Ground-Water Quality in Alluvial Aquifers in the Eastern Iowa Basins, Iowa and Minnesota

Water-Resources Investigations Report 00–4106

U.S. Department of the Interior
U.S. Geological Survey
National Water-Quality Assessment Program

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By ERIC M. SADORF and S. MICHAEL LINHART

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NATIONAL WATER-QUALITY ASSESSMENT
EASTERN IOWA BASINS

Iowa City, Iowa
2000

U.S. Department of the Interior

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study areas, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study units and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	2.54	centimeter
feet (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
pound (lb)	0.4536	kilogram
gallon (gal)	3.785	liter

Temperature in degrees Celsius (^oC) can be converted to degrees Fahrenheit (^oF) as follows:

$$^oF = 1.8(^oC) + 32.$$

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

Abbreviated water-quality units: Chemical concentrations are given in metric units of milligrams per liter (mg/L) and micrograms per liter (μg/L). Milligrams per liter and micrograms per liter are units expressing the concentration of chemical constituents in solution as mass (milligrams or micrograms) of solute per unit volume (liter) of water. For concentrations less than 7,000 mg/L, the numerical value of milligrams per liter is the same as for concentrations in parts per million. The numerical value of micrograms per liter is the same as for concentrations in parts per billion.

Radioactivity is expressed in picocuries per liter (pCi/L). A picocurie is the amount of radioactivity that yields 2.22 radioactive disintegrations per minute.

Ground-Water Quality in Alluvial Aquifers in the Eastern Iowa Basins, Iowa and Minnesota

By Eric M. Sadorf *and* S. Michael Linhart

Abstract

The quality of shallow alluvial ground water that is used for domestic supplies in the Wapsipinicon, Cedar, Iowa, and Skunk River Basins (Eastern Iowa Basins) is described. Water samples from 32 domestic-supply wells were collected from June through July 1998. This study of ground-water quality in alluvial aquifers in the Eastern Iowa Basins is part of the U.S. Geological Survey's National Water-Quality Assessment Program.

Calcium and bicarbonate were the dominant ions in solution, likely derived from the dissolution of carbonate minerals in the alluvial aquifer material. Concentrations of iron exceeded the U.S. Environmental Protection Agency Secondary Maximum Contaminant Level (300 micrograms per liter) for drinking water in 53 percent of the samples, and 50 percent of the samples exceeded the Secondary Maximum Contaminant Level for manganese (50 micrograms per liter). pH and alkalinity increased and sulfate concentrations decreased with increasing well depth.

Nitrite plus nitrate nitrogen was detected in 53 percent of the samples and exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level of 10 milligrams per liter for drinking water in 13 percent of the samples. Nitrite plus nitrate nitrogen concentrations were negatively correlated with well depth and positively correlated with percentage of oxygen saturation. Ammonia plus organic nitrogen concentrations were positively correlated with well depth, and ratios of nitrite plus nitrate to ammonia were positively correlated with percentage of oxygen saturation.

The majority of samples, 72 percent, contained water recharged since the early 1950's. The recharge date of water was earlier in deeper wells. Nitrite plus nitrate and total pesticide concentrations were greater in more recently recharged water.

Eight pesticides and eight pesticide metabolites were detected in ground-water samples. Atrazine was the most commonly detected pesticide, and metolachlor ethanesulfonic acid was the most commonly detected metabolite. No pesticide detections exceeded U.S. Environmental Protection Agency drinking-water Maximum Contaminant Levels.

The effects of land use on ground-water quality also were examined. There was a positive correlation between percentage of land used for soybean production and concentrations of metolachlor, metolachlor ethanesulfonic acid, and metolachlor oxanilic acid in ground-water samples.

Data from this study and from previous studies in the Eastern Iowa Basins were compared statistically by well type (domestic, municipal, and monitoring wells). Well depths were significantly greater in domestic and municipal wells than in monitoring wells. pH, calcium, sulfate, chloride, and atrazine concentrations were significantly higher in municipal-well samples than in domestic-well samples. pH and sulfate concentrations were significantly higher in municipal-well samples than in monitoring-well samples. Ammonia was significantly higher in domestic-well samples

than in monitoring-well samples, chloride was significantly higher in monitoring-well samples than in domestic-well samples, and fluoride was significantly higher in domestic-well samples than in municipal-well samples.

INTRODUCTION

Within the framework of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program, study-unit surveys of ground water provide a broad assessment of the water quality of the major aquifer systems within a hydrologic basin (Gilliom and others, 1995, p. 26). The Eastern Iowa Basins NAWQA study unit (fig. 1) consists of four major river basins that drain approximately 19,500 mi^2 in eastern Iowa and southern Minnesota (Kalkhoff, 1994). The major rivers are the Wapsipinicon, Cedar, Iowa, and Skunk, which drain into the Mississippi River. The focus of the first study-unit survey of the Eastern Iowa Basins was an assessment of the water quality in the Silurian-Devonian and Upper Carbonate aquifers in the eastern part of the study unit (Savoca and others, 1999). Alluvial aquifers are the focus of this, the second study-unit survey. Forty-five percent of the ground-water withdrawals in the Eastern Iowa Basins originate from alluvial aquifers (E. Fischer, USGS, oral commun., June 15, 1999). Alluvial aquifers consist of varying thicknesses of sand, gravel, silt, and clay deposits that occur along most of the major streams and rivers. The presence of permeable materials and shallow depth to water in these aquifers increase the potential for contamination from surface activities.

Purpose and Scope

This report presents the results of an assessment of the water quality in alluvial aquifers that are used as sources of domestic water supplies within the Eastern Iowa Basins study unit and examines relations between ground-water quality and land use. Ground-water samples were collected from 32 domestic wells during June and July 1998. Onsite measurements were obtained for specific conductance, pH, water temperature, dissolved oxygen, and alkalinity. The samples were analyzed at USGS laboratories to determine concentrations of major ions, nutrients, trace metals, dissolved organic carbon (DOC), tritium, radon, pesticides and pesticide metabolites, and volatile organic compounds (VOC's). Additionally, data from previous studies were combined with data from this study to compare water quality from different types (domestic, municipal, and monitoring) of wells.

Previous Studies

Kross and others (1990) conducted the State-Wide Rural Well-Water Survey (SWRL) to assess the number of domestic-supply wells in Iowa affected by various environmental contaminants. They found that mean concentrations for most major ions increased or remained fairly constant with depth and that nitrate reduction and denitrification occurred with depth in ground-water systems in Iowa. Concentrations of pesticides and nitrate were relatively high in wells less than 100 ft deep. Wells less than 100 ft in depth accounted for 50 percent of the domestic-supply wells statewide, for 64 percent of the wells containing water with pesticide detections, and 89 percent of the wells with nitrate concentrations greater than the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for drinking water (Kross and others, 1990).

Detroy and others (1988) reported a relation between the presence of detectable concentrations of nitrate and pesticides and decreasing well depth, principally in water from Iowa's surficial unconsolidated aquifers. Detroy and Kuzniar (1988) reported similar findings in the Iowa River alluvial aquifer. They found nitrate and herbicide concentrations were higher in water from shallower rather than deeper wells. They also suggested that surface water sometimes can be a source of nitrate and herbicides to underlying alluvial aquifers.

Kalkhoff and others (1992) suggested that agricultural chemical variation in alluvial aquifers may be the result of chemical input some distance from the well rather than leaching from the soil directly above the sampling point. Kelley and Mehrhoff (1993) investigated radon in municipal ground-water supplies in Iowa. Of 60 samples from alluvial aquifers, 73 percent exceeded the USEPA proposed MCL for radon in drinking water. Buchmiller (1994) indicated that small creeks may be possible sources of herbicide contamination to some alluvial aquifers in Iowa.

Kolpin and others (1996a) described water-quality data collected from wells in near-surface aquifers of the midcontinental United States from 1992 through

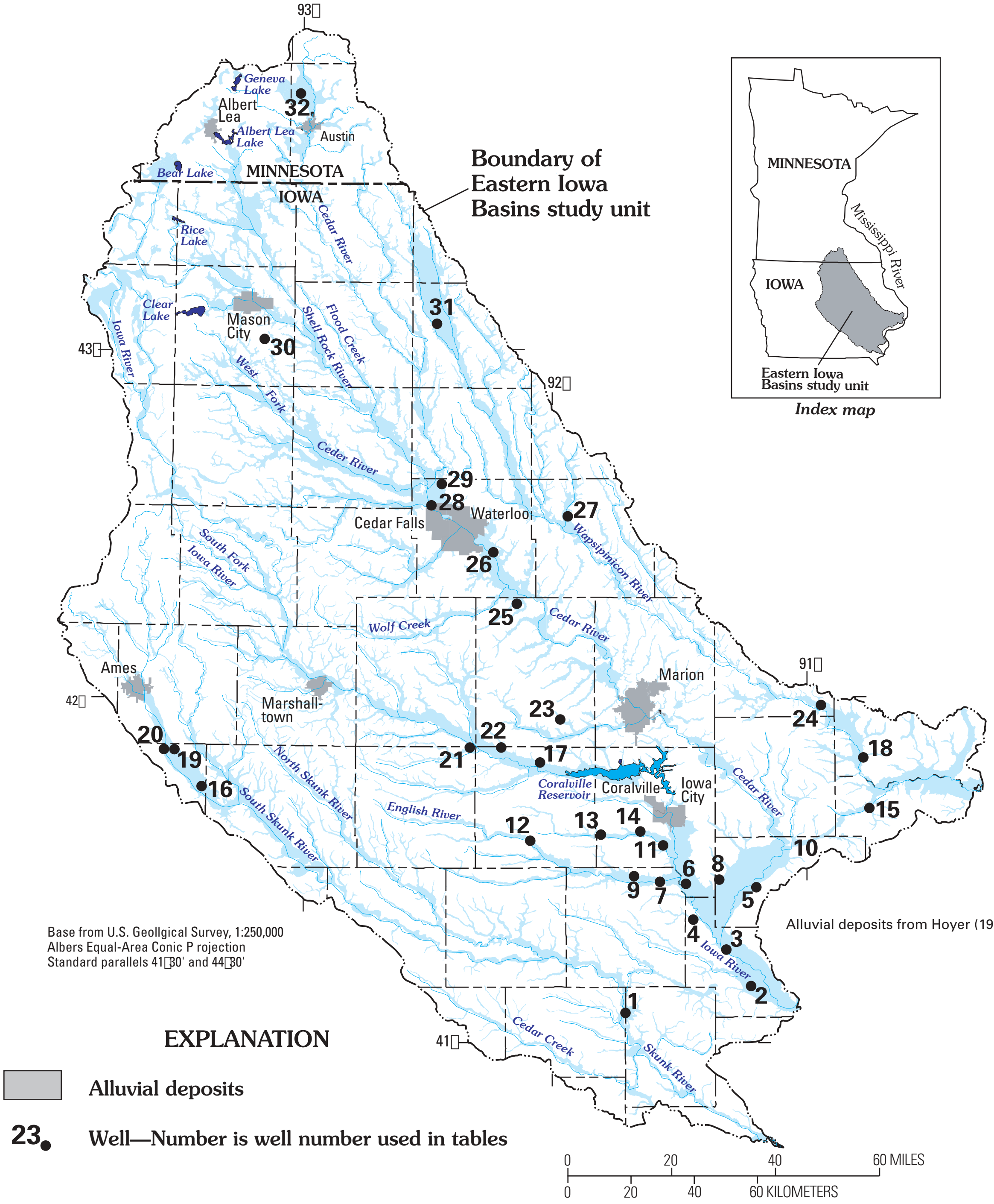

Figure 1. Location of alluvial deposits and sampled wells in Eastern Iowa Basins study unit.

