WATER QUALITY OF ALLUVIAL AQUIFERS, CARROLL AND GUTHRIE COUNTIES, IOWA, WITH EMPHASIS ON THE OCCURRENCE OF NITRATE AND PESTICIDES, 1986-87

By Mark G. Detroy, Melanie L. Clark, Maureen A. Holub, and Pamela K.B. Hunt

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CONVERSION FACTORS

For readers who prefer to use International System (SI) units rather than the inch-pound terms used in this report, the following conversion factors may be used.

Multiply inch-pound unit	By	To obtain SI units
inch	25.4	millimeter
foot	0.3048	meter
gallon per minute	0.06309	liter per second
ton	907.2	kilogram
acre	4,046.9	square meter

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 9/5 \times °C + 32.$$

Sea level: In this report "sea level" refers to National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Samples collected from wells in Carroll and Guthrie Counties, Iowa, were analyzed to describe the chemical quality of the ground water in shallow aquifers. The study began in June 1986 with the selection of 20 shallow wells in Carroll County and 22 shallow wells in Guthrie County. These wells were sampled in the summer and fall of 1986 and 1987. Samples from the wells were analyzed for major ions, nutrients, trace elements, radiochemicals, nitrate, and pesticides.

Median and mean nitrate concentrations were 9.5 and 11 milligrams per liter. About 60 percent of the samples had nitrate concentrations greater than 5.0 milligrams per liter. Detectable concentrations of a least one pesticide were in 27 percent of the samples. Atrazine, the most prevalent pesticide, was detected in 25 percent of the samples; alachlor was detected in 6 percent; and cyanazine was detected in 5 percent. Dicamba, metolachlor, trifluralin, and 2,4-D were detected in 2 percent or less of the samples.

In the summer and fall 1986, 43 and 45 percent of the water samples had nitrate concentrations larger than 10 milligrams per liter, the maximum contaminant level for public drinking water specified by the State of Iowa; in the summer and fall 1987, 41 and 55 percent of the samples had nitrate concentrations larger than the maximum contaminant level. In the summer and fall 1986, 23 and 18 percent of the samples contained detectable concentrations of at least one pesticide; in the summer and fall 1987, 21 and 47 percent of the samples contained detectable concentrations of at least one pesticide. Detection frequencies of atrazine, alachlor, and cyanazine increased for samples collected in October 1987. Pesticides were more frequently detected along Brushy Creek, and the East Nishnabotna, Middle, North Raccoon, and South Raccoon Rivers. However, pesticides also were detected along the Middle Raccoon and West Nishnabotna Rivers. Detection frequencies were greatest (50 percent) for the East Nishnabotna River and Middle River alluvial settings.

Increased nitrate concentrations generally were observed in the shallower wells and were larger than those previously reported for shallow municipal wells. Pesticide detection relative to well depth was inconsistent with the trend observed for nitrate. Pesticide detection frequencies were greater for wells that were 40 to 80 feet deep (about 40 percent) than for wells less that 40 feet deep (about 20 percent).

Of the water samples with nitrate concentrations greater than or equal to 5.0 milligrams per liter, 33 percent had detectable pesticide concentrations. Conversely, for those samples with detectable pesticide concentrations, 76 percent had nitrate concentrations larger than or equal to 5.0 milligrams per liter and 67 percent were larger than or equal to 10 milligrams per liter. The median concentration of nitrate for samples containing at least one detectable pesticide was 15 milligrams per liter and was greater than the overall median nitrate concentration of 9.5 milligrams per liter. The median for samples that did not contain a detectable pesticide was 7.3 milligrams per liter.

INTRODUCTION

Agricultural pesticides and fertilizers have contributed to the success of American agriculture. Iowa ranks second in the nation in use of nitrogen fertilizer (Hargett and Berry, 1986). Studies in Iowa since 1982 have documented increased nitrate and detectable pesticide concentrations in shallow ground water (Hallberg and Hoyer, 1982). The occurrence of agricultural chemicals in ground water in Iowa has become a primary concern of State and local officials, including Carroll and Guthrie County officials. As a result, the U.S. Geological Survey, in cooperation with the Carroll County Health Department, Guthrie County Health Department, University of Iowa Hygienic Laboratory and the Iowa Department of Natural Resources, collected data to describe the chemical quality of shallow alluvial aquifers in Carroll and Guthrie Counties. Water samples were collected from 20 wells in Carroll County and 22 wells in Guthrie County along major alluvial systems in the summer (June-July) and fall (September-October) of 1986 and 1987 (fig. 1). The objective was to describe the temporal and areal variation of the chemical quality of the ground water in shallow aquifers in the counties, with special emphasis on nitrate and pesticides.

Purpose

This report presents data that describes the chemical quality of the ground water obtained from shallow wells in Carroll and Guthrie Counties, and summarizes and discusses the occurrence, magnitude, and seasonality of nitrate and pesticide concentrations in the alluvial aquifers. The information presented in this report will be useful in the development of a monitoring program that will meet the needs of Federal, State, and county water regulators and the interest of researchers relevant to possible agricultural contamination of ground water.

Study Area

Carroll and Guthrie Counties are located in west-central Iowa. The predominant land use in the area is for agriculture. The wells selected for this study are completed in alluvial aquifers of Brushy Creek, the East Nishnabotna River, Middle River, Middle Raccoon River, North Raccoon River, South Raccoon River, and the West Nishnabotna River.

The total crop acres reported for Carroll and Guthrie Counties during 1986 are listed in table 1. The total crop acres were not available for 1987, but probably would be lower because of the Conservations Reserve Program and the Set Aside Program (Howard Holden, Crops Livestock Reporting Service, oral commun., 1987). Pesticide use data were not available for 1986 or 1987, but recent State legislation requires that the quantity of pesticides sold each year be reported beginning in 1988.

The U.S. Weather Service precipitation stations in the area include stations at Carroll in Carroll County and at Guthrie Center in Guthrie County (fig. 1). Both stations are in the center of each county. The monthly average precipitation recorded at the stations is shown in figure 2. During 1986 the area received above-normal rainfall every month, with a yearly average of 34 percent above-normal rainfall. During 1987 the area received 7 percent below-normal rainfall in April and May; in July, August, and September the area received 42 percent greater-than-normal rainfall. Monthly water levels for an observation well in Carroll are shown in figure 3. During the months June through October 1986, water levels were about 13 percent higher than for this same period during 1987.

Most wells are in alluvial sediment that is overlain by six main soil associations; the Marshall-Exira-Burchard association, Cole-Ackmore-Calco association, Wadena-Coland-Storden association, Zook-Colo-Vesser association, Sharpsburg-Ladoga-Shelby, and Gara-Lindley association (Russell and others, 1974; Sherwood, 1982).

The Marshall-Exira-Burchard association is along the headwaters of Brushy Creek, the East Nishnabotna River, and the Middle Raccoon River. These soils are found along ridges and side slopes that are dissected by valleys. The soils are silty and loamy and are formed in loess and glacial till.

The Colo-Ackmore-Calco association is along the middle stretch of Brushy Creek and the Middle Raccoon River. The soils in this association primarily are silty, are on the alluvial flood plains, and are more sandy where located near streams. The Wadena-Coland-Storden association consists of loamy soils that were formed in glacial outwash sediment, alluvium, and glacial till on both uplands and bottom lands.

The Zook-Colo-Vesser association is along the southern stretch of Brushy Creek and the South Raccoon River in Guthrie County. The soils in this association are on bottom lands, are nearly level, silty, and poorly drained. The Sharpsburg-Ladoga-Shelby association is in the divides between Brushy Creek, the Middle Raccoon River, and the South Raccoon River. These soils are on gently sloping to moderately steep terrain, are silty and loamy, and moderately well drained on the uplands. The Gara-Lindley association is along the Middle Raccoon River. These soils are on strongly sloping to steep terrain, are loamy, and are moderately well drained on the bottom lands. Soil information was obtained from the soil surveys of Carroll County (Sherwood, 1982) and Guthrie County (Russell and others, 1974).

In this report the alluvial aquifers are named according to the alluvial setting with which they are associated. For example, the alluvial aquifer associated with the Middle Raccoon River is named the Middle Raccoon aquifer.

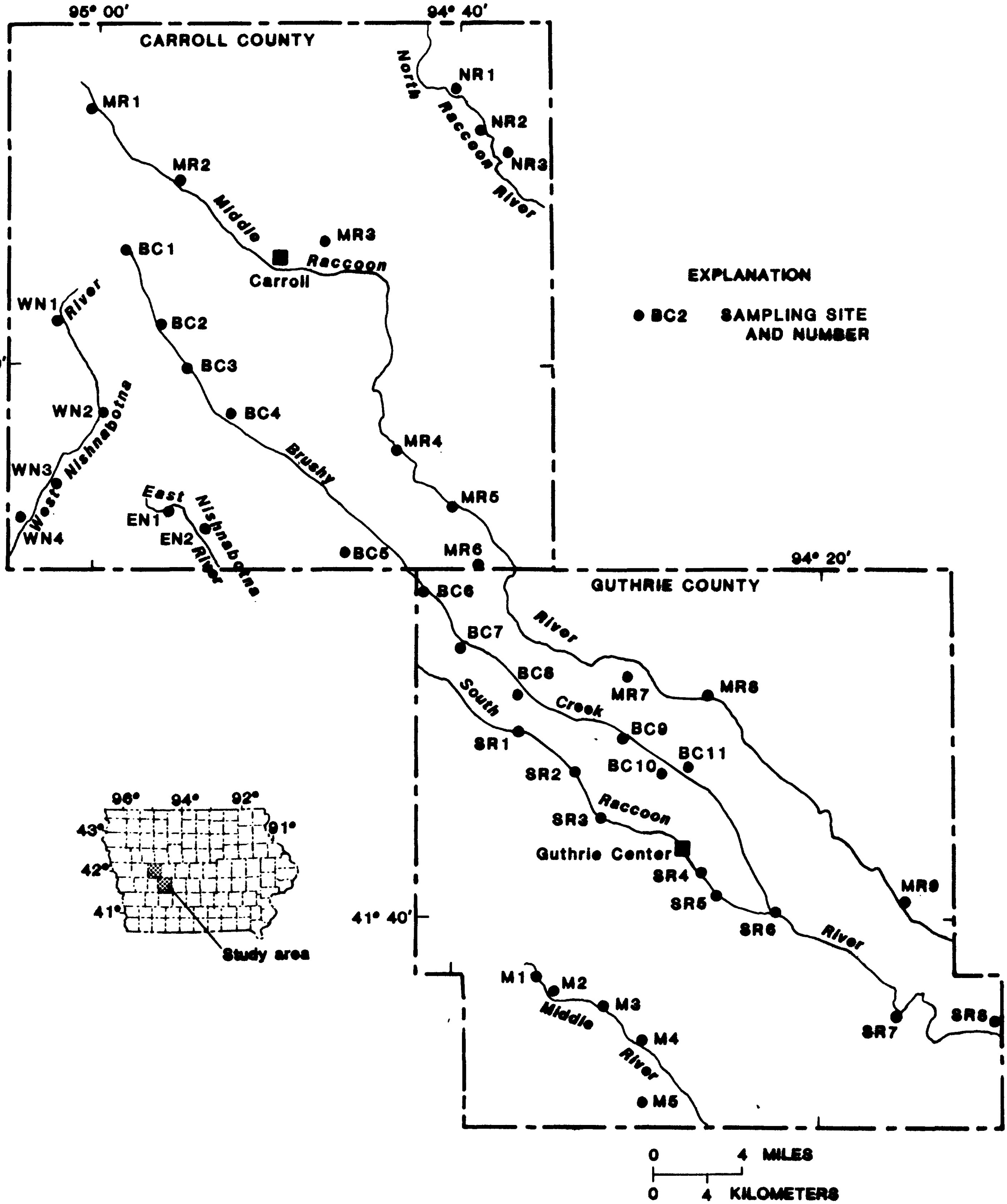

Figure 1.--Location of wells sampled.

Table 1.--*Total crop acres, 1986*

Crop	Carroll County (acres)	Guthrie County (acres)
Corn	147,000	119,000
Soybeans	109,000	75,000
Oats	7,600	8,200

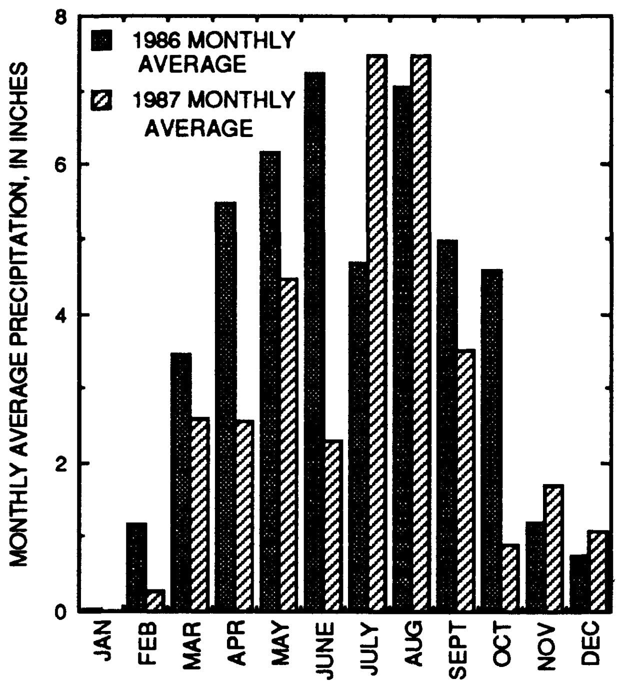

Figure 2.--Monthly average precipitation for Carroll and Guthrie Counties during 1986 and 1987.

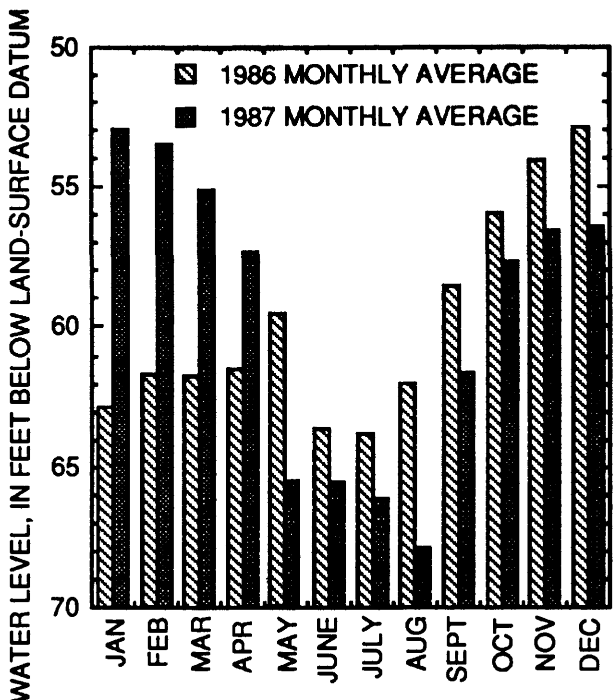

Figure 3.-- Water levels for an observation well in Carroll during 1986 and 1987.

METHODS OF STUDY

Selection of wells to be sampled was completed in consultation with the county sanitarians. Selection was based on location, well construction, availability and accessibility, and cooperation of the well owners. All selected wells were near or within major alluvial systems. It should be noted that two wells were no longer available for sampling by fall of 1987.

