Water-Quantity and Water-Quality Aspects of a 500-Year Flood—Nishnabotna River, Southwest Iowa, June 1998

Abstract

Nishnabotna River near Hamburg, Iowa, June 17, 1998. The gage at Hamburg (station number 06810000) is inundated in this photograph.

Flooding that occurred in southwest Iowa during June 15–17, 1998, was the worst flood ever recorded on the Nishnabotna River, exceeding the theoretical 500-year flood calculated from peak-flow records (1922 to present). This flood was a direct consequence of severe thunderstorm activity that caused more than 4 inches of rain to fall over a large part of the Nishnabotna River Basin. In fact, a new official State record for 24-hour total rainfall (13.18 inches) was set by this storm. The peak streamflow of the Nishnabotna River near Hamburg, Iowa, was 65,100 cubic feet per second, about 20 percent more than any previous recorded peak streamflow at this site.

To determine the concentrations of selected contaminants that might be present in this record flooding, water-quality samples were collected within hours of the flood peak. The results from these samples documented the presence of numerous herbicide compounds (11 parent compounds and 12 herbicide degradates). The highest herbicide concentration was 5.06 micrograms per liter (µg/L) for atrazine, followed by metolachlor (1.16 µg/L), metolachlor ESA (1.04 µg/L), acetochlor OA (0.99 µg/L), and acetochlor ESA (0.95 µg/L). The total herbicide concentration (summation of the 23 herbicide compounds detected) was 15.6 µg/L. The timing of the severe thunderstorm activity and flooding, which occurred shortly after chemical application associated with planting of crops, was the principal reason for the large number and concentrations of herbicide compounds found in the flood water.

At the time the water-quality samples were collected, the Nishnabotna River was transporting about 6,000 pounds of suspended sediment, 18 pounds of nitrogen, 3 pounds of phosphorus, and 0.02 pound of atrazine each second. These loads were about 10 to 150 times greater than those during a previous runoff event, and about 260 to 4,600 times greater than those during a previous base-flow condition.

This sampling demonstrates the importance of collecting both water-quantity and water-quality data during flood events to estimate contaminant loads. Potential environmental effects of a flood can only be understood when both components are measured.