1994. Many of these wells were within the Eastern Iowa Basins study unit. About 63 percent of wells with water samples containing significant increases in herbicide concentrations during the period from 1992 through 1994 were located in areas that wefare affected by stream flooding. Herbicide metabolites were the most frequently detected human-related compounds. In near-surface aquifers of the midcontinental United States, pesticide metabolites were more prevalent than their parent compounds (Kolpin and others, 1996b).

Savoca and others (1997) investigated water quality in the Iowa River alluvial aquifer prior to conversion of agricultural land to wetlands as part of the Wetland Reserve Program. They found lower concentrations of pesticides in water from the deepest wells than in water from the shallowest wells.

Description of Study Unit

Areas within the Eastern Iowa Basins study unit underlain by alluvial aquifers constitute approximately 22 percent of the study unit. These aquifers in the study unit cover 4,260 mi^2. Agriculture is the dominant land use/land cover and is present across 93 percent of the study unit. Forests cover 5 percent of the study unit, and urban areas occupy 2 percent. Wetlands and water account for less than 1 percent of the study unit (U.S. Geological Survey, 1990). The population of the study unit is approximately 1,169,000 (Bureau of Census, 1990).

Mean annual precipitation from 1961 through 1990 ranged from 30 in. in the northwestern part of the study unit to 36 in. in the southeastern part (Wendland and others, 1992), with most of the precipitation occurring in the spring and summer (April–August). Snowfall has been recorded from September to May, with accumulations rarely exceeding 10 in. in 1 day.

Alluvial deposits, along with other unconsolidated (glacial-outwash and buried channel) deposits overlying the bedrock, have been referred to collectively as the surficial aquifer system (Olcott, 1992). Alluvial aquifers are in alluvial deposits located along the major water courses and adjacent flood plains (fig. 1). They consist mainly of fine- to coarse-grained sand and gravel, interbedded with less permeable silt and clay that have been deposited by streams (Wahl and others, 1978). Alluvial aquifers range in thickness from 30 to 100 ft, are thickest where they coincide with buried-channel aquifers, and are thinnest where bedrock is near the surface. Movement of ground water is usually toward the streams and accounts for most of the flow in streams (Anderson, 1983). Recharge to the alluvial aquifers typically occurs by infiltration of precipitation. Streamflow also can recharge the aquifers during times when river levels are higher than the adjacent ground-water levels. Because of their large permeability, alluvial aquifers usually have the largest yields of the surficial aquifer system. However, they also have great potential for aquifer contamination (Karsten and Burkart, 1984; Hoyer and Hallberg, 1991). More complete descriptions of the hydrogeology of the surficial aquifer system are given by Steinhilber and Horick (1970), Wahl and others (1978), Hoyer and Hallberg (1991), and Olcott (1992).

Acknowledgments

The authors thank the residents within the study unit for allowing the USGS to sample their wells. USGS employees Denise Montgomery and Mark Savoca collected much of the data presented in this report. Steve Kalkhoff, project chief for the Eastern Iowa Basins NAWQA study unit, and Mark Savoca provided guidance and support throughout the study.

STUDY DESIGN AND METHODS

This study was designed to provide a broad assessment of the ground-water quality in the alluvial aquifers within the Eastern Iowa Basins study unit. Ground-water samples were collected from June through July 1998 from 32 randomly selected domestic wells. Domestic wells were selected instead of municipal or monitoring wells to maintain consistency with other NAWQA study units that had completed their alluvial ground-water studies using domestic wells. Monitoring wells were not used due to the cost of installation.

Well Selection

Potential sampling sites were identified using a stratified-random-selection process as described by Scott (1990). For statistical purposes, at least 30 wells were required for the sampling effort. Onsite reconnaissance was conducted within a 1-mi radius of each potential site to determine if a suitable well could be found. Potential alternate sampling sites also were selected using the same random selection process in the event that wells near the primary site did not meet well-selection criteria. Well-selection criteria required that: (1) wells be for domestic use; (2) wells be completed in an alluvial aquifer; (3) permission to sample the wells could be obtained; (4) well depths are known; (5) wells are equipped with a submersible pump; and (6) a water sample could be obtained before a pressure tank or any treatment system. If a suitable well could not be found near the primary site, an onsite reconnaissance was conducted around the closest alternate site. Information about each well was obtained from interviews with well owners and from driller's logs provided by the driller.

In some instances, wells suitable for sampling could not be found at either the primary or secondary sites. This was typically due to difficulty in locating wells with submersible pumps. In this instance, wells were selected where a portable submersible pump could be used. In other instances, suitable wells completed in alluvial aquifers could not be located within the vicinity of either the primary or secondary sites. It then became necessary to look for wells along flood plains of nearby streams until a suitable well was located. Figure 1 and table 1 show the location and describe wells sampled for this study.

Sample Collection

Ground-water samples were collected from 32 wells during June and July 1998. Sample collection followed NAWQA protocols (Koterba and others, 1995). Static water levels were measured with an electric tape to the nearest 0.01 ft, when possible, before pumping each well. Most wells were sampled after three well-casing volumes were purged and onsite measurements of specific conductance, pH, water temperature, and dissolved oxygen (recorded 3 to 5 minutes apart) stabilized for five consecutive readings. In wells that had large diameters (large volume) and where a portable submersible pump was being used, three volumes of purge water were not always obtained. In those cases, the well was purged until the onsite measurements stabilized. Samples were collected for the analysis of major ions, nutrients, trace metals, DOC, tritium, radon, pesticides, pesticide metabolites, and VOC's.

Alkalinity, major ion, and nutrient samples were filtered onsite using 0.45-micron cartridge filters. Pesticide samples were filtered using 0.7-micron baked glass-fiber filters. DOC samples were filtered using 0.45-micron silver membrane filters. Tritium, radon, and VOC samples were not filtered. Major ion and VOC samples were acidified prior to shipping. Samples were chilled and shipped overnight to USGS analytical laboratories in Denver, Colorado, Menlo Park, California, and Lawrence, Kansas. All sampling and filtering equipment was decontaminated after each use using methods described in Koterba and others (1995).

Water-Quality Analysis

Major ions, nutrients, trace metals, DOC, radon, pesticides, and VOC's were analyzed at the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado. Tritium was analyzed at the USGS Isotope Tracers Project Laboratory in Menlo Park, California. Selected pesticides and pesticide metabolites were analyzed at the USGS Organic Geochemistry Research Laboratory in Lawrence, Kansas. Analytical methods and reporting limits used for each constituent are listed in tables 2-4.

Results were reported relative to method detection limits (MDL's) or to minimum reporting levels (MRL's). MDL's are the minimum concentration of a constituent that can be measured and that can be reported as being greater than zero with a 99-percent confidence level (Wershaw and others, 1987). MRL's are the minimum concentrations of a constituent that can be reported reliably using a given analytical method (Timme, 1995). MRL's are generally higher than MDL's because MRL's are not statistically determined. MRL's are used more commonly (Timme, 1995). Commonly, MDL's are reported for pesticides and pesticide metabolites, and MRL's are reported for other constituents. Estimated values are used when (1) constituents are detected but concentrations are less than the lowest calibration standard or greater than the highest calibration standard, (2) when the quality-control data indicate low constituent recovery, or (3) when quantitative analysis was compromised by analytical interference. Table 2 lists the MRL's and references for analytical techniques used in this study for major ions, nutrients, trace metals, carbon, and radiochemical isotopes, including tritium and radon. Table 3 lists the MDL's and references for analytical techniques used for pesticides and pesticide metabolites, and table 4 lists the MRL's and reference for analytical techniques used for VOC's. Some of the MRL's listed for a constituent appear as a range because those constituents were analyzed at different times using different MRL values.

Quality Assurance

Several quality-assurance/quality-control samples were collected to ensure that sampling and analysis procedures were not responsible for the presence of constituents. These samples included one equipment blank (major ion, nutrient, pesticide and metabolite,

Table 1. Wells completed in alluvial aquifers in eastern Iowa and southern Minnesota from which water samples were collected, June–July 1998

Well number (fig. 1)	Location (degrees, minutes, seconds)		Date sampled (month-day-year)	Well depth (feet)	County, State	Major land-use type[1]	Percentage of major land-use type	Secondary land-use type[1]	Percentage of secondary land-use type
	Latitude	Longitude							
1	41°05′13″	91°43′04″	07-22-98	14	Jefferson, IA	syb.rwc	43	gen.wpl	21
2	41°09′56″	91°13′56″	06-24-98	25	Louisa, IA	syb.rwc	50	crf.rwc	48
3	41°16′22″	91°19′34″	06-24-98	70	Louisa, IA	crl.npd	55	gen.wpl	14
4	41°21′36″	91°27′05″	06-25-98	54	Louisa, IA	gro.grc	37	gen.fdn	28
5	41°27′11″	91°12′24″	06-15-98	193	Muscatine, IA	crl.npd	28	crf.rwc	27
6	41°27′48″	91°28′51″	06-16-98	94	Johnson, IA	syb.rwc	51	crf.rwc	36
7	41°28′08″	91°34′50″	06-17-98	20	Washington, IA	syb.rwc	50	crf.rwc	36
8	41°28′31″	91°20′56″	06-16-98	40	Muscatine, IA	crf.rwc	54	syb.rwc	27
9	41°29′16″	91°40′51″	06-17-98	125	Washington, IA	lcb.pst	40	syb.rwc	15
10	41°33′38″	91°04′56″	07-16-98	12	Muscatine, IA	crf.rwc	32	syb.rwc	27
11	41°34′38″	91°34′12″	06-10-98	80	Johnson, IA	crf.rwc	43	syb.rwc	22
12	41°35′23″	92°05′05″	06-22-98	30	Iowa, IA	crf.rwc	39	syb.rwc	24
13	41°36′34″	91°48′43″	06-18-98	177	Johnson, IA	crf.rwc	65	syb.rwc	23
14	41°37′05″	91°39′27″	06-11-98	40	Johnson, IA	syb.rwc	49	crf.rwc	42
15	41°40′36″	90°46′00″	06-23-98	94	Scott, IA	crf.rwc	51	syb.rwc	40
16	41°44′30″	93°22′00″	07-14-98	20	Polk, IA	syb.rwc	70	crl.npd	16
17	41°49′14″	92°02′40″	07-15-98	40	Iowa, IA	crl.npd	51	gen.npd	19
18	41°49′44″	90°47′09″	07-09-98	65	Clinton, IA	crf.rwc	37	urc.pkd	21
19	41°50′53″	93°28′24″	07-14-98	70	Polk, IA	crf.rwc	51	syb.rwc	33
20	41°50′57″	93°30′48″	07-13-98	50	Polk, IA	syb.rwc	60	crf.rwc	17
21	41°51′39″	92°19′08″	06-30-98	25	Poweshiek, IA	crf.rwc	35	gen.fdn	22
22	41°51′47″	92°11′53″	06-30-98	28	Benton, IA	crf.rwc	54	syb.rwc	18
23	41°56′37″	91°58′10″	06-30-98	20	Benton, IA	syb.rwc	53	crf.rwc	31
24	41°58′59″	90°56′39″	06-23-98	22	Jones, IA	crf.rwc	82	syb.rwc	8
25	42°16′57″	92°08′18″	07-06-98	60	Benton, IA	crf.rwc	84	alh.rwc	10