The water samples from the domestic wells were collected from hydrants that were close to a submersible pump. Two observation wells were included in the study, and data from these are included in the data with the domestic wells. The two observation wells were purged by airlifting to ensure that fresh aquifer water was available for sampling. The water sample was collected with a suction pump to limit aeration of the sample. The wells were pumped until the water cleared and specific conductance and pH stabilized. Measurements made at each sampling site at the time of collection are listed in table 2 and were done in accordance with methods described by Brown and others (1970).

Wells were sampled twice each year. The first samples were collected in June or July, about one month after chemical application to crop areas. The second round of samples were collected in September or October during low water-table conditions and a considerable time after the last chemical application.

The major cations and trace element samples were collected in plastic bottles. The samples were filtered, and nitric acid was added as a preservative to the bottles for the analyses of calcium, magnesium, potassium, sodium, and trace elements. Nutrient samples, including nitrate and phosphate, were collected in plastic amber bottles. The samples were filtered, preserved with sulfuric acid, and

Table 2.--*Summary of measurements and data recorded at the sampling site*

Measurement
Water temperature, in degrees Celsius
Air temperature, in degrees Celsius
pH, in units
Specific conductance, in microsiemens per centimeter at 25 degrees Celsius
Water level, in feet below land surface
Pumping period before sampling, in minutes
Pumping rate, in gallons per minute

chilled. Pesticide samples were collected in glass bottles. The bottles were filled with raw water, so as to not allow any air bubbles in the sample, and chilled.

Chemical analyses for major ions, nutrients, trace elements, and radiochemicals were done by the University of Iowa Hygienic Laboratory (table 3). Pesticide analyses included common herbicides, common insecticides, acid herbicides and chlorinated hydrocarbon insecticides (table 4). Methods of analysis generally were those described by the U.S. Environmental Protection Agency (1983). During 1986 comprehensive analyses for chemical constituents were performed to establish background concentrations, but during 1987 only analyses of nitrate and common herbicides were performed because these were the constituents of specific interest.

The Federal primary and secondary drinking-water standards are adopted by the State and apply only to public-water supplies (table 5). Primary standards pertain to constituents and regulations affecting the health of consumers and are enforceable for public-water supplies by the State. Secondary standards refer to the esthetic qualitites of drinking water and are intended as a guideline for the water supplies (U.S. Environmental Protection Agency, 1986a, b).

MAJOR IONS, NUTRIENTS, TRACE ELEMENTS, AND RADIOCHEMICALS

Water samples collected during 1986 were analyzed for the constituents listed in table 3. These analyses included onsite measurements of specific conductance, pH, and temperature, major ions, nutrients, trace elements, and radiochemicals. These constituents were analyzed to document existing water-quality conditions but were not the primary interest of this investigation. A statistical summary of these properties and constituents for all analyses is provided in table 6. Well information is given in table 7. Analytical data are listed in tables 8 through 10 in the Supplemental Data Section in the back of the report.

The concentrations of the major ions were less than the primary standards for public-water supplies in all samples. About 50 percent of the samples contained concentrations of dissolved solids greater than 50 mg/L (milligrams per liter), the secondary standard recommended for public-water supplies. About 8 percent of the samples contained mercury concentrations greater than or equal to the primary standard of 2 μg/L (micrograms per liter). It should be noted that zinc concentrations may be increased because domestic wells often are cased with galvanized pipe. However, zinc concentrations were less than the secondary standard. All concentrations of radiochemicals in the samples were less than the primary standard for public-water supplies.

NITRATE

The occurrence of nitrate contamination in ground water presently (1989) is being investigated throughout the Midwest. The agricultural use of nitrogen fertilizer has been shown to contribute to the nitrate concentrations observed in ground water (Hallberg and Hoyer, 1982). Generally, nitrate concentrations larger than 3 mg/L can be attributed to human activities (Madison and Brunett, 1984).

In this report the values for "nitrate concentration" are actually for nitrite plus nitrate reported as nitrogen in mg/L. The nitrite portion of the analysis is considered negligible (Hem, 1985). One hundred and fifty-seven analyses of nitrate are available from this study. The smallest

Table 3.--Summary of inorganic laboratory analyses and methods

[mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; Ac, Actinium]

Constituent	Analytical method reference
Calcium, dissolved, mg/L as Ca	Method 215.2[a]
Magnesium, dissolved, mg/L asMg	Method 200.7[a]
Sodium, dissolved, mg/L as Na	Method 200.7[a]
Potassium, dissolved, mg/L as K	Method 322.[b]
Alkalinity, total as $CaCO_3$, mg/L	Method 310.1[a]
Sulfate, dissolved, mg/L as SO_4	Method 375.4[a]
Chloride, dissolved, mg/L as Cl	Method 325.3[a]
Fluoride, dissolved, mg/L as F	Method 14.324[c]
Dissolved solids at 180 °Celsius, mg/L	Method 160.3[a]
Nitrate, dissolved as N, mg/L[d]	Method 353.2[a]
Nitrogen, ammonia, dissolved as N, mg/L	Method 350.1[a]
Nitrogen, total kjeldahl as N, mg/L	Method 351.2[a]
Phosphorus, dissolved orthophosphate as P, mg/L	Method 365.1[a]
Arsenic, dissolved as As, µg/L	Method 206.2[a]
Barium, dissolved as Ba, µg/L	Method 200.7[a]
Cadmium, dissolved as Cd, µg/L	Method 213.2[a]
Chromium, dissolved as Cr, µg/L	Method 218.2[a]
Iron, dissolved as Fe, µg/L	Method 200.7[a]
Lead, dissolved as Pb, µg/L	Method 239.2[a]
Manganese, dissolved as Mn, µg/L	Method 200.7[a]
Mercury, dissolved as Hg, µg/L	Method 245.1[a]
Selenium, dissolved as Se, µg/L	Method 270.2[a]
Silver, dissolved as Ag, µg/L	Method 272.1[a]
Zinc, dissolved as Zn, µg/L	Method 200.7[a]
Alpha, gross dissolved as uranium natural, pCi/L	Residue procedure
Beta, gross dissolved as cesium-137, pCi/L	Residue procedure
Radium-226, dissolved as cesium-137, pCi/L	Precipation procedure, planchet counting
Radium-228, dissolved, pCi/L	Separation and counting of Ac-228

[a] U.S. Environmental Protection Agency, 1983.

[b] American Public Health Association and others, 1985.

[c] Brown and others, 1970.

[d] Values for nitrate concentrations actually are for nitrite plus nitrate, but the nitrite concentration is considered negligible (Hem, 1985).

Table 4.--Summary of pesticide analyses

[--, no data available]

Chemical name	Trade name[a]	Class
	Common herbicides	
Atrazine	Aatrex	S-triazine
Cyanazine	Bladex	S-triazine
Metribuzin	Sencor	S-triazine
Alachlor	Lasso	Phenylamide (acylanilide)
Metolachlor	Dual	Phenylamide (acetamide)
Trifluralin	Treflan	Phenylamide (toluicine)
Butylate	Sutan	Carbamate
	Common insecticides	
Chlorpyrifos	Lorsban/Dursban	Organophosphate
Ethoprop	MoCap	Organophosphate
Fonofos	Dyfonate	Organophosphate
Phorate	Thimet	Organophosphate
Terbufos	Counter	Organophosphate
Carbofuran	Furadan	Carbamate
	Acid herbicides	
Chloramben	Amiben	Benzoic acid
Dicamba	Banvel	Benzoic acid
Silvex	--	Phenoxy acid
2,4-D	Amiben	Benzoic acid
	Chlorinated hydrocarbon insecticides	
Aldrin	--	--
alpha-BHC (benzene hexachloride	--	--
beta-BHC (benzene haxachloride)	--	--
DDD, 1,1-dichloro-2,2-bis (p-chlorophenyl) ethane	--	--
DDE, 4,4-dichlorodiphenyldichloroethylene	--	--
DDT, 4,4-dichlorodiphenyltrichlorethane	--	--
Dieldrin	--	--
Endosulfan sulfate	--	--
Endosulfan I	--	--
Endosulfan II	--	--
Endrin	--	--
Endrin aldehyde	--	--
gamma-BHC (benzene hexachloride	--	--
Heptachlor	--	--
Heptachlor epoxide	--	--
Toxaphene	--	--

[a] Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 5.--*Drinking-water standards for public-water supplies*

[--, no standard determined; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; mrem/yr, millirem per year]

Property or constituent	Drinking-water standards in public-water supplies	
	Primary[a]	Secondary[b]
pH	--	6.5-8.5
Sulfate	--	250 mg/L
Chloride	--	250 mg/L
Fluoride	4 mg/L	2 mg/L[c]
Dissolved solids	--	500 mg/L
Nitrate as nitrogen	10 mg/L	--
Arsenic	50 µg/L	--
Barium	1,000 µg/L	--
Cadmium	10 µg/L	--
Chromium	50 µg/L	--
Copper	--	1,000 µg/L
Iron	--	300 µg/L
Lead	50 µg/L	--
Manganese	--	50 µg/L
Mercury	2 µg/L	--
Selenium	10 µg/L	--
Silver	50 µg/L	--
Zinc	--	5,000 µg/L
Gross-alpha activity (including radium-266 but not radon or uranium)	15 pCi/L	--
Gross-beta activity as cesium-137	4 mrem/yr	--
Radium (radium-266 and radium-228 combined)	5 pCi/L	--

[a] U.S. Environmental Protection Agency, 1986a.

[b] U.S. Environmental Protection Agency, 1986b.

[c] Flouride should not exceed 4 mg/L in drinking water. Flouride in children's drinking water of about 1 mg/L reduced the number of dental cavities. However, some children exposed to flouride concentrations larger than about 2.0 mg/L develop dental fluorosis, which in its moderate and severe forms is a brown staining or pitting of the permanent teeth.

Table 6.--*Statistical summary of properties, major ion, trace elements, and radiochemicals*

[µS/cm, microsiemens per centimeter; --, no data available; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Constituent	Mean	Median	Standard deviation	Minimum	Maximum	Number of analyses
Specific conductance, µS/cm	667	637	347	175	2,750	80
pH, units	--	7.06	.26	6.5	7.9	78
Water temperature, °C	13.5	13.0	1.9	10	17.0	80
Calcium, mg/L	83	83	36	16	180	80
Magnesium, mg/L	24	24	11	5.4	52	79
Sodium, mg/L	12	9.0	8.1	3.5	47	80
Potassium, mg/L	3.5	1.2	7.9	<.10	51	80
Alkalinity, mg/L	220	210	.992	62	440	80
Sulfate, mg/L	47	36	41	5.7	240	80
Chloride, mg/L	19	14	18	<.05	80	80
Fluoride, mg/L	.3	.3	.1	<.1	.6	80
Silica, mg/L	22	22	3.4	16	34	80
Dissolved solids, mg/L	394	381	186	84	838	80
Arsenic, µg/L	--	<10	--	<10	20	80
Barium, µg/L	--	170	--	10	630	80
Cadmium, µg/L	--	--	--	<1.0	<1.0	80
Chromium, µg/L	--	--	--	<10	<10	80
Copper, µg/L	--	<10	--	<10	160	80
Iron, µg/L	910	40	500	<20	14,000	80
Lead, µg/L	--	<10	--	<10	10	80
Manganese, µg/L	130	<20	260	<20	1,500	79
Mercury, µg/L	--	<1.0	--	<1.0	5.0	80
Selenium, µg/L	--	--	--	<10	<10	80
Silver, µg/L	--	<10	--	<10	10	80
Zinc, µg/L	--	50	--	<10	620	80
Gross alpha, pCi/L	1.5	1.2	1.4	<0.2	10	78
Gross beta, pCi/L	4.2	2.0	6.5	<.6	37	77
Radium-226, pCi/L	.6	.2	.6	.2	1.8	9
Radium-228, pCi/L	1.4	1.2	.7	.9	3.0	9

Table 7.--*Location and depth of wells sampled*

Site number (fig. 1)	Depth of well	Latitude	Longitude	County
		<u>Brushy Creek aquifer</u>		
BC1	13.00	420356	0945922	Carroll
BC2	26.00	420104	0945731	Carroll
BC3	21.00	415929	0945617	Carroll
BC4	24.00	415744	0945404	Carroll
BC5	30.00	415217	0944838	Carroll
BC6	70.00	415052	0944412	Guthrie
BC7	80.00	414844	0944216	Guthrie
BC8	35.00	414728	0943924	Guthrie
BC9	43.00	414516	0943346	Guthrie
BC10	30.00	414352	0943151	Guthrie
BC11	60.00	414400	0943007	Guthrie
		<u>East Nishnabotna River aquifer</u>		
EN1	60.00	415409	0945720	Carroll
EN2	22.00	415314	0945528	Carroll
		<u>Middle Raccoon River aquifer</u>		
MR1	14.00	420919	0950100	Carroll
MR2	16.00	420529	0956310	Carrol
MR3	65.00	420412	0944921	Carroll
MR4	30.00	415622	0944538	Carroll
MR5	25.00	415416	0944256	Carroll
MR6	30.00	415213	0944129	Carroll
MR7	60.00	414740	0943332	Guthrie
MR8	50.00	414652	0942928	Guthrie
MR9	50.00	413850	0941931	Guthrie
		<u>Middle River aquifer</u>		
M1	30.00	413607	0943812	Guthrie
M2	20.00	413525	0943725	Guthrie
M3	29.00	413453	0943447	Guthrie
M4	24.00	413334	0943251	Guthrie
M5	42.00	413107	0943007	Guthrie
		<u>North Raccoon River aquifer</u>		
NR1	16.00	421004	0944238	Carroll
NR2	20.00	420825	0944111	Carrol
NR3	18.00	420726	0944007	Carroll

Table 7.--*Location and depth of wells sampled--Continued*

Site number (fig. 1)	Depth of well	Latitude	Longitude	County
		South Raccoon River aquifer		
SR1	45.00	414525	0943915	Guthrie
SR2	35.00	414356	0943614	Guthrie
SR3	56.00	414208	0943450	Guthrie
SR4	50.00	413959	0942935	Guthrie
SR5	27.00	413902	0942851	Guthrie
SR6	27.00	414110	0942605	Guthrie
SR7	30.00	413439	0941947	Guthrie
SR8	42.00	413342	0941442	Guthrie
		West Nishnabotna River aquifer		
WN1	29.00	420115	0950306	Carroll
WN2	30.00	415751	0950049	Carroll
WN3	60.00	415513	0950317	Carroll
WN4	20.00	415355	0950442	Carroll

concentration of nitrate detected was less than 0.10 mg/L, and the largest concentration detected was 45 mg/L. The median and mean concentrations of nitrate were 9.5 and 11 mg/L, both near the drinking-water standard of 10 mg/L. Analytical results for nitrate are listed in table 11.

Temporal Variation

Ranges of nitrate concentration detected in all samples distributed by the sampling period are shown in figure 4. Graphically little difference exists in the distribution of samples among nitrate concentration ranges for the four sampling periods. Fall 1987 had the most samples in the largest range but the number of samples with nitrate concentrations larger than or equal to 5 mg/L was about the same for all periods. In summer 1986, 43 percent of the wells sampled had nitrate concentrations larger than 10 mg/L; in fall 1986, 45 percent of the wells sampled had nitrate concentrations larger than 10 mg/L. In summer 1987, 41 percent of the wells sampled had nitrate concentrations larger than 10 mg/L, and, in fall 1987, 55 percent of the wells sampled had nitrate concentrations larger than 10 mg/L.