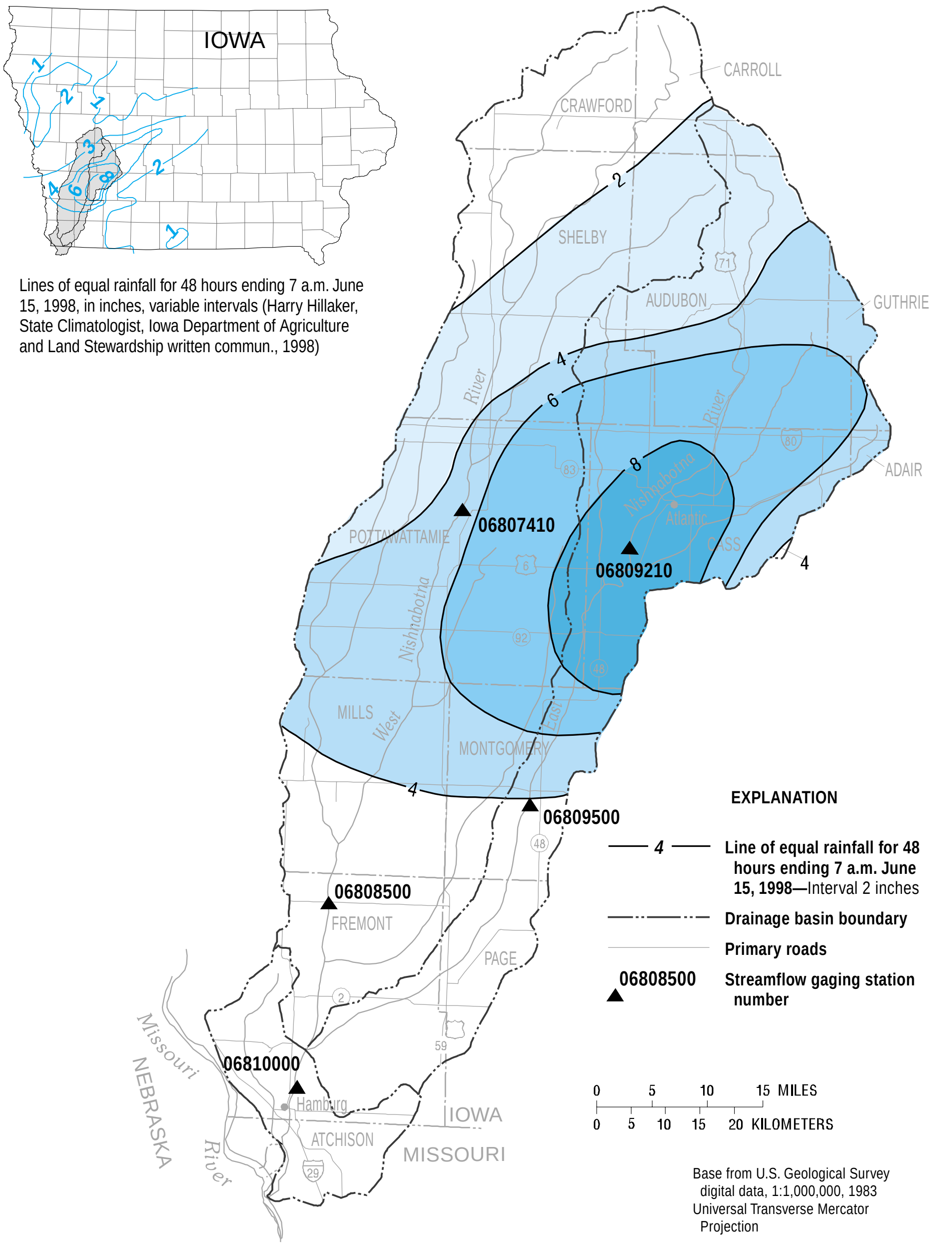
Introduction

Flooding is one type of natural hazard that is of concern not only because of the potential damage caused by the abrupt increases in streamflow, but also because of the large amounts of contaminants that can be transported by the flood waters. Although water quantity is routinely measured, relatively few data have historically been obtained on water quality during floods. The flooding of the Nishnabotna River that occurred in southwest Iowa during June 15–17, 1998, is an example where by both water-quantity and water-quality data were obtained during an event that exceeded the theoretical 500-year flood calculated from peak-flow records (1992 to present).

The objectives of this report are to: 1) document the importance of collecting water-quality data in addition to water-quantity data during a flood event, using the June 1998 flood of the Nishnabotna River as an example, and

U.S. Geological Survey
U.S. Department of the Interior

USGS Water-Resources Investigations Report 00–4025
April 2000



Lines of equal rainfall for 48 hours ending 7 a.m. June 15, 1998, in inches, variable intervals (Harry Hillaker, State Climatologist, Iowa Department of Agriculture and Land Stewardship written commun., 1998)

Base from U.S. Geological Survey digital data, 1:1,000,000, 1983 Universal Transverse Mercator Projection

Figure 1. Nishnabotna River Basin and lines of equal rainfall for 48 hours ending 7 a.m. June 15, 1998.

2) provide a perspective on the amount of contaminants transported during this flood compared to amounts transported during normal streamflow conditions.

Nishnabotna River Basin—Record Rainfall Leads To Record Flooding

The Nishnabotna River is a tributary of the Missouri River in southwest Iowa (fig. 1). The basin is characterized by broad, rolling uplands and wide valleys. Land use is predominantly agricultural. Streamflow characteristics of the Nishnabotna River have been affected by extensive channel straightening and levee construction projects that began in the early 1900’s. Channelization and levee construction have continued throughout the years for local sections of streams (U.S. Army Corps of Engineers, 1974 p. 6–7).

On June 14 and 15, 1998, severe thunderstorms occurred in much of southwest Iowa, with more than 4 inches of rain falling over much of the Nishnabotna River Basin (fig. 1). The following storm description is adapted from a summary provided by the State Climatologist (Harry Hillaker, Iowa Department of Agriculture and Land Stewardship, written commun., 1998).

A large mesoscale convective weather system developed near the center of an upper level low pressure center over southwest Iowa during the early morning hours of June 14th. Extremely heavy rain fell over southwest and central Iowa from this storm. The rain gage at Atlantic received 7 inches in a 4.5-hour period from 8:30 am to 1:00 pm Central Standard Time and had a 24-hour total rainfall of 13.18 inches, which established a new official State record for the greatest amount of rainfall in a 24-hour period. A large area of Cass County was covered by 4- to 8-inch rains. During the morning, a deformation zone formed over the area. Bands of heavy thunderstorms moved up from the south and became stationary in an east to west band from west central into central Iowa. Rainfall of 1 to 2 inches in less than 2 hours was common, with many areas receiving 3 inches or more of additional rainfall.