Table 1. Wells completed in alluvial aquifers in eastern Iowa and southern Minnesota from which water samples were collected, June–July 1998—Continued

Well number (fig. 1)	Location (degrees, minutes, seconds)		Date sampled (month-day-year)	Well depth (feet)	County, State	Major land-use type[1]	Percentage of major land-use type	Secondary land-use type[1]	Percentage of secondary land-use type
	Latitude	Longitude							
26	42°25′55″	92°13′52″	07-01-98	48	Blackhawk, IA	gen.wpl	53	lhr.pst	17
27	42°32′08″	91°56′21″	07-08-98	54	Buchanan, IA	gen.wpl	44	lcb.pst	40
28	42°34′09″	92°28′30″	07-07-98	150	Blackhawk, IA	gen.wpl	38	alh.grc	35
29	42°37′49″	92°26′08″	07-07-98	55	Blackhawk, IA	crf.rwc	63	syb.rwc	28
30	43°02′55″	93°08′33″	07-21-98	43	Cerro Gordo, IA	crf.rwc	50	syb.rwc	47
31	43°05′49″	92°27′23″	07-21-98	80	Chichasaw, IA	crf.rwc	50	syb.rwc	23
32	43°45′56″	93°00′35″	07-20-98	150	Mower, MN	crf.rwc	73	syb.rwc	23

[1] Land use determined by onsite inspection:

alh.grc = alfalfa ground cover;
alh.rwc = alfalfa row crop;
crf.rwc = corn row crop;
crl.npd = nonproductive cropland;
gen.fdn = unmanaged deciduous forest;
gen.npd = nonproductive general;
gro.grc = hay;
gen.wpl = palustrine;
lcb.pst = cattle pasture;
lhr.pst = horse pasture;
syb.rwc = soybean row crop; and
urc.pkd = developed parkland.

Table 2. Minimum reporting levels (MRL's) and references for analytical techniques for major ions, trace metals, nutrients, carbon, and radiochemical isotopes analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998

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

Constituent	Chemical Abstract Service (CAS) registry number	MRL (mg/L, except as noted)	Reference for analytical technique
	Major ions		
Calcium, dissolved	7440–70–2	0.02	Fishman, 1993
Magnesium, dissolved	7439–95–4	.01	Do.
Sodium, dissolved	7440–23–5	.2	Do.
Potassium, dissolved	7440–09–7	.1	Do.
Chloride, dissolved	16887–00–6	.1	Do.
Sulfate, dissolved	14808–79–8	.1	Do.
Fluoride, dissolved	16984–48–8	.1	Do.
Bromide, dissolved	24959–67–9	.1	Do.
Silica, dissolved	7631–86–9	.1	Do.
			Do.
	Trace metals		
Iron, dissolved	7439–89–6	10 µg/L	Do.
Manganese, dissolved	7439–96–5	1 µg/L	Do.
	Nutrients		
Nitrite as nitrogen, dissolved	14797–65–0	.01	Do.
Nitrite plus nitrate as nitrogen, dissolved		.01	Do.
Ammonia as nitrogen, dissolved	7664–41–7	.01	Do.
Ammonia plus organic nitrogen, dissolved	17778–88–0	.1	Do.
Ammonia plus organic nitrogen, total	17778–88–0	.1	Do.
Phosphorus, total	7723–14–0	.001	Do.
Orthophosphate as phosphorus, dissolved	14265–44–2	.001	Do.
			Do.
	Carbon		
Organic carbon, dissolved		.1	Do.
	Radiochemical isotopes		
Tritium, total	10028–17–8	1.0 pCi/L	Ostlund and Dorsey, 1977
Radon-222, total	14859–67–7	80 pCi/L	American Society for Testing Materials, 1996

Table 3. Method detection limits (MDL's) and references for analytical techniques for selected pesticides and pesticide metabolites analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998

[--, not available; µg/L, micrograms per liter; *, constituent not registered in the State of Iowa (Jim Ellerhof, Iowa Department of Agriculture and Land Stewardship, Pesticide Bureau, written commun., 1998)]

Constituent	Common trade names or other information	Chemical Abstract Service (CAS) registry number	MDL (µg/L)	References for analytical technique
		Pesticides (schedule 2010)		
2,6-Diethylaniline	--	579–66–8	0.003	Zaugg and others, 1995
Acetochlor	Harness, Surpass	34256–82–1	.002	Do.
Alachlor	Lasso	15972–60–8	.002	Do.
Atrazine	atrazine, AAtrex	1912–24–9	.001	Do.
Azinphos-methyl	Guthion	86–50–0	.001	Do.
Benfluralin	Balan, Benefen	1861–40–1	.002	Do.
Butylate	Sutan, Genate	2008–41–5	.002	Do.
Carbaryl	Sevin, Savit	63–25–2	.003	Do.
Carbofuran	Furadan	1563–66–2	.003	Do.
Chlorpyrifos	Dursban, Lorsban	2921–88–2	.004	Do.
Cyanazine	Bladex	21725–46–2	.004	Do.
DCPA	Dacthal	1861–32–1	.002	Do.
p, p'-DDE	metabolite of DDT	72–55–9	.006	Do.
Deethylatrazine	metabolite of atrazine	6190–65–4	.002	Do.
Diazinon	several	333–41–5	.002	Do.
Dieldrin	--	60–57–1	.001	Do.
Disulfoton	Di-Syston	298–04–4	.017	Do.
EPTC	Eradicane, Eptam	759–94–4	.002	Do.
Ethalfluralin	Sonalan, Curbit	55283–68–6	.004	Do.
Ethoprophos	Mocap	13194–48–4	.003	Do.
Fonofos	Dyfonate	944–22–9	.003	Do.
alpha-HCH	Lindane (impurity)	319–84–6	.002	Do.
Lindane	Gammasan	58–89–9	.004	Do.
Linuron	Lorox, Linex	330–55–2	.002	Do.
Malathion	several	121–75–5	.005	Do.
Metolachlor	Dual	51218–45–2	.002	Do.
Metribuzin	Sencor, Lexone	21087–64–9	.004	Do.
Molinate*	Ordram	2212–67–1	.004	Do.
Napropamide	Devrinol	15299–99–7	.003	Do.
Parathion	Parathion 15 percent wettable	56–38–2	.004	Do.
Parathion-methyl	Penncap-M	298–00–0	.006	Do.
Pebulate	Tillam	1114–71–2	.004	Do.
Pendimethalin	Prowl	40487–42–1	.004	Do.
cis-Permethrin	--	54774–45–7	.005	Do.
Phorate	Thimet	298–02–2	.002	Do.
Prometon	Pramitol	1610–18–0	.018	Do.

Table 3. Method detection limits (MDL's) and references for analytical techniques for selected pesticides and pesticide metabolites analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998—Continued

Constituent	Common trade names or other information	Chemical Abstract Service (CAS) registry number	MDL (µg/L)	References for analytical technique
		Pesticides (schedule 2010)—Continued		
Propachlor	Ramrod	1918–16–7	0.007	Zaugg and others, 1995
Propanil*	Stampede	709–98–8	.004	Do.
Propargite	Omite, Comite	2312–35–8	.013	Do.
Propyzamide	Kerb	23950–58–5	.003	Do.
Simazine	Princep	122–34–9	.005	Do.
Tebuthiuron	Spike	34014–18–1	.010	Do.
Terbacil	Sinbar	5902–51–2	.007	Do.
Terbufos	Counter	13071–79–9	.013	Do.
Thiobencarb*	Bolero	28249–77–6	.002	Do.
Tri-allate*	Far-Go	2303–17–5	.001	Do.
Trifluralin	Treflan, Trilin, Trific	1582–09–8	.002	Do.
		Pesticides (schedule 2050)		
2,4,5-T	Line Rider and others	93–76–5	.035	Werner and others, 1996
2,4-D	2,4-D and others	94–75–7	.15	Do.
2,4-DB	Butoxone	94–82–6	.24	Do.
3-Hydroxycarbofuran	--	16655–82–6	.014	Do.
Acifluorfen	Blazer, Tackle	50594–66–6	.035	Do.
Aldicarb	Temik	116–06–3	.55	Do.
Aldicarb sulfone	metabolite of aldicarb	1646–88–4	.10	Do.
Aldicarb sulfoxide	metabolite of aldicarb	1646–87–3	.021	Do.
Bentazon	Basagran	25057–89–0	.014	Do.
Bromacil	Bromax 90, Urox B	314–40–9	.035	Do.
Bromoxynil	Buctril, Brominal	1689–84–5	.035	Do.
Carbaryl	Sevin	63–25–2	.008	Do.
Carbofuran	Furadan	1563–66–2	.12	Do.
Chloramben	Amiben	133–90–4	.42	Do.
Chlorothalonil	Chlorochem and others	1897–45–6	.48	Do.
Clopyralid	Lontrel	1702–17–6	.23	Do.
Dacthal monoacid	--	887–54–7	.017	Do.
Dicamba	Banvel	1918–00–9	.035	Do.
Dichlobenil	Casoron	1194–65–6	1.2	Do.
Dichlorprop	2,4-DP	120–36–5	.032	Do.
Dinoseb	Basanite and others	88–85–7	.035	Do.
Diuron	Diurex and others	330–54–1	.020	Do.
Fenuron	Beet-Kleen	101–42–8	.013	Do.
Fluometuron	Cotoran	2164–17–2	.035	Do.
Linuron	Lorox	330–55–2	.018	Do.
MCPA	MCPA and others	94–74–6	.17	Do.
MCPB	Thistrol	94–81–5	.14	Do.

Table 3. Method detection limits (MDL's) and references for analytical techniques for selected pesticides and pesticide metabolites analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998—Continued

Constituent	Common trade names or other information	Chemical Abstract Service (CAS) registry number	MDL (μg/L)	References for analytical technique
		Pesticides (schedule 2050)—Continued		
Methiocarb	Mesurol	2032–65–7	0.026	Werner and others, 1996
Methomyl	Lannate and others	16752–77–5	.017	Do.
Neburon	Neburex, Neburon	555–37–3	.015	Do.
Norflurazon	Evital, Zorial	27314–13–2	0.024 – 0.150	Do.
Oryzalin	Surflan	19044–88–3	0.31 – 1.06	Do.
Oxamyl	Vydate	23135–22–0	0.018 – 0.210	Do.
Picloram	Tordon	1918–02–1	.05	Do.
Propham	IPC	122–42–9	.035	Do.
Propoxur	Propagon and others	114–26–1	.035	Do.
Triclopyr	Garlon	55335–06–3	.25	Do.
		Pesticide metabolites		
Acetochlor ESA	metabolite of acetochlor	--	.20	Zimmerman and Thurman, 1999
Acetochlor OA	metabolite of acetochlor	--	.20	Do.
Alachlor ESA	metabolite of alachlor	--	.20	Do.
Alachlor OA	metabolite of alachlor	--	.20	Do.
Cyanazine amide	metabolite of cyanazine	--	.05	Do.
Deethylatrazine	metabolite of atrazine	--	.05	Do.
Deisopropylatrazine	metabolite of atrazine	--	.05	Do.
Metolachlor ESA	metabolite of metolachlor	--	.20	Do.
Metolachlor OA	metabolite of metolachlor	--	.20	Do.