The median and mean concentrations of nitrate for the four sampling periods are listed in table 12. A summary of the individual changes of nitrate concentrations from the summer to fall sampling is listed in table 13. During 1986, nitrate concentrations increased from the summer sampling to the fall sampling in 27 samples or in 68 percent of the samples. Two-thirds of these increases were larger than 1.0 mg/L. Nitrate concentrations decreased from the summer sampling to the fall sampling in 10 samples or in 25 percent of the samples. Six of these decreases were larger than 1.0 mg/L. During 1987, nitrate concentrations increased from the summer sampling to the fall sampling in 24 samples or in 63 percent of the samples. Seventy-one percent of these increases were larger than 1.0 mg/L. Nitrate concentrations decreased from the summer sampling to the fall sampling in 13 samples or in 34 percent of the samples. Nine of these decreases were larger than 1.0 mg/L.

More water samples had nitrate concentrations that increased from summer to fall than decreased. This indicates that, in this alluvial setting, larger nitrate concentrations can be detected a few months after the application period of most crop chemicals than can be detected in June, which is about 4 to 6 weeks after application. Both of the fall sampling periods followed summer seasons of above-normal rainfall.

Areal Distribution

The areal distribution of nitrate concentrations larger than 10 mg/L in 1986 and 1987 is shown in figures 5 and 6. Nitrate concentrations larger than 10 mg/L were detected in all alluvial systems except Brushy Creek in Guthrie County. The soils around this reach of Brushy Creek are not substantially different from soils in the other systems and are similar to the soils near the South Raccoon River.

Table 11.--*Nitrate concentrations*

[Nitrate as nitrogen, in milligrams per liter; <, less than]

Site number (fig. 1)	Nitrate, dissolved as N, mg/L	Site number (fig. 1)	Nitrate, disolved as N, mg/L
	Brushy Creek aquifer June 10-16, 1986		
BC1	11	BC7	2.7
BC2	44	BC8	.36
BC3	18	BC9	1.8
BC4	9.5	BC10	2.9
BC5	11	BC11	8.0
BC6	.89		
	October 6-22,1986		
BC1	9.6	BC7	3.3
BC2	38	BC8	.71
BC3	18	BC9	1.9
BC4	33	BC10	4.0
BC5	13	BC11	8.9
BC6	.31		
	June 22-July 1, 1987		
BC1	9.9	BC7	3.4
BC2	17	BC8	<.10
BC3	9.5	BC9	2.7
BC4	3.8	BC10	4.5
BC5	12	BC11	9.7
BC6	.2		
	September 28-October 7, 1987		
BC1	11	BC7	3.4
BC2	37	BC9	2.2
BC3	24	BC10	4.5
BC4	32	BC11	9.9
BC5	11		
BC6	<.10		
	East Nishnabotna River aquifer June 10-16, 1986		
EN1	17	EN2	7.3
	October 6-22, 1986		
EN1	15	EN2	8.4

Table 11.--*Nitrate concentrations--Continued*

Site number (fig. 1)	Nitrate, dissolved as N, mg/L	Site number (fig. 1)	Nitrate, disolved as N, mg/L
	East Nishnabotna River aquifer--Continued June 22-July 1, 1987		
EN1	17	EN2	12
	September 28-October 7, 1987		
EN1	14	EN2	5.9
	Middle Raccoon River aquifer June 10-16, 1986		
MR1	0.72	MR6	4.4
MR2	19	MR7	16
MR3	<.10	MR8	.18
MR4	16	MR9	13
MR5	18		
	October 6-22, 1986		
MR1	1.6	MR6	5.8
MR2	35	MR7	21
MR3	<.10	MR8	.71
MR4	26	MR9	15
MR5	28		
	June 22-July 1, 1987		
MR1	8.6	MR6	5.9
MR2	.41	MR7	45
MR3	<.10	MR8	.81
MR4	21	MR9	15
MR5	25		
	September 28-October 7, 1987		
MR1	5.9	MR6	5.9
MR2	14	MR7	15
MR3	<.10	MR8	.68
MR4	19	MR9	17
MR5	19		
	Middle River aquifer June 10-16, 1986		
M2	14	M4	19
M3	4.0	M5	24

Table 11.--*Nitrate concentrations--Continued*

Site number (fig. 1)	Nitrate, dissolved as N, mg/L	Site number (fig. 1)	Nitrate, disolved as N, mg/L
	Middle River aquifer--Continued October 6-22, 1986		
M1	22	M4	24
M2	5.1	M5	31
	June 22-July 1, 1987		
M1	17	M5	25
M4	30		
	September 28-October 7, 1987		
M1	13	M5	23
M4	26		
	North Raccoon River aquifer June 10-16, 1986		
NR1	2.1	NR3	15
NR2	<.10		
	October 6-22, 1986		
NR1	19	NR3	31
NR2	.13		
	June 22-July 1, 1987		
NR1	0.90	NR3	19
NR2	18		
	September 28-October 7, 1987		
NR1	3.0	NR3	26
NR2	<.10		
	South Raccoon River aquifer June 10-16, 1986		
SR1	19	SR6	<0.10
SR2	13	SR7	1.5
SR3	1.9	SR8	2.4
SR5	3.8		

Table 11.--*Nitrate concentrations--Continued*

Site number (fig. 1)	Nitrate, dissolved as N, mg/L	Site number (fig. 1)	Nitrate, disolved as N, mg/L
	South Raccoon River aquifer--Continued October 6-22, 1986		
SR1	9.8	SR6	<0.10
SR2	11	SR7	1.1
SR3	13	SR8	1.5
SR4	13		
	June 22-July 1, 1987		
SR1	9.5	SR6	<0.10
SR2	8.1	SR7	1.3
SR3	3.0	SR8	1.5
SR4	12		
	September 28-October 7, 1987		
SR1	19	SR6	<0.10
SR2	7.2	SR7	.18
SR3	3.0	SR8	.32
SR4	11		
	West Nishnabotna River June 10-16, 1986		
WN1	8.9	WN3	<0.10
WN2	16	WN4	9.3
	October 6-22, 1986		
WN1	2.9	WN3	<0.10
WN2	8.9	WN4	13
	June 22-July 1, 1987		
WN1	16	WN3	<0.10
WN2	9.9	WN4	9.9
	September 28-October 7, 1987		
WN1	15	WN3	<0.10
WN2	13	WN4	11

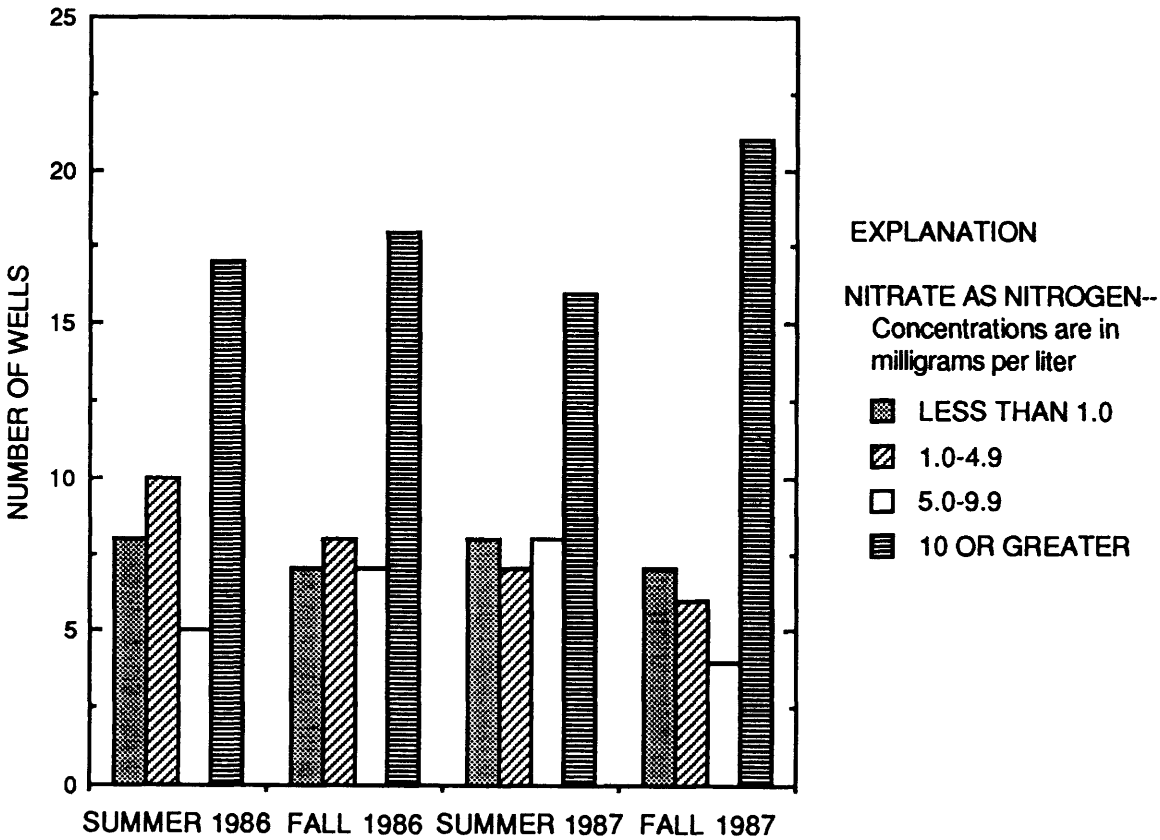

Figure 4.--Nitrate concentrations detected in each sampling period.

Table 12.--*Relation of nitrate concentrations to period of sampling*

Sampling period	Number of samples	Nitrate as nitrogen, milligrams per liter: Median	Nitrate as nitrogen, milligrams per liter: Mean
June 1986	40	8.4	9.4
October 1986	40	9.5	12
June 1987	39	9.5	10
October 1987	38	11	11
All periods	157	9.5	11

Table 13.--*Relation of increase or decrease in nitrate concentration to period of sampling*

[Nitrate concentration as nitrogen; mg/L, milligrams per liter]

Sampling period	Number of samples: Increased	Number of samples: Increased more than 1 mg/L	Number of samples: Decreased	Number of samples: Decreased more than 1 mg/L
June to October 1986	27	18	10	6
June to October 1987	24	17	13	9

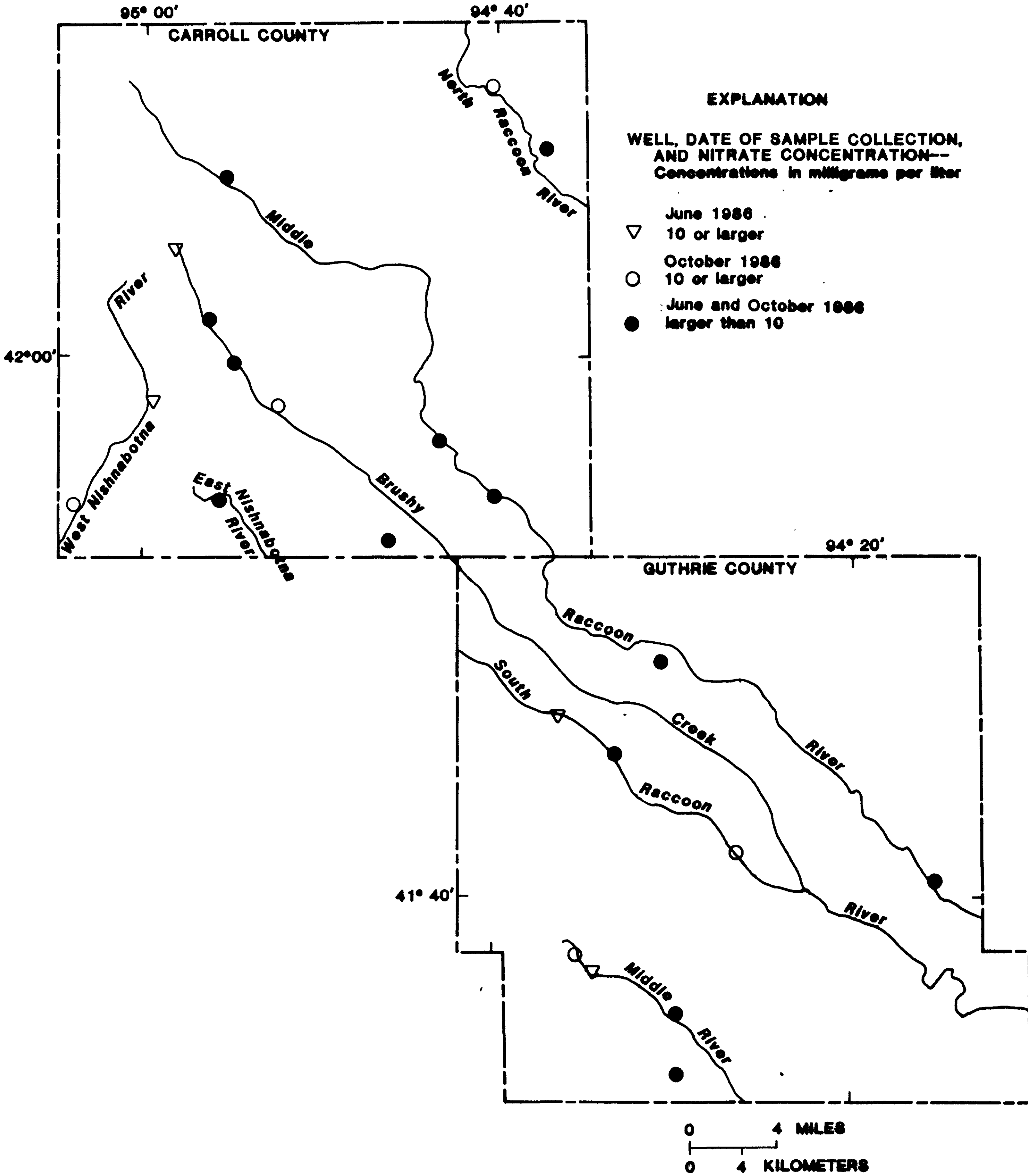

Figure 5.--Areal distribution of nitrate concentrations, 10 milligrams per liter or larger, 1986.