These intense thunderstorms quickly resulted in severe flooding on the Nishnabotna River. Numerous highways were closed (figs. 2 and 3) and many bridges were damaged or destroyed as a result of this flooding. The peak streamflow recorded at the U.S. Geological Survey (USGS) gaging station Nishnabotna River near Hamburg, Iowa (station number 06810000, fig. 1), was 65,100 cubic feet per second (ft^3/s) or 487,089 gallons per second, about 20 percent greater than the previous recorded peak streamflow and about 120 times greater than the median streamflow (fig. 4). The peak of the flood water at the gaging station was more than 17 feet above flood stage (Fischer, 1999). The recurrence interval of the flood was calculated to be greater than the theoretical 500-year flood.

Major levee failures that occurred as a result of this flood had a direct effect on streamflow at the gaging station near Hamburg. The unsteady rising limb of the hydrograph on June 15 and 16 (fig. 4) likely reflects levee failures that occurred in the vicinity of the gaging station, and the sustained large streamflow on the recession limb of the hydrograph reflects the sustained floodplain contribution to the river. Fischer (1999) provides a more complete description of the hydraulics of this record flood.

Chemicals In Flood Water

To determine the concentrations of selected contaminants that might be present in the record flooding on the Nishnabotna River, water-quality samples were collected within hours of the flood peak near Hamburg (fig. 4). Analysis for selected nutrients (Fishman and Friedman, 1989) and low-application-rate herbicides (Furlong and others, 1999) were done in the USGS National Water Quality Laboratory in Denver, Colorado; analysis of suspended sediment (Guy, 1977) was done in the USGS Sediment Laboratory in Iowa City, Iowa; and the analysis of selected herbicides and herbicide transformation products (degradates) (Hostetler and others, 1999; Zimmerman and Thurman, 1999) were done in the USGS Organic Geochemistry Research Laboratory in Lawrence, Kansas.

The results of these analyses document that numerous herbicide compounds (11 herbicides and 12 herbicide degradates) were present in the flood water (table 1). The total dissolved herbicide concentration (summation of the 23 herbicide compounds detected) measured in the flood water was 15.6 micrograms per liter (µg/L) or parts-per-billion. The highest individual herbicide concentration was 5.06 µg/L for atrazine, followed by metolachlor (1.16 µg/L), metolachlor ESA (1.04 µg/L), acetochlor OA (0.99 µg/L), and acetochlor ESA (0.95 µg/L).

Of the herbicides that were present in the flood water, three (flumetsulam, imazethapyr, and nicosulfuron) are considered low-application-rate herbicides. These herbicides represent relatively new classes of chemicals that have application rates typically 1/50th or less that of herbicides such as atrazine. Little is known about the fate and transport of these herbicides to surface water (Battaglin and others, 2000).

The timing of this flood, which occurred shortly (within several weeks) after chemical application associated with planting of crops, was the principal reason for the large number and concentrations of herbicide compounds.

Figure 2. Overflow on Interstate 29 near Hamburg, Iowa, on June 17, 1998. Water over Interstate 29 was about 0.5 foot deep and 1,775 feet wide; measured rate of overflow was 712 cubic feet per second.

Figure 3. Overflow on road near Atlantic, Iowa, on June 15, 1998. Measured rate of overflow was 16,400 cubic feet per second.

Contaminant Transport

The amount of contaminants being transported by a stream (contaminant load) can be calculated by multiplying concentration times streamflow. Because water-quality samples were collected only once (within hours of the flood peak) during this flood, only instantaneous loads for select contaminants could be calculated (table 2).