Table 4. Minimum reporting levels (MRL's) and reference for analytical techniques for volatile organic compounds analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998

[μg/L, micrograms per liter]

Constituent	Chemical Abstract Service (CAS) registry number	MRL (μg/L)	Analytical technique
Acetone	67–64–1	4.90 – 19.6	Rose and Schroeder, 1995
Acrolein	107–02–8	2	Do.
Acrylonitrile	107–13–1	1.23 – 4.90	Do.
Benzene	71–43–2	0.032 – 0.400	Do.
Bromobenzene	108–86–1	0.036 – 0.144	Do.
Bromochloromethane	74–97–5	0.044 – 0.176	Do.
Bromodichloromethane	75–27–4	0.048 – 0.192	Do.
Bromoform	75–25–2	0.104 – 0.416	Do.
Bromomethane	74–83–9	0.148 – 0.592	Do.
2-Butanone	78–93–3	5	Do.
Butylbenzene	104–51–8	.05	Do.
Carbon disulfide	75–15–0	0.08 – 0.37	Do.
Chlorobenzene	108–90–7	0.028 – 0.112	Do.
Chloroethane	75–00–3	0.120 – 0.480	Do.
Chloroform	67–66–3	0.052 – 0.208	Do.
Chloromethane	74–87–3	0.254 – 1.02	Do.
3-Chloropropene	107–05–1	0.196 – 0.784	Do.
2-Chlorotoluene	95–49–8	.05	Do.
4-Chlorotoluene	106–43–4	.05	Do.
Dibromochloromethane	124–48–1	0.182 – 0.728	Do.
1, 2-Dibromo-3-chloropropane	96–12–8	.5	Do.
1, 2-Dibromoethane	106–93–4	0.036 – 0.144	Do.
Dibromomethane	74–95–3	0.05 – 0.20	Do.
1, 2-Dichlorobenzene	95–50–1	.05	Do.
1, 3-Dichlorobenzene	541–73–1	0.054 – 0.216	Do.
1, 4-Dichlorobenzene	106–46–7	0.05 – 0.20	Do.
Dichlorodifluoromethane	75–71–8	0.096 – 0.552	Do.
1, 1-Dichloroethane	75–34–3	0.066 – 0.264	Do.
1, 2-Dichloroethane	107–06–2	0.134 – 0.536	Do.
1, 1-Dichloroethylene	75–35–4	0.044 – 0.176	Do.
Dichloromethane	75–09–2	.1	Do.
1, 2-Dichloropropane	78–87–5	0.068 – 0.272	Do.
1, 3-Dichloropropane	142–28–9	0.116 – 0.464	Do.
2, 2-Dichloropropane	594–20–7	0.078 – 0.312	Do.
1, 1-Dichloropropene	563–58–6	0.026 – 0.104	Do.
Diethyl ether	60–29–7	.1	Do.
Diisopropyl ether	108–20–3	.1	Do.
Ethyl methacrylate	97–63–2	0.278 – 1.11	Do.
Ethyl tert-butyl ether	637–92–3	.1	Do.

Table 4. Minimum reporting levels (MRL's) and reference for analytical techniques for volatile organic compounds analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998—Continued

Constituent	Chemical Abstract Service (CAS) registry number	MRL (µg/L)	Analytical technique
Ethylbenzene	100–41–4	0.030 – 0.120	Rose and Schroeder, 1995
Hexachlorobutadiene	87–68–3	0.142 – 0.568	Do.
Hexachloroethane	67–72–1	0.362 – 1.45	Do.
2-Hexanone	591–78–6	0.746 – 2.98	Do.
Isopropylbenzene	98–82–8	0.032 – 0.128	Do.
4-Isopropyl-1-methylbenzene	99–87–6	.05	Do.
Methyl acrylate	96–33–3	0.612 – 5.43	Do.
Methyl acrylonitrile	126–98–7	2.28 – 20.57	Do.
Methyl iodide	74–88–4	0.076 – 0.832	Do.
Methyl methacrylate	80–62–6	0.35 – 1.40	Do.
4-Methyl-2-pentanone	108–01–1	5	Do.
Naphthalene	91–20–3	0.25 – 1.00	Do.
Propylbenzene	103–65–1	0.042 – 0.168	Do.
Styrene	100–42–5	0.042 – 0.168	Do.
1, 1, 1, 2-Tetrachloroethane	630–20–6	0.044 – 0.176	Do.
1, 1, 2, 2-Tetrachloroethane	79–34–5	0.132 – 0.528	Do.
Tetrachloroethylene	127–18–4	0.038 – 0.41	Do.
Tetrachloromethane	56–23–5	.05	Do.
Tetrahydrofuran	109–99–9	5	Do.
1, 2, 3, 4-Tetramethylbenzene	488–23–3	.05	Do.
1, 2, 3, 5-Tetramethylbenzene	527–53–7	.05	Do.
Toluene	108–88–3	0.016 – 0.152	Do.
1, 2, 3-Trichlorobenzene	87–61–6	0.266 – 1.06	Do.
1, 2, 4-Trichlorobenzene	120–82–1	0.188 – 0.752	Do.
1, 1, 1-Trichloroethane	71–55–6	0.032 – 0.128	Do.
1, 1, 2-Trichloroethane	79–00–5	0.064 – 0.256	Do.
Trichloroethylene	79–01–6	0.038 – 0.152	Do.
Trichlorofluoromethane	75–69–4	0.092 – 0.368	Do.
1, 2, 3-Trichloropropane	96–18–4	0.070 – 0.648	Do.
1, 1, 2-Trichlorotrifluoroethane	76–13–1	.05	Do.
1, 2, 3-Trimethylbenzene	526–73–8	0.124 – 0.496	Do.
1, 2, 4-Trimethylbenzene	95–63–6	0.056 – 0.224	Do.
1, 3, 5-Trimethylbenzene	108–67–8	0.044 – 0.176	Do.
Vinyl acetate	108–05–4	5	Do.
Vinyl bromide	593–60–2	.2	Do.
Vinyl chloride	75–01–4	0.112 – 0.448	Do.
cis-1, 2-Dichloroethylene	156–59–2	.05	Do.
cis-1, 3-Dichloropropene	10061–01–5	0.092 – 0.368	Do.
m- and p-Xylene		.05	Do.
o-Ethyl toluene	611–14–3	0.100 – 0.400	Do.

Table 4. Minimum reporting levels (MRL's) and reference for analytical techniques for volatile organic compounds analyzed in water samples collected from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998—Continued

Constituent	Chemical Abstract Service (CAS) registry number	MRL (μg/L)	Analytical technique
o-Xylene	95–47–6	0.064 – 0.256	Rose and Schroeder, 1995
sec-Butylbenzene	135–98–8	0.048 – 0.192	Do.
tert-Butyl methyl ether	1634–04–4	.1	Do.
tert-Butylbenzene	98–06–6	0.096 – 0.384	Do.
tert-Pentyl methyl ether	994–05–8	0.112 – 0.448	Do.
trans-1, 2-Dichloroethylene	156–60–5	.05	Do.
trans-1, 3-Dichloropropene	10061–02–6	0.134 – 0.536	Do.
trans-1, 4-Dichloro-2-butene	110–57–6	0.692 – 2.77	Do.

VOC), two major ion and nutrient field blanks, two DOC field blanks, two pesticide field blanks, two VOC field blanks, two replicate (sequential) samples for major ions, nutrients, DOC, pesticides, and VOC's, and one pesticide and VOC field-spiked sample.

Equipment blank samples were collected by running water of known quality through the sampling and processing equipment, and collecting the blank sample in the same type of bottles used for the ground-water sampling. Equipment blank samples were collected in the USGS office in Iowa City, Iowa. This type of blank sample was used to determine if any constituent was potentially added from the equipment during sample collection and processing. Field blank samples were collected in the same manner onsite to determine if onsite conditions potentially added any constituent during the sampling process.

Replicate (sequential) samples were collected onsite immediately after the initial ground-water sample was collected. Replicate samples were used to determine the precision of onsite and laboratory procedures for the detection of ground-water constituents. Field-spiked samples also were collected. These were samples collected onsite and spiked with known amounts of selected pesticides and VOC's to determine the accuracy of constituent recovery by the analyzing laboratory and potential degradation of analytes during the time between collection and analysis.

Field and equipment blank samples showed that, for most constituents, sampling and laboratory procedures did not introduce constituents into the samples. However, several constituents were present in blank samples at detectable concentrations. These constituents are listed in table 8 in the "Supplemental Information" section at the end of this report. Some of these were estimated values near or less than the detection limits. Acetone, carbon disulfide, and toluene had estimated concentrations less than the detection-limit range. Dichlorodifluoromethane had an estimated value within the detection-limit range and an estimated value greater than the range. Carbon disulfide had a concentration within the range of detection limits. Calcium, magnesium, silica, and DOC were detected in blank samples at concentrations greater than the MRL, but their concentrations were substantially less than those found in the ground-water samples. Fluoride, nitrate, ammonia, phosphorus, orthophosphorus, and iron were detected in blank samples at concentrations greater than the detection limits, but the concentrations were less than most of the ground-water-sample concentrations.

An acceptable level of precision in laboratory procedures was evaluated by analysis of replicate (sequential) samples. Relative percentage differences (RPD's) were calculated for each constituent that had different concentrations between the replicate samples. Constituents that had RPD's greater than 10 percent are listed in table 9 in the "Supplemental Information" section. Small concentration differences for many of these constituents led to large RPD's because ground-water and replicate-sample concentrations were also small. The constituents that are in this category were bromide, ammonia, carbon disulfide, chloroform, meta/paraxylene, and toluene.

Surrogate recoveries of the ground-water samples were performed at NWQL in Denver, Colorado. The percentage recoveries for the VOC ground-water sample surrogate compounds (1,4-bromofluorobenzene, 1,2-dichloroethane, and toluene) ranged from 69 to 129 percent (median values ranged from 83 to 108 percent), and the pesticide ground-water sample surrogate compounds (diazinon-d10, tertbutylazine, alpha-HCH-d6, and BDMC) recoveries ranged from 0 to 123 percent (median values ranged from 83 to 106 percent). If the single value of zero was omitted, the range would be 63 to 123 percent for the pesticide ground-water samples. These results indicate little matrix-interference problems and that the analytical methods were effective.

Recovery for field-spiked samples ranged from 0 to 151 percent for pesticides (table 10 in “Supplemental Information” section) and 0 to 96 percent for VOC’s (table 11 in “Supplemental Information” section). The formulas used to calculate spike recovery percentage are as follows: Percentage recovery = [(spike concentration) - (sample concentration)] X 100 / expected concentration. The expected concentration in micrograms per liter = [(spike solution) X amount in milliliters added] / spiked-sample volume in liters. Where concentrations of the sample were less than the MDL or MRL, the spike recovery percentage was given as a range that covered the possible percentage value. Where concentrations of the spike were less than the MDL or MRL (except for estimated values), the spike recovery percentage was not calculated. Of the compounds detected in ground-water samples, only 3-hydroxycarbofuran (spike recovery, 38 percent) and picloram (spike recovery, 43–47 percent) had spike recoveries less than 75 percent.

