herbicides in the Western Lake Michigan Drainages study unit were compared to concentrations in streams in other NAWQA study units in the Midwest that were sampled during the same time period (fig. 6). Concentrations were

highest at sites in Indiana, Wisconsin, and Nebraska where corn and soybean growing is a major agricultural activity. Concentrations were lower in streams in northwestern Minnesota and the Ozark Plateau area of Missouri, where small grains and pastureland, respectively, are more prevalent than row cropping of corn.

NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

The Western Lake Michigan Drainages is one of 20 study units started in 1991 as part of the USGS National Water-Quality Assessment Program. The purpose of the NAWQA Program is to assess the quality of a large, representative part of the nation's waters (Hirsch and others, 1988). In all, 60 study units are planned; the first 20 study units are in areas where agriculture is a major land-use activity.

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