At the time the water-quality samples were collected, the flood waters were transporting about 6,000 pounds of suspended sediment, 18 pounds of nitrogen, 3 pounds of phosphorus, and 0.06 pound of herbicides each second. To place these loads in perspective, this is enough

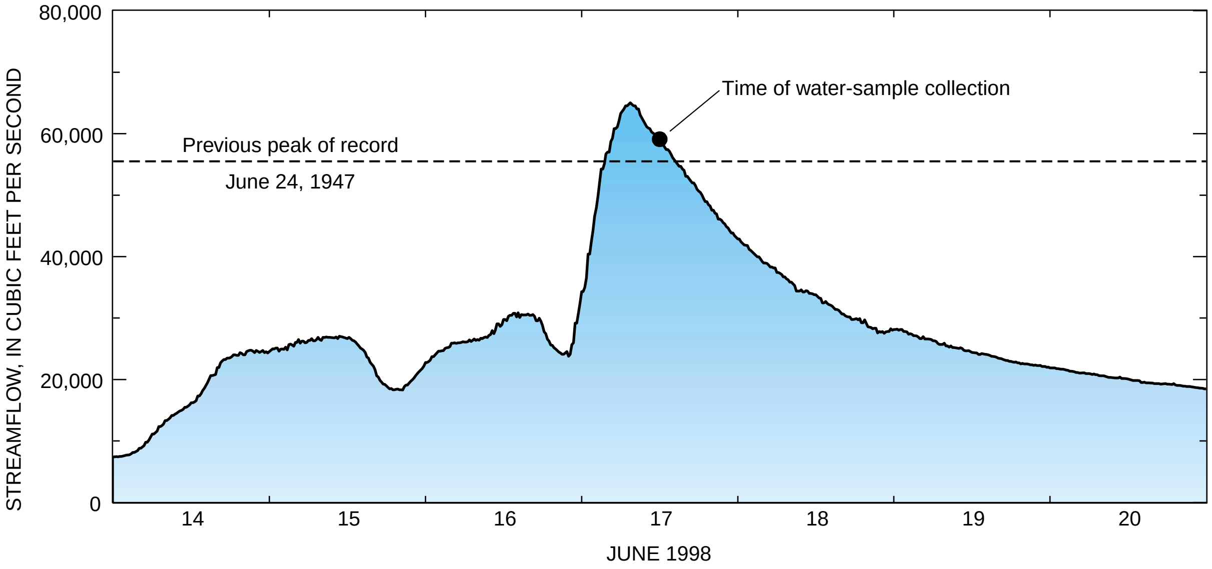


Figure 4. Streamflow in the Nishnabotna River at the U.S. Geological Survey streamflow-gaging station near Hamburg, Iowa (station number 06810000), June 14–20, 1998. Median streamflow at this site (based on 76 years of record) is 565 cubic feet per second (Fischer and Eash, 1998).

sediment to fill a 15-ton dump truck in 5 seconds, enough nitrogen to fertilize a typical acre of farmland (at an application rate of 120 pounds per acre) in about 7 seconds, and enough herbicides to treat a typical acre of farmland (at an application rate of 1 pound per acre) in about 17 seconds.

These data also show the importance of measuring contaminants in both the suspended and the dissolved phases when streams contain large concentrations of sediment, such as during flooding. Based on the samples collected during this flood, 58 percent of the nitrogen and 7 percent of the phosphorus were transported in the dissolved phase (table 2). This is in sharp contrast to baseflow conditions when 85 percent of the nitrogen and 40 percent of the phosphorus were transported in the dissolved phase (table 2). Because of the large suspended-sediment concentration (table 1), substantial amounts of herbicides also may have been transported in the suspended phase and bed load (particulates or attached to sediment). Herbicide concentrations on the sediment, however, were not measured for this study. Thus, the total herbicide concentrations in these flood waters may be higher than the dissolved concentrations reported herein.

These data also show that herbicide degradates are important to accurately determine the amount of herbicides transported during flooding. For this sampling, herbicide degradates comprised from approximately 30 to 90 percent of the total load for a given herbicide (fig. 5).

Comparison With Normal Conditions

To illustrate the magnitude of contaminant loads transported during the June1998 flood of the Nishnabotna River, data obtained during normal streamflow conditions (tables 1 and 2) were provided for comparison.