Statistical Analysis

Wilcoxon rank-sum tests (Ott, 1993) were performed using SAS software (SAS, 1990) to evaluate statistical differences between groups of data. Univariate procedures were used to determine means and percentiles. Spearman and Pearson correlation tests (Ott, 1993) were performed to find the degree of correlation between variables. On certain variables that had high probability of correlation, regression analyses were performed to find the equation of the linear relationship. A 95-percent confidence level was used in the statistical analyses for this report. A probability (p) value of 0.05 indicates a 95-percent confidence that observed differences are not the result of chance occurrence. Differences between groups with probability values of 0.05 or less were considered significant. For statistical-analysis purposes, the value used for constituents with concentrations less than their MDL or MRL was one-half the value of the MDL or MRL, except in the comparison of domestic-, municipal-, and monitoring-well data where a value of 0 was used.

Land-Use Classification

Land use was classified using low-altitude aerial photographs obtained from USGS’s Earth Resources Observation System Data Center and onsite ground surveillance for the 32 well locations. The aerial photographs were taken in the spring of 1994, and onsite ground surveillance was conducted in the fall of 1998. Transparent mylar was taped to each aerial photograph, and a circle was drawn around the well location representing a circular area 1,640 ft in diameter. Land-use types (such as corn field, residential housing, or cemetery) that occurred within the circular area were traced as polygons and labeled on the mylar. Land-use percentages were calculated from the mylar tracings using the method described in Harvey and others (1996).

GROUND-WATER QUALITY

Selected physical properties and chemical constituent concentrations for each water sample collected for this study are reported in Akers and others (2000). A statistical summary of selected well measurements and ground-water-quality data is given in table 12 in the “Supplemental Information” section.

In this report, the quality of water in alluvial aquifers in the Eastern Iowa Basins is discussed in terms of physical properties and chemical constituents. Under the Safe Drinking Water Act of 1986, the USEPA has established three sets of regulations that set maximum levels for certain physical properties of and chemical constituents in finished (treated) drinking water—Maximum Contaminant Levels (MCL’s), Secondary Maximum Contaminant Levels (SMCL’s), and Health Advisory Levels (HAL’s). These regulations apply to properties and constituents that, if present in drinking water, may cause adverse human health effects. MCL’s are enforceable, health-based standards. SMCL’s are established for properties or constituents that can adversely affect the aesthetic quality of the water (taste, odor, appearance) and may result in discontinued use of the water. HAL’s are nonregulatory levels that establish acceptable constituent concentrations for different exposure periods—1-day, 10-day, long-term, and lifetime. Lifetime HAL's are estimates of concentrations that would result in no known or anticipated adverse health effects (U.S. Environmental Protection Agency, 1999).

Table 5 lists MCL's, SMCL's, and HAL's for physical properties and chemical constituents measured or analyzed in ground-water samples collected from domestic wells completed in alluvial aquifers in the Eastern Iowa Basins for June and July 1998. Table 5 also indicates the number of samples exceeding the established USEPA regulation.

Physical Properties

Specific conductance is the ability of a substance to conduct an electric current (Hem, 1985). It provides an indication of ion concentration in a solution. The sample range of specific conductance was from 331 to 1,150 μS/cm (microsiemens per centimeter at 25 ^{o}C).

pH is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem, 1985). Temperature greatly affects pH. Most ground water in the United States has a range of 6.0 to 8.5 (Hem, 1985). The sample range for pH in the alluvial aquifers was from 5.9 to 7.4. The pH value of 5.9 was less than the typical range for ground water. This sample also had a low value for alkalinity and was from a well with a relatively shallow depth of 20 ft.

Temperature can have an effect on physical properties and chemical equilibria in ground water. The sample range for temperature was from 9.7 to 15.8 ^{o}C.

Alkalinity is the capacity for solutes to react with and neutralize acid (Hem, 1985). In natural water that has a pH less than 9.5, as in this study, the alkalinity can be assigned almost entirely to bicarbonate and carbonate. The alkalinity of ground water reflects its passage through the hydrologic cycle. The main source of the carbon dioxide species that produce alkalinity is CO_2 (carbon dioxide) in the atmosphere and atmospheric gases in the soil (Hem, 1985). Much of the bedrock in the Eastern Iowa Basins study unit is carbonate, which can be dissolved by CO_2-enriched water, increasing alkalinity in ground water. The CO_2 species that contribute to alkalinity are important participants in reactions that control the pH of natural water (Hem, 1985). The sample range for alkalinity was from 58 to 423 mg/L.

There was a significant ($p = 0.0191$) increase in pH with increasing well depth, and a significant ($p = 0.0312$) increase in alkalinity with increasing well depth (fig. 2). These two positive correlations probably are due to longer residence times of the ground water at greater depths. Increased residence time of ground water increases the time ground water has to dissolve soluble minerals, leading to higher ion concentrations.

Major Ions and Trace Metals

Major ions and trace metals found in ground water can occur naturally and through ground-water contamination. Natural occurrences are usually through dissolution of minerals in the aquifer materials. The alluvial aquifer materials contain minerals from both local sedimentary rocks and transported sedimentary, igneous, and metamorphic rocks. The dissolution of carbonate rocks can add calcium, magnesium, and manganese to ground water. Dissolution of gypsum and fluorite can add sulfate, calcium, and fluoride to ground water. Dissolution of feldspars in igneous rock and various salts contained in sedimentary rock can release sodium, potassium, and chloride to ground water. Silica, iron, and manganese are released to ground water through the dissolution of minerals contained in igneous, metamorphic, and sedimentary rocks. The solubility of iron in water is strongly affected by pH (Hem, 1985).

Ground water from wells sampled during this study was a calcium bicarbonate type (fig. 3), probably resulting from dissolution of carbonate minerals in the alluvial deposits that were derived from reworked glacial drift and loess. Most samples had 50 to 70 percent of the total cations represented by calcium and 20 to 40 percent of the total cations represented by magnesium. Sodium commonly accounted for 0 to 20 percent of total cations.

Calcium, magnesium, sodium, potassium, chloride, and silica were detected in all samples. Bromide was detected in 97 percent of all samples, sulfate and fluoride in 91 percent, manganese in 72 percent, and iron in 69 percent. Concentration ranges for these constituents are listed in table 12 in the "Supplemental Information" section.

Table 5. Maximum Contaminant Levels, Secondary Maximum Contaminant Levels, and Health Advisory Levels for physical properties and chemical constituents detected in water samples collected from domestic wells completed in alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998

[USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level; SMCL, Secondary Maximum Contaminant Level; HAL, Health Advisory Level; µg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; E, estimated; --, not applicable; <, less than]

Constituent	MCL[1]	SMCL[1]	HAL[1]	Number of samples exceeding USEPA regulation	Sample concentration range
Physical properties					
pH (standard units)	--	6.5–8.5	--	1	5.9 – 7.4
Major ions, dissolved (µg/L)					
Chloride	--	250	--	0	<0.1 – 113
Sulfate	500	250	--	0	<0.1 – 106
Fluoride	4	2.0	--	0	<0.1 – 1.6
Trace metals, dissolved (µg/L)					
Iron	--	300	--	17	<0.10 – 10,700
Manganese	--	50	--	16	<0.4 – 654
Nutrients, dissolved (mg/L)					
Nitrite as nitrogen	1.0	--	--	0	<0.01 – 0.12
Nitrite plus nitrate as nitrogen	10	--	--	4	<0.05 – 22.0
Ammonia as nitrogen	--	--	30	0	<0.02 – 6.28
Radiochemical isotopes, (pCi/L)					
Radon-222	[2]300	--	--	18	53 – 2,146
Pesticides and pesticide metabolites, dissolved (µg/L)					
2,4-D	70	--	70	0	<0.150
2,4,5-T	--	--	70	0	<.035
Aldicarb	7.0	--	7.0	0	<.550
Aldicarb sulfone	7.0	--	7.0	0	<.021
Aldicarb sulfoxide	7.0	--	7.0	0	<.021
Atrazine	3.0	--	[3]3.0	0	<0.001 – 0.26
Bentazon	--	--	200	0	<0.014 – 0.22
Bromacil	--	--	90	0	<.035
Butylate	--	--	350	0	<.002
Carbaryl	--	--	700	0	<.008
Carbofuran	40	--	40	0	<.003
Chloramben	--	--	100	0	<.014
Chlorpyrifos	--	--	20	0	<.004
Cyanazine	--	--	1.0	0	<.004
Diazinon	--	--	.6	0	<.002
Dicamba	--	--	200	0	<.002
Dinoseb	7.0	--	7.0	0	<.003
Disulfoton	--	--	.3	0	<.017
Diuron	--	--	10	0	<.017

Table 5. Maximum Contaminant Levels, Secondary Maximum Contaminant Levels, and Health Advisory Levels for physical properties and chemical constituents detected in water samples collected from domestic wells completed in alluvial aquifers in eastern Iowa and southern Minnesota, June– July 1998—Continued

Constituent	MCL[1]	SMCL[1]	HAL[1]	Number of samples exceeding USEPA regulation	Sample concentration range
Pesticides and pesticide metabolites, dissolved (µg/L)—Continued					
Fluometron	--	--	90	0	<0.035
Fonofos	--	--	10	0	<.003
Lindane	0.2	--	.2	0	<.004
Malathion	--	--	200	0	<.005
MCPA	--	--	10	0	<.17
Methomyl	--	--	200	0	<.017
Metolachlor	--	--	70	0	< 0.002 – 0.02
Metribuzin	--	--	100	0	<.004
Oxamyl	200	--	200	0	<.210
Picloram	500	--	500	0	<0.05 – 0.17
Prometon	--	--	[3]100	0	< 0.018 – 0.19
Pronamide	--	--	50	0	<.003
Propachlor	--	--	90	0	<.007
Propham	--	--	100	0	<.035
Simazine	4.0	--	4.0	0	<.005
Tebuthiuron	--	--	500	0	<0.01 – 0.01
Terbacil	--	--	90	0	<.007
Terbufos	--	--	.9	0	<.013
Trifluralin	--	--	5.0	0	<.002
Volatile organic compounds, total (µg/L)					
Benzene	5.0	--	--	0	<.40
Benzene, 1,2,4-trichloro-	70	--	70	0	<.752
Benzene, O-dichloro-	600	--	600	0	<.192
Benzene, ethyl-	700	--	700	0	<.120
Bromoform	100/[4]80	--	--	0	<.416
Carbon tetrachloride	5.0	--	--	0	<.352
Chloroform	100/[4]80	--	--	0	< 0.052 – 16.8
Ethane, 1,1,2,2-tetrachloro-	--	--	70	0	<.176
Ethane, 1,1,1-trichloro-	200	--	200	0	<.256
Ethane, 1,2-dichloro-	5.0	--	--	0	<.536
Ethane, 1,1-dichloro-	7.0	--	7.0	0	<.264
Ethane, hexachloro-	--	--	1.0	0	<1.45
Ether, methyl-tert-butyl-	--	--	20 – [5]200	0	<.664
Ethylene, tetrachloro-	5.0	--	--	0	<.408
Ethylene, trichloro-	5.0	--	--	0	<.152

Table 5. Maximum Contaminant Levels, Secondary Maximum Contaminant Levels, and Health Advisory Levels for physical properties and chemical constituents detected in water samples collected from domestic wells completed in alluvial aquifers in eastern Iowa and southern Minnesota, June– July 1998—Continued

Constituent	MCL[1]	SMCL[1]	HAL[1]	Number of samples exceeding USEPA regulation	Sample concentration range
Volatile organic compounds, total (µg/L)—Continued					
Hexachlorobutadiene	--	--	1.0	0	<0.568
Methane, bromochloro-	--	--	10	0	<.176
Methane, dibromochloro-	100/[4]80	--	60	0	< 0.182 – 3.10
Methane, dichlorobromo-	100/[4]80	--	--	0	< 0.048 – 7.00
Methane, dichlorodifluoro-	--	--	1,000	0	<.552
Naphthalene	--	--	20	0	<1.00
Propane, 1,2,3-trichloro-	--	--	40	0	<.648
Propane, dibromochloro-	.2	--	--	0	<1.00
Propane, 1,2-dichloro-	5.0	--	--	0	<.272
Styrene	100	--	100	0	<.168
Toluene	1,000	--	1,000	0	E 0.02 – 0.18
Toluene, o-chloro-	--	--	100	0	<.168
Toluene, p-chloro-	--	--	100	0	<.224
Vinyl chloride	2.0	--	--	0	<.448
Xylene	10,000	--	10,000	0	<.256

[1] U.S. Environmental Protection Agency (1999).