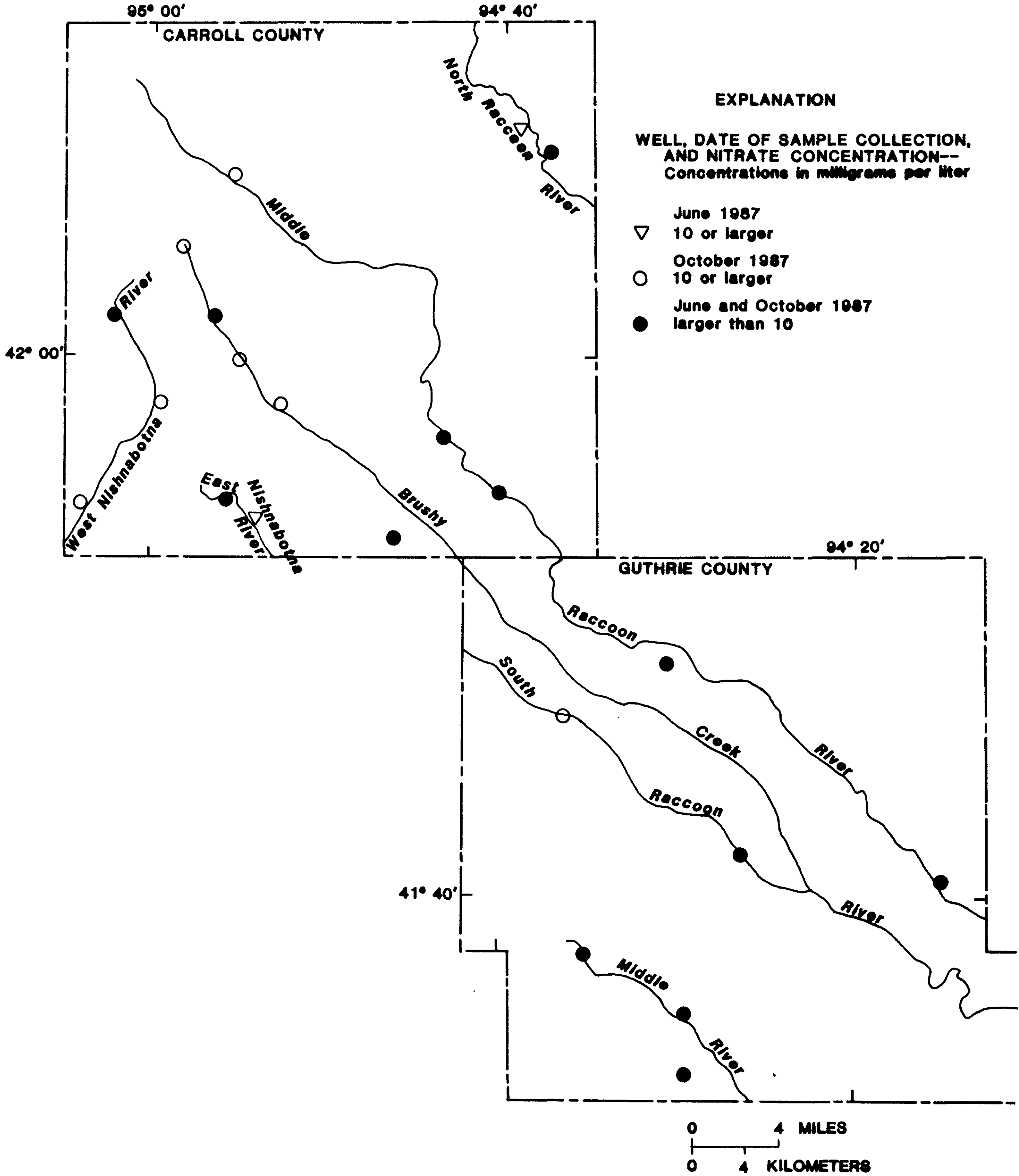

Figure 6.--Areal distribution of nitrate concentrations, 10 milligrams per liter or larger, 1987.

However, wells sampled along Brushy Creek in Guthrie County generally are deeper than the wells in the other alluvial systems. Nitrate concentrations for the alluvial aquifers are summarized in table 14. Except for the South Raccoon River samples that have a median nitrate concentration of 2.8 mg/L, all median concentrations are near or larger than 10 mg/L. The median nitrate concentration for the Middle River samples is 23 mg/L. East Nishnabotna, Middle Raccoon, Middle River, and the North Raccoon alluvial settings had at least 50 percent of their samples with nitrate concentrations greater than 10 mg/L.

Variation with Depth

The distribution of nitrate concentrations compared with well depth are shown in table 15. During 1986 and 1987, samples from a substantial number of wells had nitrate concentrations larger than 10 mg/L at all depths. Over 50 percent of the samples collected from wells less than 40 feet deep had nitrate concentrations larger than 10 mg/L. Samples from wells 21 to 29 feet deep had the largest median and mean nitrate concentrations of 16 mg/L. Samples from wells at least 40 feet deep had smaller nitrate concentrations, and the median concentration for the deeper than 50-foot wells was only 3.0 mg/L. These values are consistent with data from municipal wells less than 200 feet deep in that there is a trend of increasing concentration with decreasing well depth (Detroy and Holub, 1988). However, the mean is near 10 mg/L for samples from wells less than 50 feet, which is larger than the mean of 1.8 mg/L reported for municipal wells for that same depth range.

PESTICIDES

Analytical results for common herbicides are listed in table 16 and for acid herbicides in table 17. Herbicides were the only pesticides detected. Their frequency of occurrence is shown in figure 7. A detectable concentration of one or more herbicides was measured in 27 percent of the 157 samples collected. Atrazine, the most prevalent herbicide, was detected in 25 percent of the samples, alachlor was detected in 6 percent and cyanazine was detected in 5 percent. Dicamba, metolachlor, trifluralin, and 2,4-D were detected in 2 percent or less of the samples. The largest detectable concentrations of herbicides in μg/L were atrazine, 12; cyanazine, 12; trifluralin, 0.95; alachlor, 0.72; metolachlor, 0.40; 2,4-D, 0.23; and dicamba, 0.19. A total of 64 detections of herbicides was measured in the samples. Of the 42 samples with detectable concentrations, 17 had more than one detectable herbicide, 12 samples had two detections, and 5 samples had three detections.

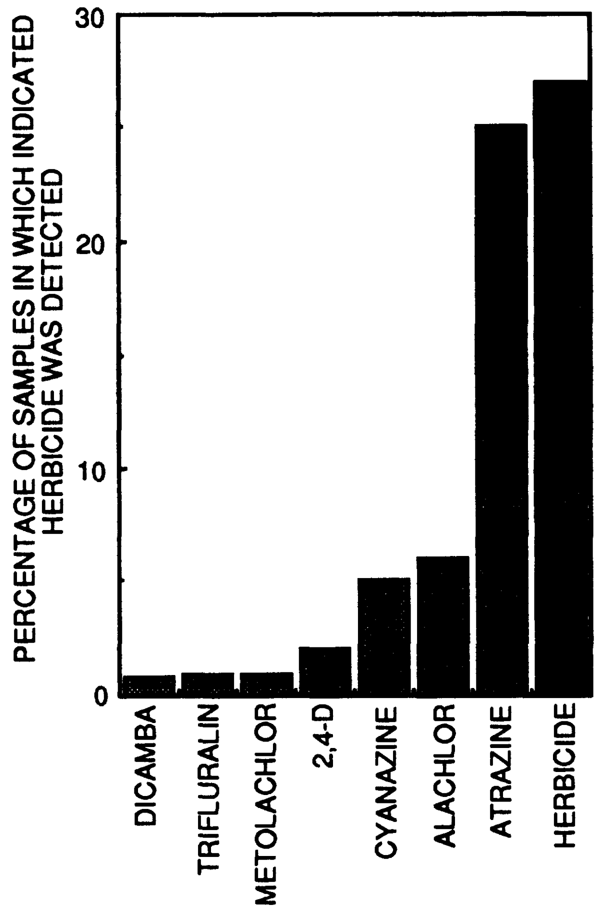

Figure 7.--Percentage of herbicide detections in all samples.

The samples also were analyzed for the common insecticides and chlorinated hydrocarbon insecticides listed in table 4. Concentration of common insecticides were all smaller than the laboratory detection limit of 0.10 μg/L. The concentrations of chlorinated hydrocarbon insecticides, except chlordane, were all smaller than the laboratory detection limit of 0.2 μg/L. As a result of only herbicides being detected in the samples, only common herbicides and acid herbicides will be discussed further.

Temporal Variation

A summary of the three most frequently detected herbicides (atrazine, cyanazine, and alachlor) in the four sampling periods is presented in table 18. In summer 1986, 23 percent of the samples contained detectable concentrations of herbicides, and in fall 1986, 18 percent of the samples contained detectable concentrations of herbicides. In summer 1987, 21 percent of the samples contained detectable herbicide concentrations, and in fall 1987, 47 percent of the samples contained detectable herbicide concentrations. The first three sampling periods

Table 14.--*Relation of nitrate concentrations to alluvial aquifer setting*

[mg/L, milligrams per liter; <, less than; ≥, greater than or equal to]

Aquifer	Number of samples	Nitrate as nitrogen, mg/L		Percentage of samples with nitrate concentrations			
		Median	Mean	<1.0 mg/L	1.0 to 4.9 mg/L	5.0 to 9.9 mg/L	≥10 mg/L
Brushy Creek	43	8.8		16	30	14	40
East Nishnabotna	8	13	12	0	0	38	62
Middle Raccoon	36	14	11	28	5	14	53
Middle River	14	23	20	0	7	7	86
North Raccoon	12	9.0	11	33	17	0	50
South Raccoon	28	2.8	5.6	18	43	14	25
West Nishnabotna	16	9.6	8.4	25	6	31	38
All aquifers	157	9.5	11	19	20	15	46

Table 15.--*Relation of nitrate concentrations to well depth*

[mg/L, milligrams per liter; <, less than; ≥, greater than or equal to; ≤, less than or equal to; >, greater than]

Depth, feet	Number of samples	Nitrate as nitrogen, mg/L		Percentage of samples with nitrate concentrations			
		Median	Mean	<1.0 mg/L	1.0 to 4.9 mg/L	5.0 to 9.9 mg/L	≥10 mg/L
≤20	29	10	11	21	10	17	52
21 - 29	34	16	16	12	12	20	56
30 - 39	35	8.9	9.6	8	26	20	46
40 - 50	27	9.8	10	19	26	7	48
>50	32	3.0	7.0	38	25	9	28
All depths	157	9.5	11	19	20	15	46

Table 16.--*Chemical analyses of common herbicides*

[µg/L, micrograms per liter; <, less than]

Site number (fig. 1)	Alachlor, µg/L	Atrazine, µg/L	Butylate, µg/L	Cyanazine, µg/L	Metolachlor, µg/L	Metribuzin, µg/L	Trifluralin, µg/L
			Brushy Creek aquifer June 6-16, 1986				
BC1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
BC2	<.10	.13	<.10	<.10	<.10	<.10	<.10
BC3	<.10	1.4	<.10	<.10	<.10	<.10	<.10
BC4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC7	<.10	1.7	<.10	<.10	<.10	<.10	<.10
BC8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC9	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC10	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC11	<.10	<.10	<.10	<.10	<.10	<.40	<.10
			October 6-22, 1986				
BC1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
BC2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC3	.66	3.0	<.10	<.10	<.10	<.10	<.10
BC4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC7	<.10	1.4	<.10	<.10	<.10	<.10	<.10
BC8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC9	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC10	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC11	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			June 22-July 1, 1987				
BC1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
BC2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC3	<.10	.18	<.10	<.10	<.10	<.10	<.10
BC4	<.10	.12	<.10	<.10	<.10	<.10	<.10
BC5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC7	<.10	1.1	<.10	<.10	<.10	<.10	<.10
BC8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC9	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC10	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC11	<.10	<.10	<.10	<.10	<.10	<.10	<.10

Table 16.--*Chemical analyses of common herbicides--Continued*

Site number (fig. 1)	Alachlor, µg/L	Atrazine, µg/L	Butylate, µg/L	Cyanazine, µg/L	Metolachlor, µg/L	Metribuzin, µg/L	Trifluralin, µg/L
			Brushy Creek aquifer--Continued September 28-October 7, 1987				
BC1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
BC2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC3	<.10	.25	<.10	<.10	<.10	<.10	<.10
BC4	<.10	.79	<.10	.25	<.10	<.10	<.10
BC5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC6	.23	.23	<.10	<.10	<.10	<.10	<.10
BC7	.14	1.0	<.10	<.10	<.10	<.10	<.10
BC9	.24	.18	<.10	<.10	<.10	<.10	<.10
BC10	<.10	<.10	<.10	<.10	<.10	<.10	<.10
BC11	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			East Nishnabotna River aquifer June 10-16, 1986				
EN1	<0.10	5.4	<0.10	<0.10	<0.10	<0.10	<0.10
EN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			October 6-22, 1986				
EN1	<0.10	1.6	<0.10	<0.10	<0.10	<0.10	<0.10
EN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			June 22-July 1, 1986				
EN1	<0.10	1.2	<0.10	<0.10	<0.10	<0.10	<0.10
EN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			September 28-October 7, 1987				
EN1	<0.10	1.2	<0.10	<0.10	<0.10	<0.10	<0.10
EN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			Middle Raccoon River aquifer June 10-16, 1986				
MR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
MR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR4	<.10	.57	<.10	<.10	<.10	<.10	<.10
MR5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR9	<.10	<.10	<.10	<.10	<.10	<.10	<.10

Table 16.--*Chemical analyses of common herbicides--Continued*

Site number (fig. 1)	Alachlor, µg/L	Atrazine, µg/L	Butylate, µg/L	Cyanazine, µg/L	Metolachlor, µg/L	Metribuzin, µg/L	Trifluralin, µg/L
			Middle Raccoon River aquifer--Continued October 6-22, 1986				
MR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
MR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR4	<.10	.28	<.10	<.10	<.10	<.10	<.10
MR5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR9	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			June 22-July 1, 1987				
MR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
MR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR9	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			September 28-October 7, 1987				
MR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
MR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR4	<.10	.20	<.10	<.10	<.10	<.10	<.10
MR5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR7	.26	.38	<.10	.26	<.10	<.10	<.10
MR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
MR9	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			Middle River aquifer June 10-16, 1986				
M2	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
M3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
M4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
M5	<.10	12	<.10	12	<.10	<.10	.95

Table 16.--*Chemical analyses of common herbicides--Continued*

Site number (fig. 1)	Alachlor, µg/L	Atrazine, µg/L	Butylate, µg/L	Cyanazine, µg/L	Metolachlor, µg/L	Metribuzin, µg/L	Trifluralin, µg/L
			Middle River aquifer--Continued October 6-22, 1986				
M1	<0.10	0.75	<0.10	<0.10	<0.10	<0.10	<0.10
M3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
M4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
M5	<.10	2.1	<.10	3.2	<.10	<.10	.12
			June 22-July 1, 1987				
M1	<0.10	0.59	<0.10	<0.10	<0.10	<0.10	<0.10
M4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
M5	<.10	.88	<.10	.50	<.10	<.10	<.10
			September 28-October 7, 1987				
M1	<0.10	0.44	<0.10	<0.10	<0.10	<0.10	<0.10
M4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
M5	<.10	.41	<.10	.34	<.10	<.10	<.10
			North Raccoon aquifer June 10-16, 1986				
NR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
NR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			October 6-22, 1986				
NR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
NR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			June 22-July 1, 1987				
NR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
NR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			September 28-October 7, 1987				
NR1	0.66	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NR2	.72	.25	<.10	<.10	<.10	<.10	<.10
NR3	<.10	.15	<.10	<.10	<.10	<.10	<.10

Table 16.--*Chemical analyses of common herbicides--Continued*

Site number (fig. 1)	Alachlor, µg/L	Atrazine, µg/L	Butylate, µg/L	Cyanazine, µg/L	Metolachlor, µg/L	Metribuzin, µg/L	Trifluralin, µg/L
South Raccoon River aquifer June 10-16, 1986							
SR1	<0.10	0.35	<0.10	<0.10	0.10	<0.10	<0.10
SR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR5	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
October 6-22, 1986							
SR1	<0.10	0.21	<0.10	<0.10	<0.10	<0.10	<0.10
SR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR4	<.10	.27	<.10	<.10	<.10	<.10	<.10
SR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
June 22-July 1, 1987							
SR1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
SR2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR4	<.10	.30	<.10	<.10	<.10	<.10	<.10
SR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
September 28-October 7, 1987							
SR1	0.14	0.43	<0.10	0.17	<0.10	<0.10	<0.10
SR2	<.10	.21	<.10	<.10	<.10	<.10	<.10
SR3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR4	<.10	.19	<.10	<.10	<.10	<.10	<.10
SR6	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR7	<.10	<.10	<.10	<.10	<.10	<.10	<.10
SR8	<.10	<.10	<.10	<.10	<.10	<.10	<.10
West Nishnabotna River aquifer June 10-16, 1986							
WN1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
WN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN4	<.10	<.10	<.10	<.10	<.10	<.10	<.10