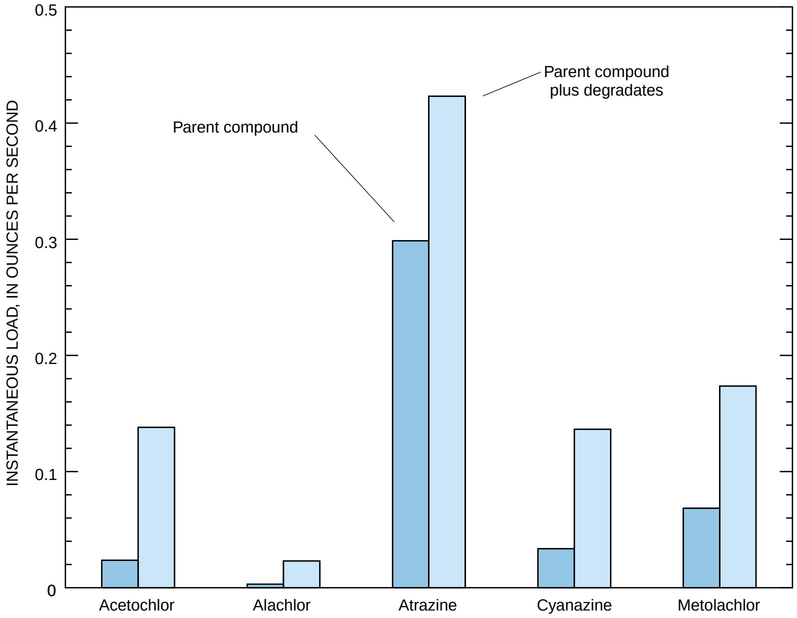


Figure 5. Instantaneous loads of parent compounds and parent compounds plus degradates, for selected herbicides present during the June 1998 flood of the Nishnabotna River.

Table 1. Selected water-quality results from water samples collected from the Nishnabotna River near Hamburg, Iowa

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; µg/L, micrograms per liter; - , no data; <, less than]

	Record flood (6-17-1998)	Previous runoff (6-5-1989)	Previous base flow (3-5-1990)
Streamflow (ft^3/s)	59,100	738	348
Nutrients and Suspended Sediment (mg/L)			
Dissolved nitrogen	2.79	4.06	2.64
Total nitrogen	4.80	5.50[1]	3.10
Dissolved phosphorus	0.06	0.13[1]	0.07
Total phosphorus	0.87	0.46[1]	0.14
Suspended sediment	1,627	3,840[1]	60
Herbicide Compounds (µg/L)			
Acetochlor	0.40	-	-
Acetochlor ESA[2]	0.95	-	-
Acetochlor OA[2]	0.99	-	-
Alachlor	0.05	12	<0.10
Alachlor ESA[2]	0.26	-	-
Alachlor OA[2]	0.08	-	-
Atrazine	5.06	37	<0.10
Deethylatrazine[2]	0.73	2.2	-
Deisopropylatrazine[2]	0.45	2.0	-
Hydroxyatrazine[2]	0.93	-	-
Cyanazine	0.57	34	<0.10
Cyanazine acid[2]	0.74	-	-
Cyanaine amide[2]	0.73	-	-
Deethylcyanazine acid[2]	0.27	-	-
Flumetsulam	0.03	-	-
Imazethapyr	0.10	-	-
Metolachlor	1.16	19	<0.10
Metolachlor ESA[2]	1.04	-	-
Metolachlor OA[2]	0.74	-	-
Metribuzin	0.10	1.5	<0.10
Nicosulfuron	0.09	-	-
Propazine	0.06	0.51	-
Simazine	0.06	0.39	-

[1] Data from water samples collected on 6-29-1989.

[2] Herbicide transformation product (degradate).

Table 2. Instantaneous loads transported by the Nishnabotna River near Hamburg during three flow conditions

[N, Nitrogen; P, Phosphorus; oz/s, ounces per second; <, less than]

Streamflow condition	Suspended sediment (oz/s)	Total N (oz/s)	Dissolved N (oz/s)	Total P (oz/s)	Dissolved P (oz/s)	Atrazine (oz/s)
Record flood (6-17-1998)	96,044	283	165	51.5	3.5	0.30
Normal spring runoff (6-5-1989)	2,832	4.06	3.00	0.34	0.10	0.03
Base flow (3-5-1990)	20.8	1.08	0.92	0.05	0.02	<0.001

The June 1989 samples (table 1) represent data collected at about the same time of year as the flood sample, but during a typical late-spring runoff event. The June 1989 samples had large concentrations of agricultural contaminants (nutrients, suspended sediment, and herbicides) commonly found in many midwestern streams during late spring and early summer runoff events (Thurman and others, 1992). Even though the chemical concentrations were much higher during the June 1989 sampling (table 1), the loads were about 10 to 150 times larger during the 1998 flood (table 2) because of the larger amount of flow. The herbicide alachlor was the only exception to this trend, with its load being about 3 times smaller in the June 1998 flood than in the June 1989 sampling. This difference is probably due to the dramatic decrease in alachlor use between 1989 and 1998 (Battaglin and Goolsby, 1999).