[2] 1991 proposed National Primary Drinking-Water Regulation for radionuclides.

[3] Under review.

[4] 1994 proposed regulation for disinfectants and disinfection by-products. Total for all trihalomethanes combined cannot exceed the 80-µg/L level.

[5] If cancer classification is accepted, the lifetime HAL is 0.02 µg/L; otherwise, it is 0.2 µg/L.

Sulfate decreased significantly with increasing well depth ($p = 0.0137$), possibly through sulfate reduction, a bacteria-mediated anaerobic process whereby sulfate is converted to H_2S and HS^-. There appeared to be a general trend of decreasing oxygen with increasing well depth, but it was not statistically significant. Concentrations of iron exceeded the USEPA SMCL (300 µg/L) in 53 percent of the samples. Fifty percent of the samples exceeded the SMCL for manganese (50 µg/L).

Nutrients and Dissolved Organic Carbon

Nitrite and nitrate can occur in ground water through natural processes. Small amounts are produced in the atmosphere through a reaction of molecular N_2 and lightning and can be absorbed in rainwater (Hem, 1985). Under aerobic conditions, soil bacteria convert nitrogen to nitrate through the process of nitrification. Nitrite plus nitrate concentrations in ground water greater than 3.0 mg/L commonly are attributed to human activities (Madison and Brunett, 1984). In general, agricultural activities are the main source of nitrogen and are the primary cause of widespread ground-water contamination in shallow alluvial aquifers (Hallberg, 1986). Corn and soybeans are the main crops grown in the Eastern Iowa Basins study unit. More nitrogen fertilizers are used for corn than for any other crop (U.S. Department of Agriculture, 1999).

Nitrite was detected in 38 percent of the samples, and nitrite plus nitrate was detected in 53 percent of the samples. Sample concentrations of nitrite ranged from less than 0.01 to 0.12 mg/L, and concentrations of nitrite plus nitrate ranged from less than 0.05 to

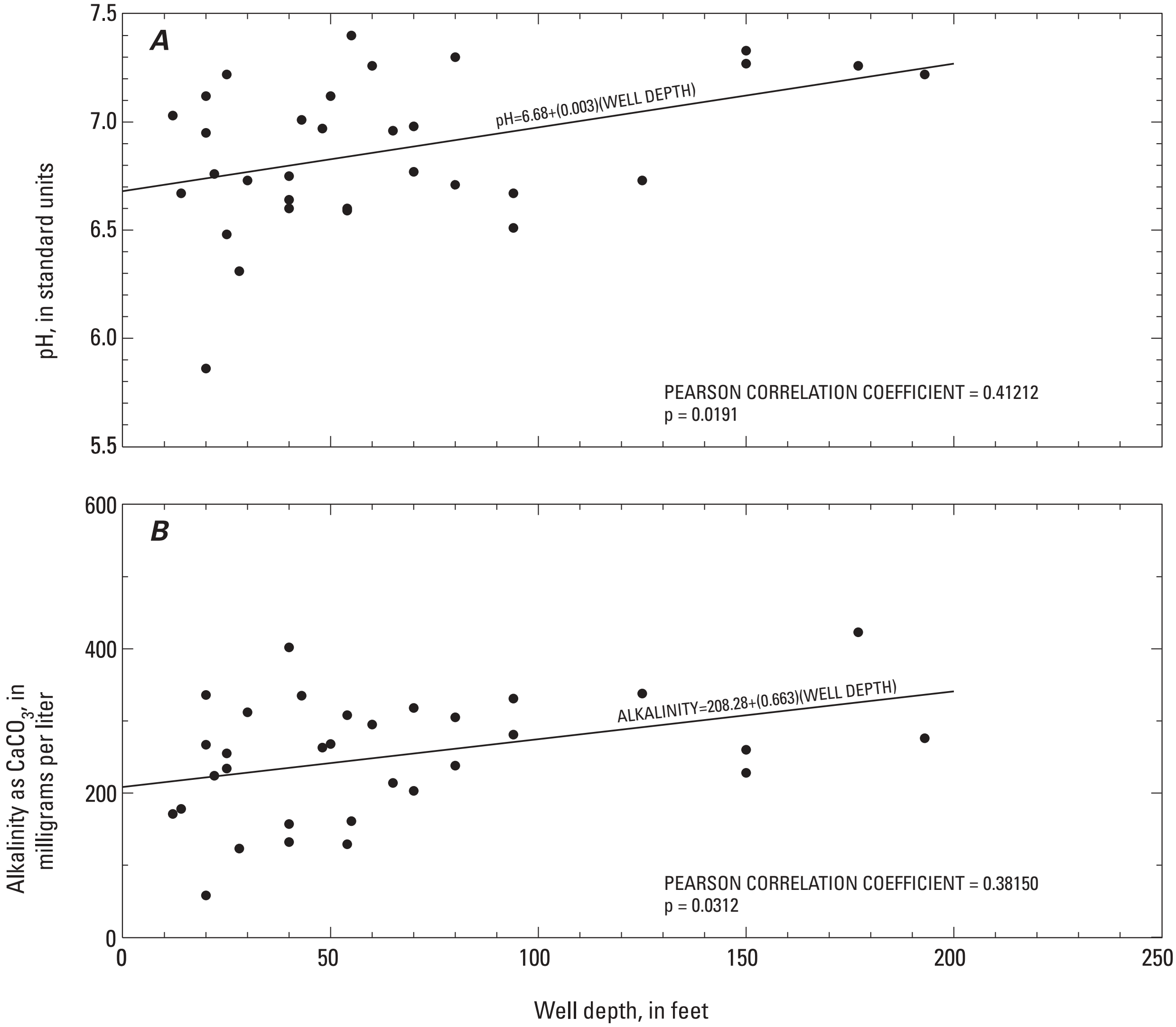

Figure 2. Relations between *(A)* well depth and pH and *(B)* well depth and alkalinity in alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998.

22 mg/L. Nitrite plus nitrate exceeded the MCL (10 mg/L) in 13 percent of the samples (table 5). Nitrite did not exceed the MCL (1.0 mg/L) in any of the samples.

Ammonia and ammonium are the most common nitrogen compounds in fertilizers (Anderholm, 1996). These compounds also occur in human and animal waste, through ammonification of organic nitrogen, and in precipitation (Freeze and Cherry, 1979; Hem, 1985). Ammonia plus organic nitrogen is associated with animal-produced fertilizers, livestock runoff, and septic systems. Ammonia was detected in 91 percent of the samples and ammonia plus organic nitrogen in 72 percent of the samples. Sample concentrations of ammonia ranged from less than 0.02 to 6.3 mg/L, and concentrations of ammonia plus organic nitrogen ranged from less than 0.1 to 6.4 mg/L.

Phosphorus is a common element in igneous and sedimentary rock but has a low solubility for most of its compounds (Hem, 1985). Elevated concentrations of phosphorus compounds in natural water can be caused by human activities. Phosphorus is a component in sewage and in some fertilizers and pesticides. Orthophosphorus was detected in 94 percent of the samples. Sample concentrations of orthophosphorus ranged from less than 0.01 to 0.77 mg/L.

DOC in ground water can occur naturally from organic debris along flow paths or can be a synthetic contaminant (Hem, 1985). All ground-water samples

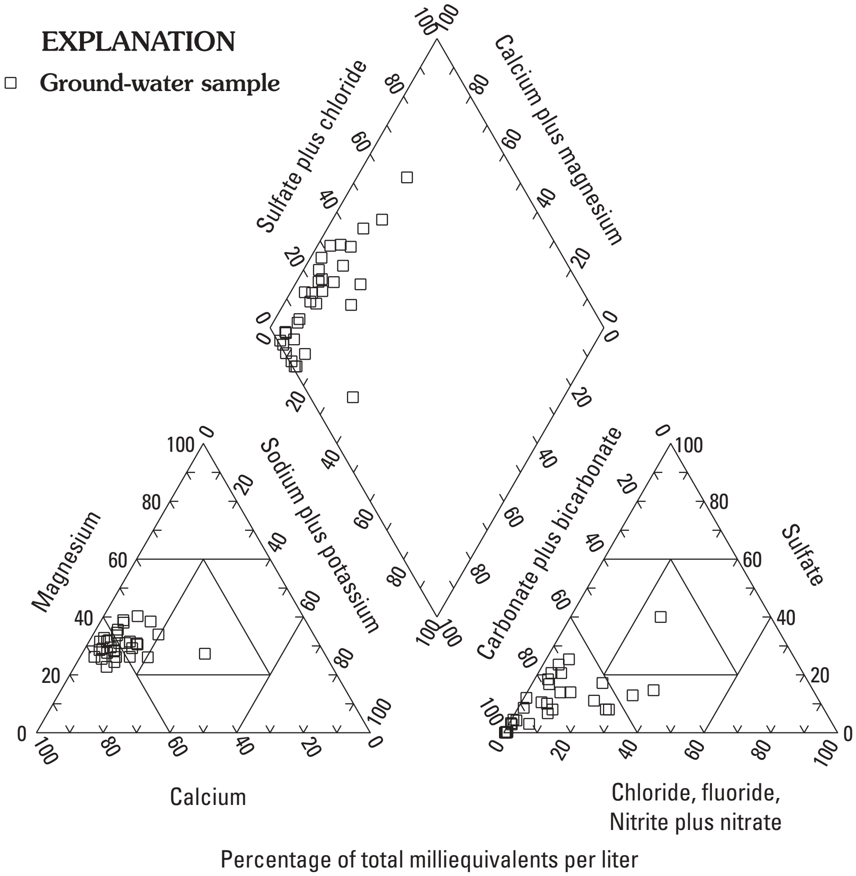

Figure 3. Chemical composition of water samples from domestic wells completed in alluvial aquifers in the Eastern Iowa Basins study unit, June– July 1998.

had detectable amounts of DOC. Sample concentrations of DOC ranged from 0.5 to 5.8 mg/L.

There was a positive correlation between ammonia plus organic nitrogen and well depth (p = 0.0260). There was a negative correlation (p = 0.0149) between nitrite plus nitrate concentration and well depth, and a positive correlation (p = 0.0001) between nitrite plus nitrate concentration and percentage of oxygen saturation (fig. 4). Oxygen is supplied to ground water through oxygen-rich recharge water and movement of air through the unsaturated zone (Hem, 1985). Depletion of dissolved oxygen in ground water can occur rapidly if there is oxidizable minerals or organic matter in the aquifer material.The sample range for dissolved oxygen was from 0.1 to 8.3 mg/L. Denitrification, the reduction by bacteria of nitrate to nitrogen gases, occurs in low-oxygen environments. The ratio of nitrite plus nitrate to ammonia had a positive correlation with percentage of oxygen saturation (p = 0.0010).