Table 16.--*Chemical analyses of common herbicides--Continued*

Site number (fig. 1)	Alachlor, µg/L	Atrazine, µg/L	Butylate, µg/L	Cyanazine, µg/L	Metolachlor, µg/L	Metribuzin, µg/L	Trifluralin, µg/L
			West Nishnabotna River aquifer--Continued October 6-22, 1986				
WN1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
WN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			June 22-July 1, 1987				
WN1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
WN2	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN4	<.10	<.10	<.10	<.10	<.10	<.10	<.10
			September 28-October 7, 1987				
WN1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
WN2	.17	.38	<.10	.37	<.10	<.10	<.10
WN3	<.10	<.10	<.10	<.10	<.10	<.10	<.10
WN4	<.10	.17	<.10	<.10	<.10	<.10	<.10

Table 17.--*Chemical analyses of acid herbicides*

[µg/L, micrograms per liter; --, no data available; <, less than]

Site number (fig. 1)	Date	Chloramben, µg/L	Dicamba, total, µg/L	2,4-D, total, µg/L	Silvex, total, µg/L
		Brushy Creek aquifer			
BC1	6-11-86	--	<0.10	<0.10	<0.10
BC1	10-15-86	<0.10	<.10	<.10	<.10
BC1	7-1-87	<.10	<.10	<.10	<.10
BC2	6-11-86	--	<.10	<.10	<.10
BC2	10-22-86	<.10	<.10	<.10	<.10
BC2	7-1-87	<.10	<.10	<.10	<.10
BC3	6-11-86	--	<.10	<.10	<.10
BC3	10-21-86	<.10	<.10	<.10	<.10
BC3	7-1-87	<.10	<.10	<.10	<.10
BC4	6-10-86	--	<.10	<.10	<.10
BC4	10-16-86	<.10	<.10	<.10	<.10
BC4	7-1-87	<.10	<.10	<.10	<.10
BC5	6-10-86	--	<.10	<.10	<.10
BC5	10-17-86	<.10	<.10	<.10	<.10
BC5	6-25-87	<.10	<.10	<.10	<.10
BC6	6-10-86	--	<.10	<.10	<.10
BC6	10-10-86	<.10	<.10	<.10	<.10
BC6	6-24-87	<.10	<.10	<.10	<.10
BC7	6-10-86	--	<.10	.23	<.10
BC7	10-10-86	<.10	<.10	<.10	<.10
BC7	6-24-87	<.10	<.10	<.10	<.10
BC8	6-12-86	--	<.10	<.10	<.10
BC8	10-20-86	<.10	<.10	<.10	<.10
BC8	6-25-87	<.10	<.10	<.10	<.10
BC9	6-10-86	--	<.10	<.10	<.10
BC9	10-8-86	<.10	<.10	<.10	<.10
BC9	6-23-87	<.10	<.10	<.10	<.10
BC10	10-11-86	--	<.10	<.10	<.10
BC10	10-9-86	<.10	<.10	<.10	<.10
BC10	6-24-87	<.10	<.10	<.10	<.10
BC11	6-16-86	--	.19	<.10	<.10
BC11	10-8-86	<.10	<.10	<.10	<.10
BC11	6-23-87	<.10	<.10	<.10	<.10

Table 17.--*Chemical analyses of acid herbicides--Continued*

Site number (fig. 1)	Date	Chloramben, µg/L	Dicamba, total, µg/L	2,4-D, total, µg/L	Silvex, total, µg/L
		East Nishnabotna River aquifer			
EN1	6-10-86	--	<0.10	<0.10	<0.10
EN1	10-16-86	<0.10	<.10	<.10	<.10
EN1	6-25-87	<.10	<.10	<.10	<.10
EN2	6-13-86	--	<.10	<.10	<.10
EN2	10-17-86	<.10	<.10	<.10	<.10
EN2	6-25-87	<.10	<.10	<.10	<.10
		Middle Raccoon River aquifer			
MR1	6-12-86	--	<0.10	<0.10	<0.10
MR1	10-15-86	<0.10	<.10	<.10	<.10
MR1	6-30-87	<.10	<.10	<.10	<.10
MR2	6-13-86	--	<.10	<.10	<.10
MR2	10-16-86	<.10	<.10	<.10	<.10
MR2	6-30-87	<.10	<.10	<.10	<.10
MR3	6-13-86	--	<.10	<.10	<.10
MR3	10-15-86	<.10	<.10	<.10	<.10
MR3	6-30-87	<.10	<.10	<.10	<.10
MR4	6-11-86	--	<.10	<.10	<.10
MR4	10-14-86	<.10	<.10	<.10	<.10
MR4	6-25-87	<.10	<.10	<.10	<.10
MR5	6-11-86	--	<.10	<.10	<.10
MR5	10-14-86	<.10	<.10	<.10	<.10
MR5	6-25-87	<.10	<.10	<.10	<.10
MR6	6-13-86	--	<.10	<.10	<.10
MR6	10-14-86	<.10	<.10	<.10	<.10
MR6	6-25-87	<.10	<.10	<.10	<.10
MR7	6-10-86	--	<.10	<.10	<.10
MR7	10-8-86	<.10	<.10	<.10	<.10
MR7	6-23-87	<.10	<.10	<.10	<.10
MR8	6-11-86	--	<.10	<.10	<.10
MR8	10-8-86	<.10	<.10	<.10	<.10
MR8	6-23-87	<.10	<.10	<.10	<.10
MR9	6-9-86	--	<.10	<.10	<.10
MR9	10-7-86	<.10	<.10	<.10	<.10
MR9	6-23-87	<.10	<.10	<.10	<.10

Table 17.--*Chemical analyses of acid herbicides--Continued*

Site number (fig. 1)	Date	Chloramben, µg/L	Dicamba, total, µg/L	2,4-D, total, µg/L	Silvex, total, µg/L
		Middle River aquifer			
M1	10-21-86	<0.10	<0.10	0.20	<0.10
M1	6-24-87	<.10	<.10	<.10	<.10
M2	6-9-86	--	<.10	<.10	<.10
M3	6-6-86	<.10	<.10	<.10	<.10
M3	6-9-87	--	<.10	<.10	<.10
M4	6-10-86	--	<.10	<.10	<.10
M4	10-6-86	<.10	<.10	<.10	<.10
M4	6-24-87	<.10	<.10	<.10	<.10
M5	6-24-86	<.10	<.10	<.10	<.10
M5	6-10-86	--	<.10	<.10	<.10
M5	10-6-87	<.10	<.10	<.10	<.10
		North Raccoon River aquifer			
NR1	6-11-86	--	<0.10	<0.10	<0.10
NR1	10-15-86	<0.10	<.10	<.10	<.10
NR1	6-30-87	<.10	<.10	<.10	<.10
NR2	6-12-86	--	<.10	<.10	<.10
NR2	10-15-86	<.10	<.10	<.10	<.10
NR2	7-1-87	<.10	<.10	<.10	<.10
NR3	6-12-86	--	<.10	<.10	<.10
NR3	10-15-86	<.10	<.10	<.10	<.10
NR3	6-30-87	<.10	<.10	<.10	<.10
		South Raccoon River aquifer			
SR1	6-10-86	--	<0.10	<0.10	<0.10
SR1	10-9-86	<0.10	<.10	<.10	<.10
SR1	6-25-87	<.10	<.10	<.10	<.10
SR2	6-10-86	--	<.10	<.10	<.10
SR2	10-9-86	<.10	<.10	<.10	<.10
SR2	6-24-87	<.10	<.10	<.10	<.10
SR3	6-9-86	--	<.10	.20	<.10
SR3	10-9-86	<.10	<.10	<.10	<.10
SR3	6-24-87	<.10	<.10	<.10	<.10
SR4	10-22-86	<.10	<.10	<.10	<.10
SR4	6-23-87	<.10	<.10	<.10	<.10
SR5	6-9-86	--	<.10	<.10	<.10

Table 17.--*Chemical analyses of acid herbicides--Continued*

Site number (fig. 1)	Date	Chloramben, µg/L	Dicamba, total, µg/L	2,4-D, total, µg/L	Silvex, total, µg/L
		South Raccoon River aquifer--Continued			
SR6	6-12-86	--	<0.10	<0.10	<0.10
SR6	10-20-86	<0.10	<.10	<.10	<.10
SR6	6-23-87	<.10	<.10	<.10	<.10
SR7	6-9-86	--.	<.10	<.10	<.10
SR7	10-7-86	<.10	<.10	<.10	<.10
SR7	6-22-87	<.10	<.10	<.10	<.10
SR8	6-9-86	--	<.10	<.10	<.10
SR8	10-7-86	<.10	<.10	<.10	<.10
SR8	6-23-87	<.10	<.10	<.10	<.10
		West Nishnabotna River aquifer			
WN1	6-10-86	--	<0.10	<0.10	<0.10
WN1	10-21-86	<0.10	<.10	<.10	<.10
WN1	7-1-87	<.10	<.10	<.10	<.10
WN2	6-10-86	--	<.10	<.10	<.10
WN2	10-16-86	<.10	<.10	<.10	<.10
WN2	6-30-87	<.10	<.10	<.10	<.10
WN3	6-10-86	--	<.10	<.10	<.10
WN3	10-16-86	<.10	<.10	<.10	<.10
WN3	6-26-87	<.10	<.10	<.10	<.10
WN4	6-11-86	--	<.10	<.10	<.10
WN4	10-22-86	<.10	<.10	<.10	<.10
WN4	6-26-87	<.10	<.10	<.10	<.10

Table 18.--*Relation of detectable herbicide concentrations to sampling period*

Sampling period	Number of samples	Percentage of samples containing detectable concentrations			
		Herbicide	Atrazine	Cyanazine	Alachlor
Summer 1986	40	23	18	2	0
Fall 1986	40	18	18	2	0
Summer 1987	39	21	21	2	2
Fall 1987	38	47	45	13	21
All sampling	157	27	25	5	6

are similar in overall detection frequency and specific detection frequencies for atrazine, cyanazine, and alachlor. A substantial increase in overall detection frequency occurred in the fall 1987 samples--an increase of 27 percent over previous sampling periods. Atrazine detection more than doubled and cyanazine and alachlor substantially increased. Alachlor, which previously had been detected in 1 of 119 samples, was detected in 8 of 38 samples collected in October 1987. Late summer and early fall precipitation following a dry summer may be part of the reason the detection frequencies increased.

The distribution of herbicide concentrations detected during each sampling period is shown in figure 8. Herbicides were more frequently detected during the fall 1987 sampling period, but larger concentrations of herbicides were detected in summer and fall 1986. Of the samples that contained detectable herbicide concentrations during 1986, 50 percent contained more than one herbicide in the summer sampling and 33 percent contained more than one herbicide in the fall sampling. Of the samples that contained detectable herbicide concentrations during 1987, 14 percent contained more than one herbicide in the summer sampling and 39 percent contained more than one herbicide in the fall sampling.

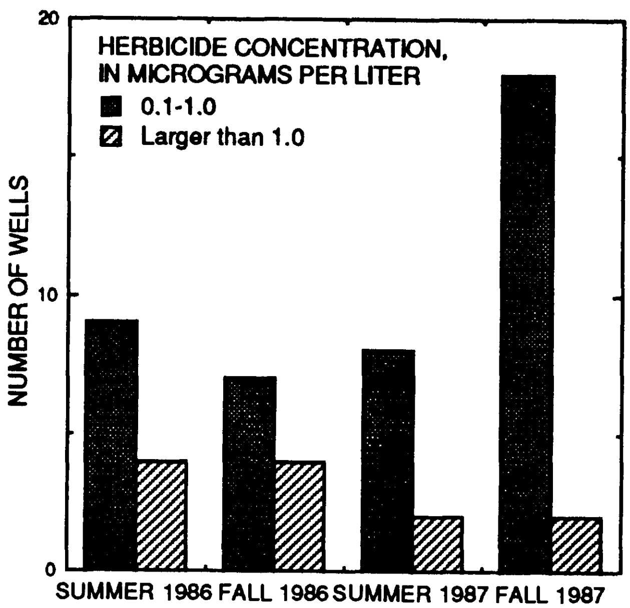

Figure 8.--Herbicide concentration detected for each sampling period.

Areal Distribution

The areal distribution of the detectable herbicide concentrations is shown in figures 9 and 10. Herbicides were more frequently detected along Brushy Creek, East Nishnabotna, Middle, North Raccoon, and South Raccoon Rivers. Brushy Creek and the South Raccoon River have similar soil types: both aquifers contain Colo soils that are poorly drained and silty on bottom lands. Detectable herbicide concentrations in relation to their alluvial aquifer setting are summarized in table 19. Detection frequencies were greatest (50 percent) for the East Nishnabotna River and Middle River, and if a herbicide was detected, it was atrazine alone or atrazine and another herbicide. Cyanazine detection was substantially greater in the Middle River setting compared to the other settings. Alachlor detection in the Brushy Creek and North Raccoon aquifers also was substantially greater than in other settings.