The March 1990 samples (tables 1 and 2) represent data obtained during base-flow conditions. During base flow, ground water contributes a greater proportion of the total streamflow, in contrast to during the 1998 flood when essentially all of the streamflow was derived from surface runoff. The March 1990 samples generally had low concentrations of agricultural contaminants — typical of midwestern streams during base-flow conditions (Thurman and others, 1992). Because of the substantial differences in both chemical concentrations and streamflow between the March 1990 and the 1998 flood sampling, the contaminant loads during the flood were about 260 to 4,600 times greater than those during base-flow. Thus, the 15-ton dump truck that could be filled with sediment in a mere 5 seconds during the 1998 flood would require more than 6 hours to fill during base-flow conditions.

This sampling demonstrates the importance of collecting both water-quantity and water-quality data during flood events to estimate contaminant loads. Potential environmental effects of a flood can only be understood when both components are measured.

Acknowledgments

The authors thank USGS personnel, Rich Kopish and Joe Gorman, for their efforts in the collection and processing of the water-quality samples that formed the basis of this report. Their dedication to collecting high-quality data under difficult field conditions is greatly appreciated.

References

Battaglin, W.A., Furlong, E.T., Burkhardt, M.R., and Peter, C.J., 2000, Occurrence of sulfonylurea, sulfonamide, imidazolinone, and other herbicides in rivers, reservoirs, and ground water in the Midwestern United States: Science of the Total Environment, v. 248, nos. 2–3, p. 123–133.

Battaglin, W.A., and Goolsby, D.A., 1999, Are shifts in herbicide use reflected in concentrations changes in midwestern rivers?: Environmental Science and Technology, v. 33, n. 17 p. 2917–2925.

Fischer, E.E., and Eash, D.A., 1998, Statistical summaries of selected Iowa streamflow data through September 1996: U.S. Geological Survey Open-File Report 98–170, 681 p.

Fischer, E.E., 1999, Flood of June 15–17, 1998, Nishnabotna and East Nishnabotna Rivers, southwest Iowa: U.S. Geological Survey Open-File Report 99–70, 15 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water Resources Investigation, book 5, chap. A1, 545 p.

Furlong, E.T., Burkhardt, M.R., Gates, P.M., Werner, S.L., and Battaglin, W.A., 1999, Routine determination of sulfonylurea, imidazolinone, and sulfonamide herbicides at nanogram-per-liter concentrations by solid-phase extraction and liquid chromatography/mass spectrometry: *in* Morganwalp, D.W., and Buxton, H.T., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the Technical Meeting, Charleston, South Carolina, March 8–12, 1999—Volume 2 of 3—Contamination of Hydrologic Systems and Related Ecosystems: U.S. Geological Survey Water-Resources Investigations Report 99–4018B, p. 275–288.

Guy, H.P., 1977, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water Resources Investigations, book 5, chap. C1, 58 p.

Hostetler, K.A., and Thurman, E.M, 1999, Determination of chloroacetanilide herbicide metabolites in water using high-performance liquid chromatography-diode array detection and high-performance liquid chromatography/mass spectrometry: *in* Morganwalp, D.W., and Buxton, H.T., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the Technical Meeting, Charleston, South Carolina, March 8–12, 1999—Volume 2 of 3—Contamination of Hydrologic Systems and Related Ecosystems: U.S. Geological Survey Water-Resources Investigations Report 99–4018B, p. 345–353.

Thurman, E.M., Goolsby, D.A., Meyer, M.T., Mills, M.S., Pomes, M.L., and Kolpin, D.W., 1992, A reconnaissance study of herbicides and their metabolites in surface water of the midwestern United States using immunoassay and gas chromatography/mass spectrometry: Environmental Science and Technology, v. 26, n. 12, p. 2440–2447.

U.S. Army Corps of Engineers, 1974, Nishnabotna River basin, Iowa, report on flood of September 1972: Omaha, Nebraska, 79 p.

Zimmerman, L.R., and Thurman, E.M., 1999, Method of analysis by the U.S. Geological Survey Organic Geochemistry Research Group — Determination of triazine and chloroacetanilide herbicides in water by solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected ion monitoring: U.S. Geological Survey Open-File Report 98–634, 21 p.

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