Tritium

Tritium samples were analyzed as a means to determine the relative age of ground water. Natural ground-water concentrations of tritium are less than 2.6 pCi/L (Plummer and others, 1993). Atmospheric nuclear testing beginning in the early 1950's enriched the atmosphere with tritium, thus enriching ground water through infiltration of precipitation. Ground-water samples with tritium concentrations greater than 2.6 pCi/L are considered to represent ground water that contains at least some portion of water recharged after the early 1950's. Because most pesticides were developed and used after 1950, ground-water samples with tritium values less than 2.6 pCi/L are not likely to contain pesticides or pesticide metabolites. Tritium was detected in 78 percent of the ground-water samples collected for this study; 72 percent of the samples contained tritium concentrations greater than 2.6 pCi/L. None of the ground-water samples with tritium values less than 2.6 pCi/L had detectable pesticide or pesticide metabolite concentrations.

Wilcoxon rank-sum tests were performed to compare ground-water samples representing recharge before the early 1950's (tritium concentrations less than 2.6 pCi/L) and ground-water samples representing recharge after the early 1950's (tritium concentration equal to and greater than 2.6 pCi/L). There was a significant difference (p = 0.0002) in well depth (fig. 5) between the two groups of samples (older and younger water). Ground-water samples from greater well depths generally had lower concentrations of tritium due to longer residence time. There were significant differences, between the older and younger water, in concentrations of nitrite plus nitrate (p = 0.0103) and total pesticide plus metabolite (p = 0.0014). Ground-water samples from younger water had higher

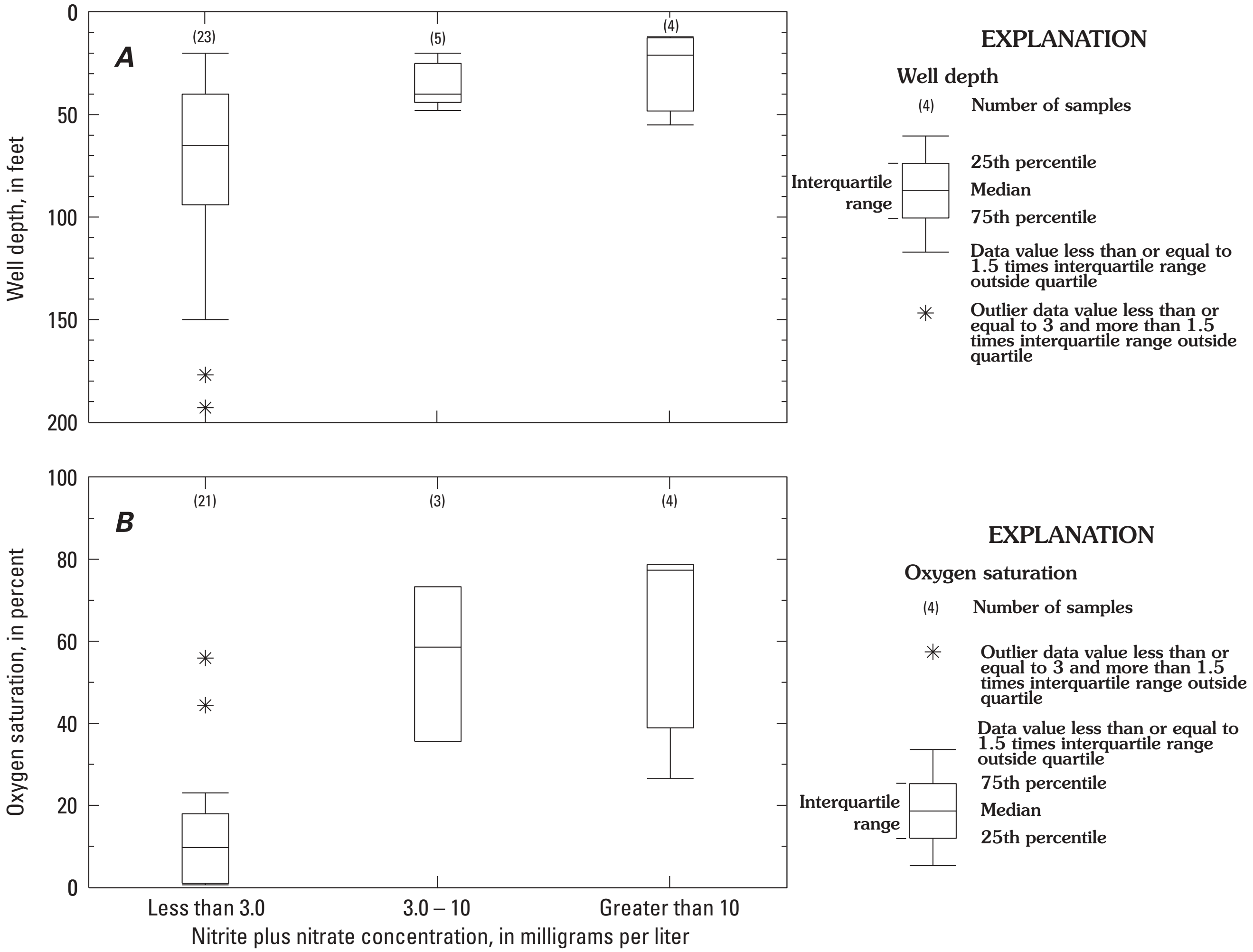

Figure 4. Relations between *(A)* well depth and nitrite plus nitrate concentration and *(B)* percentage of oxygen saturation and nitrite plus nitrate concentration in water samples from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998.

concentrations of nitrite plus nitrate and total pesticide plus metabolite.

Radon

Radon is produced naturally from the radioactive decay of radium^{226}, is water soluble, and has a half-life of 3.8 days (Hem, 1985). The source of radon is uranium-rich rock and sediment. Radon has been implicated in the development of lung cancer in people exposed over long periods to high concentrations of airborne radon (Zapecza and Szabo, 1988; Robillard and others, 1991). The USEPA previously proposed MCL for radon is 300 pCi/L. A higher alternative MCL was being considered as required by the 1996 Safe Drinking Water Act amendments (U.S. Congress, 1996).

All samples in this study had detectable concentrations of radon. Fifty-seven percent of the samples exceeded the USEPA previously proposed drinking-water MCL for radon (table 5).

Pesticides and Pesticide Metabolites

Crop yields are improved through the application of pesticides to control weeds, insects, and fungus. These pesticides may reach ground water by downward movement after application, through accidental spills, by back-siphoning accidents, and through improper disposal of formulation or rinse water (Kross and others, 1990). The frequency of pesticide detections in Iowa rural wells exceeds the national level (Glanville and others, 1995).

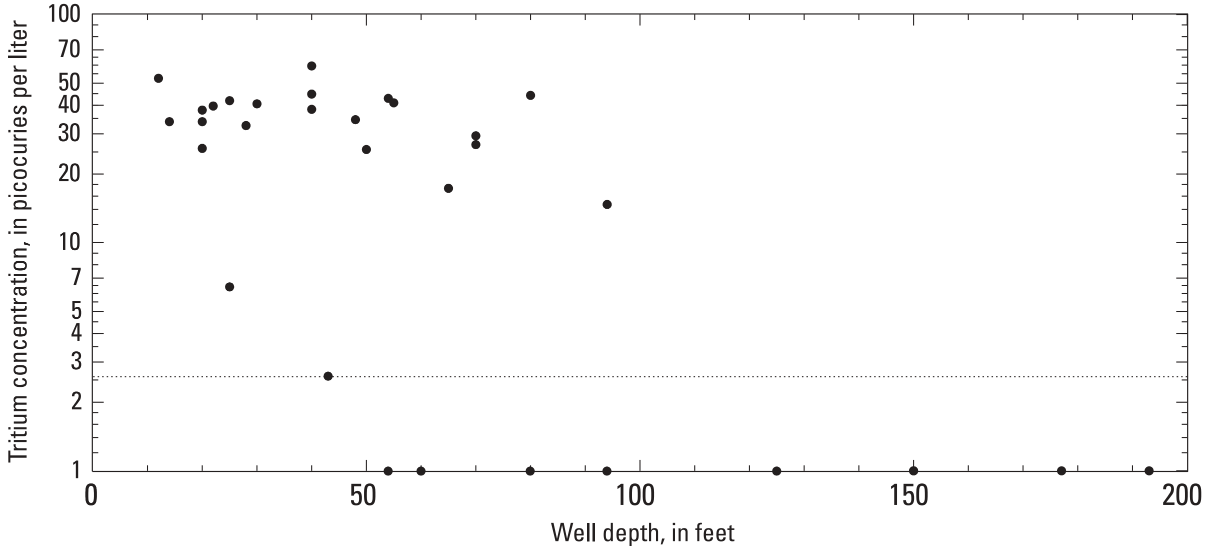

Figure 5. Relation between well depth and tritium concentration in water samples from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998. Dotted line at 2.6 picocuries per liter represents the division between pre- and post-1950's water. Concentrations at 1.0 picocurie per liter represent the minimum reporting level or less for total tritium concentrations.

Atrazine was the most commonly detected pesticide (excluding pesticide metabolites) in ground-water samples collected for this study and was detected in 38 percent of the samples (fig. 6). Sample concentrations of atrazine ranged from less than 0.001 to 0.26 µg/L. Prometon was detected in 16 percent of the samples and had a concentration range from less than 0.018 to 0.19 µg/L. Metolachlor was detected in 9 percent of the samples and had a range from less than 0.002 to 0.02 µg/L; bentazon was detected in 6 percent and had a range from less than 0.014 to 0.22 µg/L; and tebuthiuron, 3-hydroxycarbofuran, dichlorprop, and picloram were detected in 3 percent and had ranges from less than 0.01 to 0.01 µg/L, less than 0.003 to 0.07 µg/L, less than 0.032 to 0.10 µg/L, and less than 0.05 to 0.17 µg/L, respectively. Concentrations of pesticide and pesticide metabolites are graphically represented in figure 7. No pesticide exceeded its MCL (table 5).

Atrazine, bentazon, and metolachlor are herbicides frequently used on row crops. Dichlorprop, picloram, and tebuthiuron are used to control broadleaf weeds and brush in noncrop areas, commonly on utility rights-of-way. Prometon is a nonselective herbicide frequently mixed into asphalt for road construction to prevent plant growth, and 3-hydroxycarbofuran is an insecticide.

Pesticide metabolites are formed when pesticides break down into different compounds in the environment. Metabolites can be more persistent and mobile than their parent compound (Kolpin and others, 1996b), which can lead to more frequent detections and higher concentrations in ground water (figs. 6 and 7). Of the 10 most commonly detected herbicides and metabolites, 7 were metabolites. Metolachlor ethanesulfonic acid (metolachlor ESA) was the most commonly detected metabolite and was present in 45 percent of the samples. Sample concentrations of metolachlor ESA ranged from less than 0.20 to 20 µg/L. Acetochlor ESA, alachlor ESA, alachlor oxanilic acid (alachlor OA), cyanazine amide, deethylatrazine, deisopropylatrazine, and metolachlor OA also were detected. Pesticide metabolite detections are listed in table 12 in the “Supplemental Information” section. Figure 8 graphically shows concentrations of alachlor and its metabolites, atrazine and its metabolites, and metolachlor and its metabolites, in water from each well.