Variation with Depth

The relation of detectable herbicide concentrations to well depth is shown in table 20. Detection frequency is variable among the five depth ranges and no trend of increasing detection frequency with decreasing well depth is evident. Those samples collected from wells at least 40 feet deep had the greatest detection frequency, which was about 40 percent. The more shallow depths, less than or equal to 20 feet, 21 to 29 feet, and 30 to 39 feet had detection frequencies of 14, 20 and 26 percent. The deepest wells that were sampled in the deeper than 50-foot group are 70 and 80 feet in depth. During this study, there was no indication that herbicide concentrations were detected at certain depths, although it does seem that herbicide concentrations were

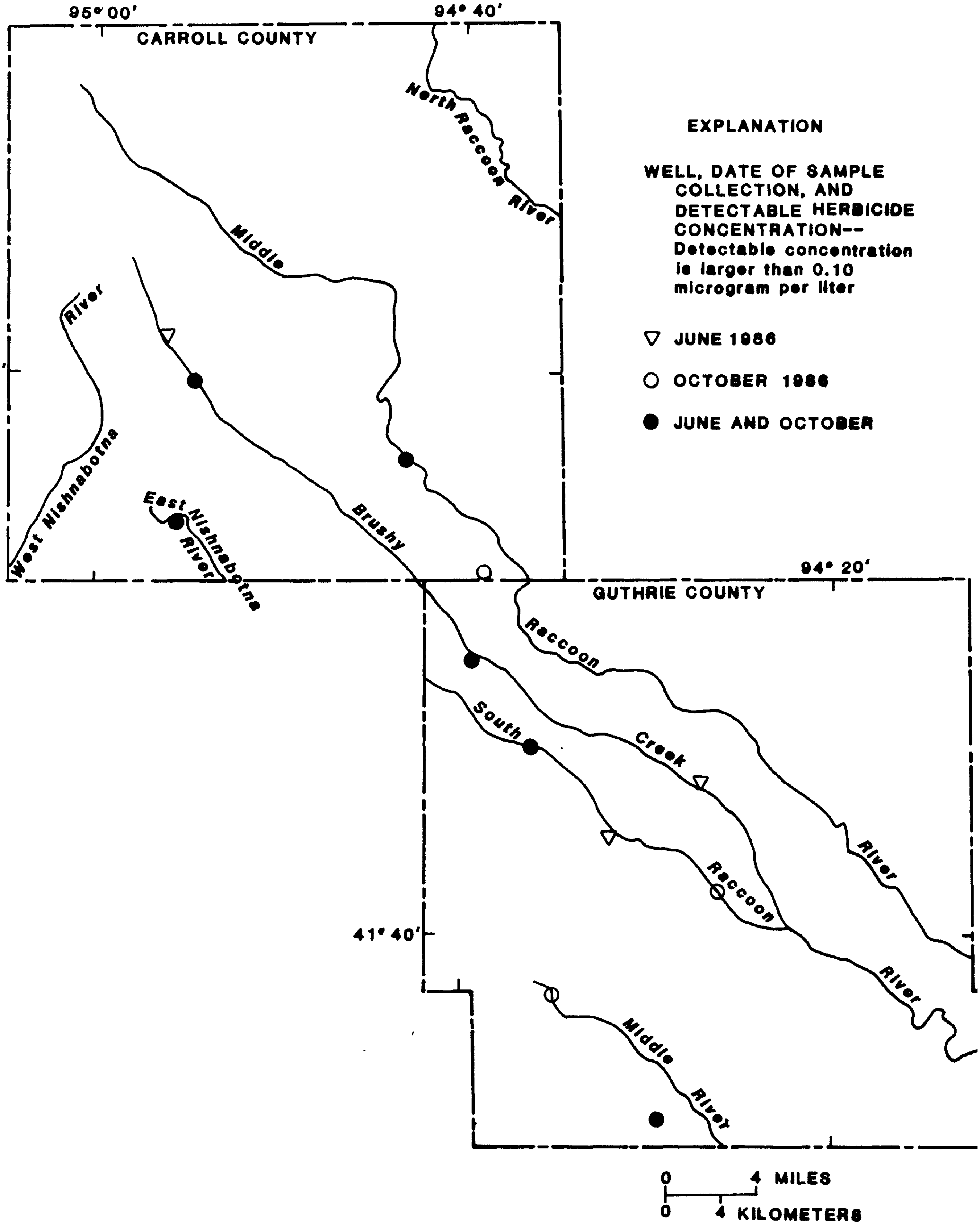

Figure 9.--Areal distribution of detectable herbicide concentrations, 1986.

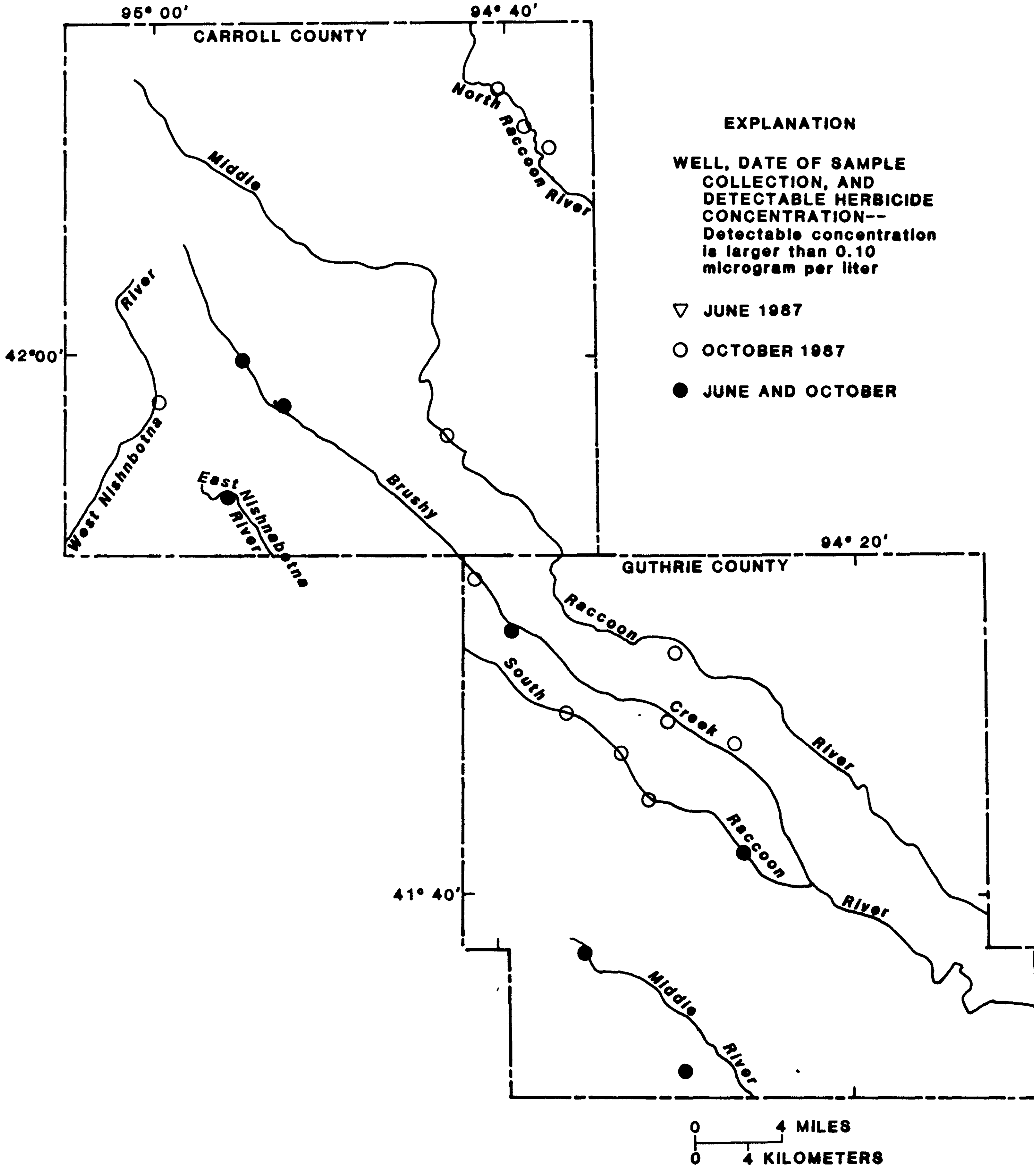

Figure 10.--Areal distribution of detectable herbicide concentrations, 1987.

Table 19.--*Relation of detectable herbicide concentrations to alluvial aquifer setting*

Aquifer	Percentage of samples containing detectable concentrations: Herbicide	Atrazine	Cyanazine	Alachlor
Brushy Creek	33	30	2	12
East Nishnabotna	50	50	0	0
Middle Raccoon	11	11	3	3
Middle River	50	50	29	0
North Raccoon	25	17	0	17
South Raccoon	29	25	4	4
West Nishnabotna	13	13	6	6
All aquifers	27	25	5	6

Table 20.--*Relation of detectable herbicide concentrations to well depth*

[>, greater than; µg/L, micrograms per liter; ≤, less than or equal to]

Depth, in feet	Number of samples	Percentage of samples containing detectable concentrations: >0.10 to 1.0 µg/L	>1.0 µg/L
≤20	29	14	0
21 - 29	34	14	6
30 - 39	35	26	0
40 - 50	27	33	7
>50	32	11	23
All depths	157	20	7

detected more frequently at 30 feet or deeper. All wells in alluvial aquifers are considered shallow because they have little protection from activities at the land surface and are hydraulically connected to nearby streams and ditches, which can be sources of agricultural chemicals during runoff and recharge.

COMPARISON OF NITRATE AND PESTICIDE DATA

Nitrate and herbicide concentrations generally were larger in the fall 1986 and fall 1987 sampling periods. The larger concentrations for these two sampling periods probably were a result of the above-normal precipitation during these periods. Most nitrate concentrations larger than 10 mg/L and detectable herbicide concentrations occurred along Brushy Creek in Carroll County, the Middle River, and the South Raccoon River. Soils along Brushy Creek and the South Raccoon River are similar because they are both near bottom land, silty and loamy, and moderately well drained. The geographic distribution of nitrate concentrations greater than 10 mg/L and the detected herbicides are similar.

Of the samples with nitrate concentrations 5 mg/L or greater, 33 percent had detectable herbicide concentrations. For the samples with detectable herbicides, 76 percent had a nitrate concentration larger than or equal to 5.0 mg/L and 67 percent had a nitrate concentration larger than or equal to 10 mg/L. The median concentration for nitrate for the samples containing at least one detectable herbicide was 15 mg/L, which is larger than the overall median nitrate concentration of 9.5 mg/L. The median for samples not containing a detectable herbicide was 7.3 mg/L (table 21).

Table 21.--*Relation of median and mean nitrate concentrations to herbicide detection*

Types of samples	Number of samples	Nitrate as nitrogen, in milligrams per liter	
		Median	Mean
Herbicide detected	42	15	15
Herbicide not detected	115	7.3	9.4
All samples	157	9.5	11

Table 22.--*Relation of nitrate concentration and detectable herbicide concentrations to well depth*

[mg/L, milligrams per liter; µg/L, micrograms per liter; ≤, less than or equal to; >, greater than]

Depth, feet	Percentage of nitrate concentrations larger than 5 mg/L	Percentage of herbicide concentrations larger than 0.10 µg/L
≤20	69	14
21 - 29	76	20
30 - 39	66	26
40 - 50	55	40
>50	37	34
All depths	61	27

No correlation is apparent between increased nitrate concentrations and detectable herbicide concentrations relative to well depth (table 22). However, there seems to be an inverse relation with nitrate occurring in larger concentrations at shallow depths and the detectable herbicide concentrations increasing with depth. The validity of this relation, however, may not be conclusive because 65 percent of the wells sampled are less than 35 feet deep, while only 35 percent of the wells are between 36 and 80 feet.

SUMMARY

Samples collected from wells in Carroll and Guthrie Counties, Iowa, were analyzed to describe the chemical quality of the ground water in shallow aquifers. The selected wells were completed in the alluvial aquifers of Brushy Creek, East Nishnabotna River, Middle River, Middle Raccoon River, North Raccoon River, South Raccoon River, and the West Nishnabotna River. Wells were sampled in summer and fall of 1986 and 1987. Samples from the wells were analyzed for major ions, nutrients, trace elements, radiochemicals, nitrate, and pesticides. The major ions, nutrients, trace elements, and radiochemicals were analyzed to document existing water-quality conditions. Nitrate and pesticides were the constituents of interest.

Median and mean nitrate concentrations were 9.5 and 11 mg/L, both near the drinking-water standard of 10 mg/L. The smallest concentration of nitrate detected was smaller than 0.10 mg/L, and the largest concentration was 45 mg/L. In summer and fall 1986, 43 and 45 percent of the samples had nitrate concentrations larger than 10 mg/L. In summer and fall 1987, 41 and 55 percent of the samples had nitrate concentrations larger than 10 mg/L.

During 1986, nitrate concentrations increased from the summer sampling to the fall sampling in 68 percent of the samples. Nitrate concentrations decreased from the summer sampling to the fall sampling in 25 percent of the samples. During 1987, nitrate concentrations increased from the summer sampling to the fall sampling in 63 percent of the samples. Nitrate concentrations decreased from the summer sampling to the fall sampling in 34 percent of the samples. More water samples had nitrate concentrations that increased from summer to fall than decreased. This indicates that, in this alluvial setting, larger nitrate concentrations can be detected a few months after the application period of most crop chemicals than can be detected in June, which is 4 to 6 weeks after application.

Nitrate concentrations greater than 10 mg/L were detected in all alluvial settings except Brushy Creek in Guthrie County. Wells sampled along Brushy Creek in Guthrie County generally are deeper than the wells in the other alluvial systems. Of the samples collected in the East Nishnabotna, Middle River, Middle Raccoon, and the North Raccoon alluvial aquifers at least 50 percent had nitrate concentrations greater than 10 mg/L.

More than 50 percent of the samples collected from wells less than 40 feet deep had nitrate concentrations larger than 10 mg/L. Samples from wells 21 to 29 feet deep had the largest median and mean nitrate concentrations of 16 mg/L. The median concentration for samples from wells deeper than 50-feet was 3.0 mg/L. This indicates there is a trend of increasing nitrate concentration with decreasing well depth.

Concentrations of at least one herbicide were detected in 27 percent of the samples. Atrazine, the most prevalent herbicide, was detected in 25 percent of the samples, alachlor was detected in 6 percent, and cyanazine was detected in 5 percent. Dicamba, metolachlor, trifluralin, and 2,4-D were detected in 2 percent or fewer of the samples.

In summer and fall 1986, 23 and 18 percent of the samples contained detectable concentrations of at least one herbicide, and in summer and fall 1987, 21 and 47 percent of the samples contained detectable concentrations of a least one herbicide. Detection frequencies for atrazine, alachlor, and cyanazine increased for samples collected in fall 1987.

Herbicides were detected in each alluvial setting. They were more frequently detected along Brushy Creek, the East Nishnabotna, Middle, North Raccoon, and the South Raccoon Rivers. Detection frequencies were greatest (50 percent) for the East Nishnabotna and Middle River alluvial aquifers.

Herbicide detection relative to well depth was inconsistent with the trend observed for nitrate. Herbicide detection frequencies were greater for wells that are 40 to 80 feet deep (about 40 percent) than for wells less than 40 feet deep (about 20 percent).

In water samples with nitrate concentrations larger than or equal to 5 mg/L, 33 percent had detectable herbicide concentrations. Conversely, for those samples with detectable herbicides, 76 percent had a nitrate concentration larger than or equal to 5.0 mg/L; and 67 percent larger than or equal to 10 mg/L. The median concentration for nitrate for the samples containing at least one detectable herbicide was 15 mg/L, which is larger than the overall median nitrate concentration of 9.5 mg/L. The median for samples not containing a detectable pesticide was 7.3 mg/L.

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SUPPLEMENTAL DATA

Table 8.--*Chemical analyses of common inorganics*

[µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; <, less than]

Site number (fig. 1)	Date	Specific con- ductance µS/cm	pH, standard units	Temper- ature, water, °C	Hardness, mg/L as $CaCO_3$	Calcium, dis- solved, mg/L as Ca	Mag- nesium dis- solved, mg/L as mg	Sodium dis- solved, mg/L as Na	Potas- sium dis- solved, mg/L as K	Alka linity, total as $CaCO_3$ mg/L
					Brushy Creek aquifer					
BC1	6-11-86	499	7.4	15.0	260	74	19	7.2	1.4	172
BC1	10-15-86	445	7.9	14.5	230	63	17	6.5	1.2	160
BC2	6-11-86	1,050	7.1	13.0	500	140	37	15	2.1	202
BC2	10-22-86	1,020	6.9	15.5	510	140	38	17	3.9	299
BC3	6-11-86	870	7.2	13.0	420	120	30	13	8.1	314
BC3	10-21-86	1,050	7.0	13.0	500	150	31	20	26	404
BC4	6-10-86	1,030	7.1	10.0	520	150	36	17	4 5	384
BC4	10-16-86	1,040	7.0	14.0	530	150	37	22	7.3	358
BC5	6-10-86	700	7.3	16.0	360	98	27	8.8	<.1	254
BC5	10-17-86	655	7.2	15.5	310	82	26	9.4	.1	248
BC6	6-10-86	770	7.1	15.0	420	120	30	8.7	2.7	340
BC6	10-10-86	750	7.1	17.0	390	110	29	8.0	2.7	322
BC7	6-10-86	320	--	13.0	130	34	11	7.5	<.1	120
BC7	10-10-86	340	6.9	12.0	170	48	13	5.7	.4	144
BC8	6-12-86	440	6.9	13.0	220	64	15	11	1.2	218
BC8	10-20-86	455	7.4	16.0	200	58	14	12	2.0	202
BC9	6-10-86	175	6.8	16.0	71	17	6.8	7.2	<.1	66
BC9	10-8-86	175	6.7	13.0	66	16	6.2	7.4	<.1	66
BC10	6-11-86	240	7.8	12.0	100	28	7.3	4.3	<.1	76
BC10	10-9-86	230	7.1	12.0	100	30	7.2	4.8	.1	82
BC11	6-16-86	485	7.1	13.0	250	66	20	9.1	<.1	174
BC11	10-8-86	480	6.9	14.5	230	61	20	10	<.1	176
					East Nishnabotna River aquifer					
EN1	6-10-86	540	7.2	12.0	260	66	22	8.6	<0.1	160
EN1	10-16-86	525	7.1	15.0	250	65	22	8.8	<.1	184
EN2	6-13-86	700	7.0	12.0	380	110	26	14	2.6	216
EN2	10-17-86	750	7.0	16.0	360	100	27	16	1.6	270

Table 8.--*Chemical analyses of common inorganics--Continued*

Site number (fig. 1)	Date	Sulfate, dissolved, mg/L as SO_4	Chloride, dissolved, mg/L as Cl	Flouride, dissolved, mg/L as F	Silica, dissolved, mg/L as SIO_2	Dissolved solids, residue at 105 °C mg/L	Nitrogen, ammonia, dissolved, as N, mg/L	Phosphorus, dissolved, ortho-phosphate as P, mg/L
				Brushy Creek aquifer				
BC1	6-11-86	36	8.5	0.35	18	240	<0.01	0.06
BC1	10-15-86	28	8.0	.35	17	246	.01	.10
BC2	6-11-86	68	36	.35	19	828	<.01	.14
BC2	10-22-86	52	28	.30	22	648	.03	.18
BC3	6-11-86	56	18	.20	19	524	--	--
BC3	10-21-86	46	34	.20	19	670	.48	.33
BC4	6-10-86	140	14	.30	22	672	<.01	.04
BC4	10-16-86	71	23	.25	22	690	.01	.07
BC5	6-10-86	38	14	.30	22	406	--	--
BC5	10-17-86	25	16	.35	22	378	<.01	.10
BC6	6-10-86	76	5.0	.30	22	496	--	--
BC6	10-10-86	60	4.5	.35	23	422	.06	.05
BC7	6-10-86	16	4.5	.20	34	190	--	--
BC7	10-10-86	14	3.0	.25	22	202	<.01	.12
BC8	6-12-86	30	6.0	.20	23	276	<.01	.10
BC8	10-20-86	23	7.0	.20	23	382	.06	.35
BC9	6-10-86	8.9	3.0	.20	25	96	--	--
BC9	10-8-86	5.7	1.5	.25	25	84	<.01	.11
BC10	6-11-86	9.9	5.5	.20	18	116	<.01	.05
BC10	10-9-86	9.6	4.0	.20	18	120	<.01	.19
BC11	6-16-86	31	12	.40	22	276	<.01	.07
BC11	10-8-86	30	8.0	.20	22	278	<.01	.12
				East Nishnabotna River aquifer				
EN1	6-10-86	25	9.0	0.40	21	318	--	--
EN1	10-16-86	16	8.0	.50	22	302	<0.01	0.07
EN2	6-13-86	86	42	.30	19	440	--	--
EN2	10-17-86	81	39	.35	23	474	<.01	.16
				Middle Raccoon River aquifer				
MR1	6-12-86	240	50	0.15	18	724	<0.01	0.05
MR1	10-15-86	170	40	.40	19	690	.11	.21
MR2	6-13-86	160	59	.25	21	775	--	--
MR2	10-16-86	74	34	.31	23	738	.04	.10
MR3	6-13-86	24	<.05	.35	29	404	--	--
MR3	10-15-86	18	1.0	.35	27	376	1.21	.28

Table 8.--*Chemical analyses of common inorganics--Continued*

Site number (fig. 1)	Date	Specific con-ductance µS/cm	pH, standard units	Temper-ature, water, °C	Hardness, mg/L as $CaCO_3$	Calcium, dis-solved, mg/L as Ca	Mag-nesium dis-solved, mg/L as mg	Sodium dis-solved, mg/L as Na	Potas-sium dis-solved, mg/L as K	Alka linity, total as $CaCO_3$ mg/L
					Middle Raccoon River aquifer					
MR1	6-12-86	1,030	--	13.0	510	130	45	32	5.2	278
MR1	10-15-86	980	7.1	15.0	470	120	41	31	8.8	298
MR2	6-13-86	1,040	6.8	14.0	490	130	39	28	40	284
MR2	10-16-86	1,020	7.0	15.5	420	110	36	26	51	268
MR3	6-13-86	640	7.3	11.0	370	100	28	12	4.3	375
MR3	10-15-86	670	7.5	11.5	340	91	28	13	4.0	374
MR4	6-11-86	1,340	6.9	12.0	660	180	52	23	.1	438
MR4	10-14-86	1,070	7.	13.0	530	140	43	24	.2	338
MR5	6-11-86	950	6.8	11.0	440	110	41	9.5	.6	246
MR5	10-14-86	985	7.0	13.0	510	130	46	11	.8	294
MR6	6-13-86	438	7.0	12.0	220	63	16	5.5	.6	176
MR6	10-14-86	425	7.0	13.0	220	60	16	5.6	.5	164
MR7	6-10-86	815	6.8	13.0	340	92	26	17	14	166
MR7	10-8-86	820	7.0	12.0	320	85	26	17	18	170
MR8	6-11-86	620	7.2	13.0	320	86	26	6.1	1.9	302
MR8	10-8-86	610	7.1	16.0	300	75	27	7.7	2.0	298
MR9	6-9-86	585	7.5	13.0	270	80	16	7.5	1.5	170
MR9	10-7-86	555	6.9	16.0	260	79	16	7.5	1.4	166
					Middle River aquifer					
M1	10-21-86	905	6.6	17.0	180	20	31	21	4.6	246
M2	6-9-86	635	7.1	13.0	310	91	20	8.0	1.0	174
M3	6-9-86	290	6.5	10.0	130	33	11	7.6	<.1	104
M3	10-6-86	275	6.5	13.0	110	28	10	8.6	<.1	98
M4	6-10-86	645	7.1	16.0	290	83	21	14	.4	126
M4	10-6-86	695	6.5	16.0	290	81	22	15	.7	144
M5	6-10-86	635	6.8	12.0	280	75	22	9.9	<.1	127
M5	10-6-86	590	6.7	16.0	250	67	20	10	<.1	100
					North Raccoon River aquifer					
NR1	6-11-86	690	7.2	10.0	350	94	29	4.7	2.5	270
NR1	10-15-86	845	7.3	13.0	450	120	37	6.8	2.7	296
NR2	6-12-86	560	7.3	12.0	310	84	25	3.5	3.5	250
NR2	10-15-86	540	7.3	17.0	300	79	24	4.3	3.5	248
NR3	6-12-86	760	7.2	11.0	450	120	36	7.6	1.6	362
NR3	10-15-86	895	7.1	13.0	450	120	37	8.5	1.8	310

Table 8.--*Chemical analyses of common inorganics--Continued*

Site number (fig. 1)	Date	Sulfate, dissolved, mg/L as SO_4	Chloride, dissolved, mg/L as Cl	Flouride, dissolved, mg/L as F	Silica, dissolved, mg/L as SIO_2	Dissolved solids, residue at 105 °C mg/L	Nitrogen, ammonia, dissolved, as N, mg/L	Phosphorus, dissolved, ortho-phosphate as P, mg/L
				Middle Raccoon River aquifer--Continued				
MR4	6-11-86	90	80	0.20	27	838	--	--
MR4	10-14-86	57	49	.25	25	668	<0.01	0.11
MR5	6-11-86	37	54	.15	24	560	<.01	.03
MR5	10-14-86	30	65	.25	23	618	.01	.05
MR6	6-13-86	28	1.0	.25	22	242	<.01	.05
MR6	10-14-86	24	3.0	.30	21	252	<.01	.09
MR7	6-10-86	92	35	<.10	28	524	--	--
MR7	10-8-86	77	55.	<.10	25	462	<.01	.07
MR8	6-11-86	6.6	7.0	.20	21	290	<.01	.04
MR8	10-8-86	7.8	14	.35	20	324	<.01	.07
MR9	6-9-86	39	16	.15	18	352	<.01	.08
MR9	10-7-86	34	14	.15	25	360	<.01	.17
				Middle River aquifer				
M1	10-21-86	58	51	0.25	19	578	0.01	0.13
M2	6-9-86	46	20	.30	18	396	<.01	.08
M3	6-9-86	21	4.0	.30	25	132	<.01	.06
M3	10-6-86	20	4.0	.25	24	154	<.01	.10
M4	6-10-86	50	38	.15	23	482	<.01	.06
M4	10-6-86	50	41	.20	25	479	<.01	.18
M5	6-10-86	36	18	.35	18	418	<.01	.05
M5	10-6-86	34	22	.20	22	456	<.01	.18
				North Raccoon River aquifer				
NR1	6-11-86	53	18	0.10	26	408	--	--
NR1	10-15-86	45	29	.15	26	512	0.01	0.10
NR2	6-12-86	47	2.5	.15	20	316	--	--
NR2	10-15-86	48	4.0	.20	22	326	.05	.04
NR3	6-12-86	21	10	.10	25	460	--	--
NR3	10-15-86	19	17	.10	25	506	.07	.09
				South Raccoon River aquifer				
SR1	6-10-86	39	31	0.15	24	438	--	--
SR1	10-9-86	32	26	.20	22	364	<0.01	0.17
SR2	6-10-86	7.2	9.5	.15	22	288	--	--
SR2	10-9-86	40	12	.20	22	290	<.01	.09
SR3	6-9-86	14	1.0	.35	21	152	<.01	.03
SR3	10-9-86	13	1.0	.30	18	160	<.01	.07

Table 8.--*Chemical analyses of common inorganics--Continued*

Site number (fig. 1)	Date	Specific con- ductance µS/cm	pH, standard units	Temper- ature, water, °C	Hardness, mg/L as $CaCO_3$	Calcium, dis- solved, mg/L as Ca	Mag- nesium dis- solved, mg/L as mg	Sodium dis- solved, mg/L as Na	Potas- sium dis- solved, mg/L as K	Alka linity, total as $CaCO_3$ mg/L
					South Raccoon River aquifer					
SR1	6-10-86	710	6.9	13.0	320	88	24	11	5.1	192
SR1	10-9-86	615	6.6	14.0	--	81	--	10	3.2	216
SR2	6-10-86	420	7.1	10.0	190	58	9.9	7.2	.8	126
SR2	10-9-86	480	6.8	14.0	210	66	12	7.9	.9	142
SR3	6-9-86	310	7.1	15.0	160	45	12	4.9	<.1	156
SR3	10-9-86	310	7.0	12.0	150	39	12	5.1	.1	134
SR4	10-22-86	410	6.6	13.0	190	50	16	8.4	.8	105
SR5	6-9-86	245	7.1	15.0	100	26	9.0	8.9	.3	62
SR6	6-12-86	330	7.1	11.0	130	33	11	11	<.1	108
SR6	10-20-86	370	6.6	11.5	140	36	13	12	.5	110
SR7	6-9-86	575	7.3	12.0	320	100	17	4.5	<.1	282
SR7	10-7-86	740	6.9	17.0	360	110	20	5.9	.7	334
SR8	6-9-86	241	7.0	13.0	110	37	5.4	4.1	<.1	92
SR8	10-7-86	2,750	6.6	16.0	100	33	5.4	4.5	<.1	102
					West Nishnabotna River aquifer					
WN1	6-10-86	750	7.1	11.0	320	86	25	40	5.3	302
WN1	10-21-86	815	7.2	15.5	330	86	27	47	4.9	316
WN2	6-10-86	640	7.1	12.0	330	88	26	9.2	<.1	199
WN2	10-16-86	700	7.0	16.0	360	95	30	11.	<.1	282
WN3	6-10-86	530	7.1	13.0	280	76	22	7	1.9	245
WN3	10-16-86	530	7.5	15.0	290	76	24	7.3	1.8	230
WN4	6-11-86	850	7.3	11.0	420	120	30	18	2.9	230
WN4	10-22-86	785	6.9	14.0	410	110	32	20	4.8	203

Table 8.--*Chemical analyses of common inorganics--Continued*

Site number (fig. 1)	Date	Sulfate, dissolved, mg/L as SO_4	Chloride, dissolved, mg/L as Cl	Flouride, dissolved, mg/L as F	Silica, dissolved, mg/L as SIO_2	Dissolved solids, residue at 105 °C mg/L	Nitrogen, ammonia, dissolved, as N, mg/L	Phosphorus, dissolved, ortho-phosphate as P, mg/L
				South Raccoon River aquifer--Continued				
SR4	10-22-86	28	20	0.15	19	254	<0.01	0.10
SR5	6-9-86	31	5.0	.15	33	146	<.01	.12
SR6	6-12-86	30	14	.15	21	148	--	--
SR6	10-20-86	28	21	.20	23	216	.08	.66
SR7	6-9-86	21	23	.20	20	332	<.01	.04
SR7	10-7-86	32	3.5	.20	24	414	<.01	.17
SR8	6-9-86	14	3.0	.30	18	126	<.01	.06
SR8	10-7-86	14	2.0	.15	20	90	<.01	.11
				West Nishnabotna River aquifer				
WN1	6-10-86	60	14	0.60	16	494	--	--
WN1	10-21-86	58	14	.45	19	490	0.01	0.05
WN2	6-10-86	50	16	.35	16	380	--	--
WN2	10-16-86	36	15	.40	17	404	<.01	.07
WN3	6-10-86	59	1.5	.40	21	324	--	--
WN3	10-16-86	51	3.0	.45	20	310	.07	.13
WN4	6-11-86	160	46	.15	23	564	--	--
WN4	10-22-86	110	45	.10	25	578	<.01	.19

Table 9.--*Chemical analyses of trace elements*

[µg/L, micrograms per liter; <, less than]

Site number (fig.1)	Date	Arsenic, dissolved, µg/L as As	Barium, dissolved, µg/L as Ba	Cadmium, dissolved, µg/L as Cd	Chromium, dissolved, µg/L as Cr	Copper, dissolved, µg/L as Cu	Iron, dissolved, µg/L as Fe	Lead, dissolved, µg/L as Pb	Manganese, dissolved, µg/L as Mn	Mercury, dissolved, µg/L as Hg	Selenium, dissolved, µg/L as Se	Silver, dissolved, µg/L as Ag	Zinc, dissolved, µg/L as Zn
							Brushy Creek aquifer						
BC1	6-11-86	<10	180	<1	<10	<10	20	<10	<20	<1.0	<10	<10	90
BC1	10-15-86	<10	170	<1	<10	<10	100	<10	<20	<1.0	<10	<10	<20
BC2	6-11-86	<10	110	<1	<10	<10	<20	<10	20	<1.0	<10	<10	150
BC2	10-22-86	<10	120	<1	<10	<10	120	<10	60	<1.0	<10	<10	100
BC3	6-11-86	<10	300	<1	<10	50	<20	<10	<20	<1.0	<10	<10	30
BC3	10-21-86	<10	290	<1	<10	<10	910	<10	1,000	<1.0	<10	<10	50
BC4	6-10-86	<10	70	<1	<10	<10	70	<10	20	<1.0	<10	<10	200
BC4	10-16-86	<10	90	<1	<10	<10	90	<10	<20	<1.0	<10	<10	160
BC5	6-10-86	<10	160	<1	<10	20	40	<10	<20	<1.0	<10	<10	60
BC5	10-17-86	<10	160	<1	<10	30	<20	<10	<20	<1.0	<10	<10	20
BC6	6-10-86	<10	180	<1	<10	20	1,200	<10	80	<1.0	<10	<10	620
BC6	10-10-86	<10	200	<1	<10	20	2,500	<10	90	<1.0	<10	<10	330
BC7	6-10-86	<10	110	<1	<10	<10	20	<10	<20	<1.0	<10	<10	200
BC7	10-10-86	<10	150	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	30
BC8	6-12-86	<10	170	<1	<10	<10	7,900	<10	610	<1.0	<10	<10	<10
BC8	10-20-86	<10	170	<1	<10	<10	8,000	<10	520	<1.0	<10	<10	<20
BC9	6-10-86	<10	80	<1	<10	<10	30	10	<20	<1.0	<10	<10	20
BC9	10-8-86	<10	80	<1	<10	<10	40	<10	<20	<1.0	<10	<10	<20
BC10	6-11-86	<10	140	<1	<10	30	<20	<10	<20	<1.0	<10	<10	430
BC10	10-9-86	<10	160	<1	<10	40	<20	<10	<20	<1.0	<10	<10	140
BC11	6-16-86	<10	140	<1	<10	<10	50	<10	<20	<1.0	<10	<10	90
BC11	10-8-86	<10	140	<1	<10	<10	40	<10	<20	<1.0	<10	<10	80

Table 9.--*Chemical analyses of trace elements--Continued*

Site number (fig.1)	Date	Arsenic, dissolved, µg/L as As	Barium, dissolved, µg/L as Ba	Cadmium, dissolved, µg/L as Cd	Chromium, dissolved, µg/L as Cr	Copper, dissolved, µg/L as Cu	Iron, dissolved, µg/L as Fe	Lead, dissolved, µg/L as Pb	Manganese, dissolved, µg/L as Mn	Mercury, dissolved, µg/L as Hg	Selenium, dissolved, µg/L as Se	Silver, dissolved, µg/L as Ag	Zinc, dissolved, µg/L as Zn
East Nishnabotna River aquifer													
EN1	6-10-86	<10	150	<1	<10	<10	70	<10	30	<1.0	<10	<10	40
EN1	10-16-86	<10	180	<1	<10	20	920	<10	420	<1.0	<10	<10	50
EN2	6-13-86	<10	240	<1	<10	<10	200	<10	1,500	<1.0	<10	<10	80
EN2	10-17-86	<10	200	<1	<10	<10	4,500	<10	340	<1.0	<10	<10	370
Middle Raccoon River aquifer													
MR1	6-12-86	<10	90	<1	<10	<10	40	<10	--	<1.0	--	<10	50
MR1	10-15-86	<10	110	<1	<10	<10	50	<10	<20	<1.0	<10	<10	100
MR2	6-13-86	<10	10	<1	<10	<10	40	<10	50	<1.0	<10	<10	90
MR2	10-16-86	<10	120	<1	<10	20	<20	<10	<20	<1.0	<10	<10	100
MR3	6-13-86	20	630	<1	<10	<10	4,600	<10	180	<1.0	<10	<10	<10
MR3	10-15-86	20	620	<1	<10	<10	5,500	<10	190	<1.0	<10	<10	<20
MR4	6-11-86	<10	190	<1	<10	30	40	<10	110	<1.0	<10	<10	100
MR4	10-14-86	<10	160	<1	<10	30	<20	<10	90	5.0	<10	<10	<20
MR5	6-11-86	<10	460	<1	<10	<10	60	<10	<20	<1.0	<10	<10	420
MR5	10-14-86	<10	510	<1	<10	<10	190	<10	<20	2.0	<10	<10	540
MR6	6-13-86	<10	90	<1	<10	<10	280	<10	<20	<1.0	<10	<10	50
MR6	10-14-86	<10	90	<1	<10	<10	<20	<10	<20	1.0	<10	<10	50
MR7	6-10-86	<10	100	<1	<10	<10	170	<10	<20	<1.0	<10	<10	600
MR7	10-8-86	<10	100	<1	<10	<10	310	<10	<20	<1.0	<10	<10	500
MR8	6-11-86	<10	230	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	120
MR8	10-8-86	<10	240	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	80
MR9	6-9-86	<10	100	<1	<10	<10	120	<10	<20	<1.0	<10	<10	50
MR9	10-7-86	<10	140	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	30

Table 9.--*Chemical analyses of trace elements--Continued*

Site number (fig.1)	Date	Arsenic, dissolved, µg/L as As	Barium, dissolved, µg/L as Ba	Cadmium, dissolved, µg/L as Cd	Chromium, dissolved, µg/L as Cr	Copper, dissolved, µg/L as Cu	Iron, dissolved, µg/L as Fe	Lead, dissolved, µg/L as Pb	Manganese, dissolved, µg/L as Mn	Mercury, dissolved, µg/L as Hg	Selenium, dissolved, µg/L as Se	Silver, dissolved, µg/L as Ag	Zinc, dissolved, µg/L as Zn
						Middle River aquifer							
M1	10-21-86	<10	110	<1	<10	<10	<20	<10	30	<1.0	<10	<10	<10
M2	6-9-86	<10	190	<1	<10	<10	<20	<10	50	<1.0	<10	<10	130
M3	6-9-86	<10	200	<1	<10	<10	20	<10	<20	<1.0	<10	<10	<10
M3	10-6-86	<10	200	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	<20
M4	6-10-86	<10	210	<1	<10	180	<20	<10	<20	<1.0	<10	<10	30
M4	10-6-86	<10	250	<1	<10	160	<20	<10	<20	<1.0	<10	<10	20
M5	6-10-86	<10	120	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	70
M5	10-6-86	<10	150	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	100
						North Raccoon River aquifer							
NR1	6-11-86	<10	70	<1	<10	<10	370	<10	30	<1.0	<10	<10	10
NR1	10-15-86	<10	100	<1	<10	<10	40	<10	<20	1.0	<10	<10	40
NR2	6-12-86	<10	100	<1	<10	<10	360	<10	440	<1.0	<10	<10	<10
NR2	10-15-86	<10	100	<1	<10	<10	270	<10	410	2.0	<10	<10	<20
NR3	6-12-86	<10	110	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	<10
NR3	10-15-86	<10	120	<1	<10	<10	<20	<10	<20	2.0	<10	<10	20
						South Raccoon River aquifer							
SR1	6-10-86	<10	230	<1	<10	20	20	<10	60	<1.0	<10	<10	430
SR1	10-9-86	<10	260	<1	<10	<10	<20	<10	40	<1.0	<10	<10	120
SR2	6-10-86	<10	200	<1	<10	<10	40	<10	<20	<1.0	<10	<10	20
SR2	10-9-86	<10	270	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	<20
SR3	6-9-86	<10	110	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	80
SR3	10-9-86	<10	110	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	<20

Table 9.--*Chemical analyses of trace elements--Continued*

Site number (fig.1)	Date	Arsenic, dissolved, µg/L as As	Barium, dissolved, µg/L as Ba	Cadmium, dissolved, µg/L as Cd	Chromium, dissolved, µg/L as Cr	Copper, dissolved, µg/L as Cu	Iron, dissolved, µg/L as Fe	Lead, dissolved, µg/L as Pb	Manganese, dissolved, µg/L as Mn	Mercury, dissolved, µg/L as Hg	Selenium, dissolved, µg/L as Se	Silver, dissolved, µg/L as Ag	Zinc, dissolved, µg/L as Zn
South Raccoon River aquifer--Continued													
SR4	10-22-86	<10	220	<1	<10	<10	340	<10	<20	<1.0	<10	<10	110
SR5	6-9-86	<10	80	<1	<10	20	40	<10	<20	<1.0	<10	<10	10
SR6	6-12-86	<10	20	<1	<10	<10	12,000	<10	810	<1.0	<10	<10	<10
SR6	10-20-86	<10	230	<1	<10	<10	14,000	<10	930	<1.0	<10	<10	<20
SR7	6-9-86	<10	120	<1	<10	<10	90	<10	<20	<1.0	<10	<10	30
SR7	10-7-86	<10	160	<1	<10	<10	<20	<10	<20	<1.0	<10	<10	<20
SR8	6-9-86	<10	70	<1	<10	<10	70	<10	<20	<1.0	<10	<10	110
SR8	10-7-86	<10	100	<1	<10	<10	120	<10	<20	<1.0	<10	<10	20
West Nishnabotna River aquifer													
WN1	6-10-86	<10	80	<1	<10	<10	40	<10	<20	<1.0	<10	<10	30
WN1	10-21-86	<10	100	<1	<10	<10	<20	<10	30	<1.0	<10	<10	60
WN2	6-10-86	<10	150	<1	<10	<10	80	<10	<20	<1.0	<10	<10	40
WN2	10-16-86	<10	190	<1	<10	<10	<20	<10	<20	<1.0	<10	10	40
WN3	6-10-86	<10	100	<1	<10	<10	2,600	<10	170	<1.0	<10	<10	120
WN3	10-16-86	<10	100	<1	<10	<10	2,000	<10	170	<1.0	<10	<10	70
WN4	6-11-86	<10	140	<1	<10	<10	1,200	<10	630	<1.0	<10	<10	80
WN4	10-22-86	<10	150	<1	<10	<10	470	<10	320	<1.0	<10	<10	<20

Table 10.--*Chemical analyses of radiochemicals*

[pCi/L, picocuries per liter; <, less than; --, no data available]

Site number (fig. 1)	Date	Gross alpha, dissolved, pCi/L as u-NAT	Gross beta, dissolved, pCi/L as CS-137	Radium 226 dissolved, pCi/L	Radium 228 dissolved, pCi/L as RA-228
		Brushy Creek aquifer			
BC1	6-11-86	1.8	<0.7	--	--
BC1	10-15-86	<.3	<1.1	--	--
BC2	6-11-86	<.4	<.7	--	--
BC2	10-22-86	<.4	2.0	--	--
BC3	6-11-86	1.9	7.0	--	--
BC3	10-21-86	<.5	28	--	--
BC4	6-10-86	2.0	6.0	--	--
BC4	10-16-86	.8	2.0	--	-
BC5	6-10-86	1.5	11	--	--
BC5	10-17-86	1.2	<1.1	--	--
BC6	6-10-86	3.0	5.4	0.7	1.6
BC6	10-10-86	2.6	4.0	--	--
BC7	6-10-86	1.3	8.0	--	--
BC7	10-10-86	2.0	<1.2	--	--
BC8	6-12-86	3.3	2.0	1.8	1.9
BC8	10-20-86	10	15	1.1	3.0
BC9	6-10-86	1.9	<.6	--	--
BC9	10-8-86	.5	3.0	--	--
BC10	6-11-86	1.7	2.0	--	--
BC10	10-9-86	.4	3.0	--	--
BC11	6-16-86	.4	<.7	--	--
BC11	10-8-86	.4	<1.2	--	--
		East Nishnabotna River aquifer			
EN1	6-10-86	<0.4	<0.7	--	--
EN1	10-16-86	5.8	8.0	0.2	<0.90
EN2	6-13-86	1.2	<.6	--	--
EN2	10-17-86	1.4	<1.1	--	--
		Middle Raccoon River aquifer			
MR1	6-12-86	2.3	1.0	--	--
MR1	10-15-86	1.1	6.0	--	--
MR2	6-13-86	.6	29.	--	--
MR2	10-16-86	4.7	37.	<0.2	<0.90
MR3	6-13-86	1.2	<.6	--	--
MR3	10-15-86	1.0	<1.1	--	--

Table 10.--*Chemical analyses of radiochemicals--Continued*

Site number (fig. 1)	Date	Gross alpha, dissolved, pCi/L as u-NAT	Gross beta, dissolved, pCi/L as CS-137	Radium 226 dissolved, pCi/L	Radium 228 dissolved, pCi/L as RA-228
		Middle Raccoon River aquifer--Continued			
MR4	6-11-86	2.6	12.	--	--
MR4	10-14-86	.4	<1.2	--	--
MR5	6-11-86	.5	<.9	--	--
MR5	10-14-86	<.2	--.	--	--
MR6	6-13-86	1.8	1.0	--	--
MR6	10-14-86	.7	<1.1	--	--
MR7	6-10-86	.8	12	--	--
MR7	10-8-86	1.0	12	--	--
MR8	6-11-86	1.6	2.0	--	--
MR8	10-8-86	2.1	4.0	--	--
MR9	6-9-86	.7	2.0	--	--
MR9	10-7-86	<.3	1.0	--	--
		Middle River aquifer			
M1	10-21-86	2.6	4.0	--	--
M2	6-9-86	3.4	5.0	0.0	1.4
M3	6-9-86	1.3	1.0	--	--
M3	10-6-86	<.3	<1.0	--	--
M4	6-10-86	.4	3.0	--	--
M4	10-6-86	<.3	1.0	--	--
M5	6-10-86	<.4	<.8	--	--
M5	10-6-86	.6	<1.0	--	--
		North Raccoon River aquifer			
NR1	6-11-86	<0.4	1.0	--	--
NR1	10-15-86	1.8	<1.2	--	--
NR2	6-12-86	--	--.	--	--
NR2	10-15-86	2.6	4.0	--	--
NR3	6-12-86	.9	<.6	--	--
NR3	10-15-86	1.5	<1.1	--	--
		South Raccoon River aquifer			
SR1	6-10-86	1.3	3.0	--	--
SR1	10-9-86	1.2	<1.0	--	--
SR2	6-10-86	3.4	12	0.6	1.0
SR2	10-9-86	1.5	2.0	--	--
SR3	6-9-86	<.4	1.0	--	--
SR3	10-9-86	1.0	5.0	--	--

Table 10.--*Chemical analyses of radiochemicals--Continued*

Site number (fig. 1)	Date	Gross alpha, dissolved, pCi/L as u-NAT	Gross beta, dissolved, pCi/L as CS-137	Radium 226 dissolved, pCi/L	Radium 228 dissolved, pCi/L as RA-228
		South Raccoon River aquifer--Continued			
SR4	10-22-86	0.4	<1.0	--	--
SR5	6-9-86	<.2	3.0	--	--
SR6	6-12-86	2.3	<.6	--	--
SR6	10-20-86	1.0	<1.0	--	--
SR7	6-9-86	.4	<.8	--	--
SR7	10-7-86	.6	<1.0	--	--
SR8	6-9-86	2.3	2.0	--	--
SR8	10-7-86	.8	2.0	--	--
		West Nishnabotna River aquifer			
WN1	6-10-86	3.2	7.0	0.2	1.2
WN1	10-21-86	1.1	9.0	--	--
WN2	6-10-86	--	--	--	--
WN2	10-16-86	1.7	<1.1	<.2	<.90
WN3	6-10-86	1.5	4.0	--	--
WN3	10-16-86	.9	<1.1	--	--
WN4	6-11-86	2.1	<.9	--	--
WN4	10-22-86	<.4	3.0	--	--