Volatile Organic Compounds

The VOC carbon disulfide was detected in 9 percent of the ground-water samples collected for this study. Dibromochloromethane, chloroform, dichlorobromomethane, and toluene were detected in 3 percent of the samples. No other VOC's were detected. No VOC exceeded its respective MCL (table 5). The detections of dibromochloromethane, chloroform, and dichlorobromomethane all occurred in a single sample from a 14-ft deep, 48-in. diameter, hand-dug well. The

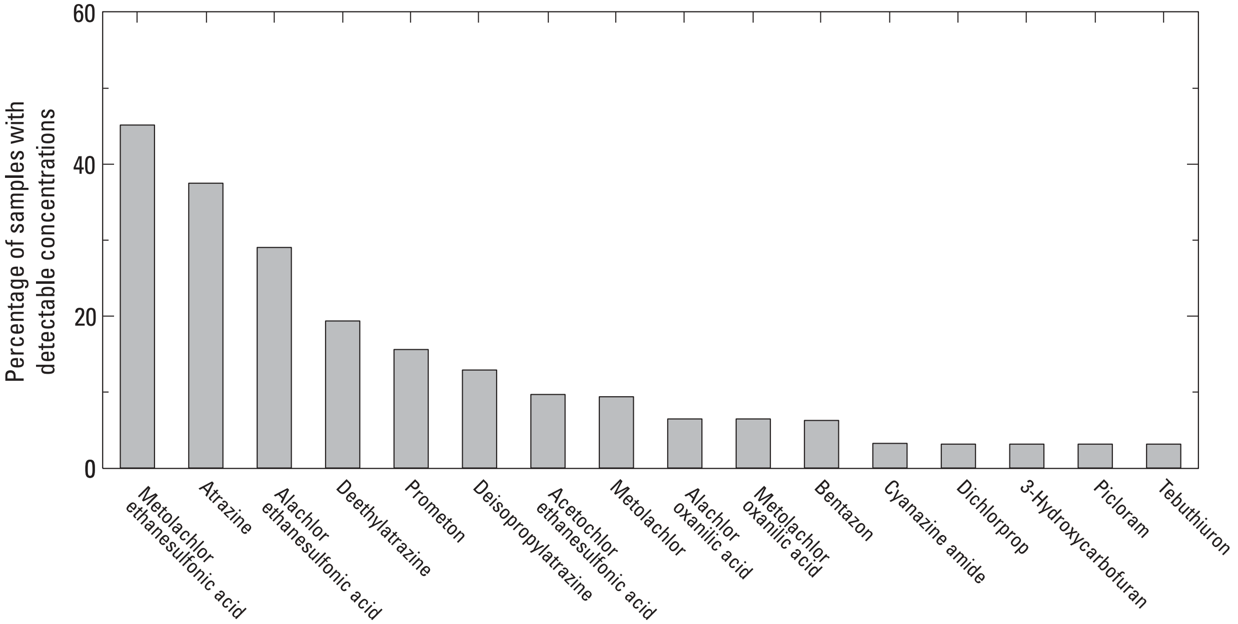

Figure 6. Percentage of water samples from alluvial aquifers in eastern Iowa and southern Minnesota with detectable concentrations of pesticides and pesticide metabolites, June–July 1998.

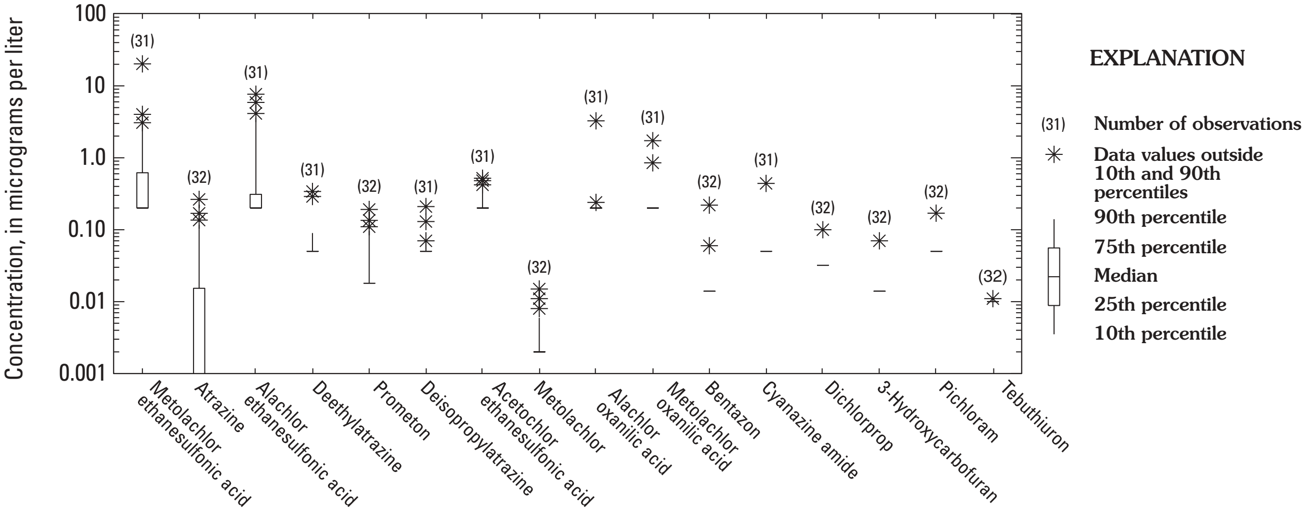

Figure 7. Concentrations of pesticides and pesticide metabolites in water samples from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998.

data suggest this well may have been disinfected with chlorine.

RELATIONS BETWEEN GROUND-WATER QUALITY AND LAND USE

The concentration and distribution of water-quality constituents determined in this study were compared statistically with land-use type in a 1,640-ft radius around the well to evaluate relations between ground-water quality and land use in the Eastern Iowa Basins. Major and secondary land-use types for each well site are listed in table 1. There was a positive correlation ($p = 0.0465$) between metolachlor and percentage of land used for soybean production, between metolachlor ESA and percentage of land used for soybean production ($p = 0.0075$) (fig. 9), and between metolachlor OA and percentage of land used for soybean production ($p = 0.0036$). These were the

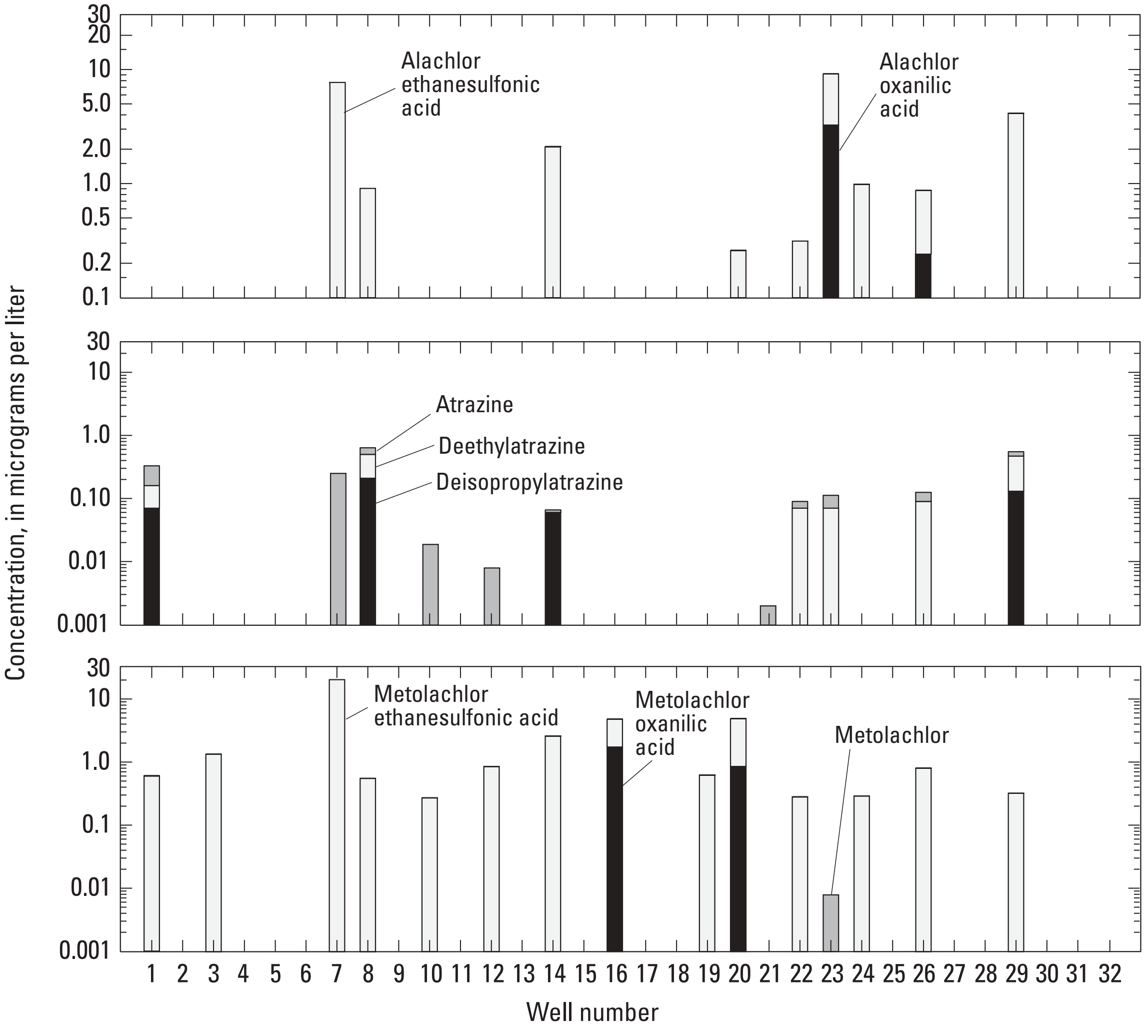

Figure 8. Concentrations of selected pesticides and their metabolites in water samples from alluvial aquifers in eastern Iowa and southern Minnesota, June–July 1998. Well numbers are shown in figure 1.

only significant relations. These relations are difficult to explain as metolachlor is used more commonly in corn rather than soybean production. Nationally, metolachlor is the second most commonly used pesticide on corn in total pounds applied, but it is only the fourth most used pesticide on soybeans (U.S. Department of Agriculture, 1999). There was no significant relation between metolachlor and percentage of land used for corn production. Perhaps landowners have rotated plantings of corn and soybeans on land near the sampled wells. Metolachlor may have been applied to these fields and later affected the underlying ground water.

RELATIONS BETWEEN GROUND-WATER QUALITY AND TYPE OF WELL SAMPLED

Well construction and pumping capacity may affect the quality of water withdrawn from wells. Data from several different studies were analyzed to provide a comparison between water-quality data collected from domestic, municipal, and monitoring wells. All data represent water from alluvial aquifers in the Eastern Iowa Basins study unit.

In 1988–89, Iowa domestic wells were sampled as part of the State-Wide Rural Well-Water Survey (SWRL) (Kross and others, 1990). Eleven wells from the SWRL data set occurred within the Eastern Iowa

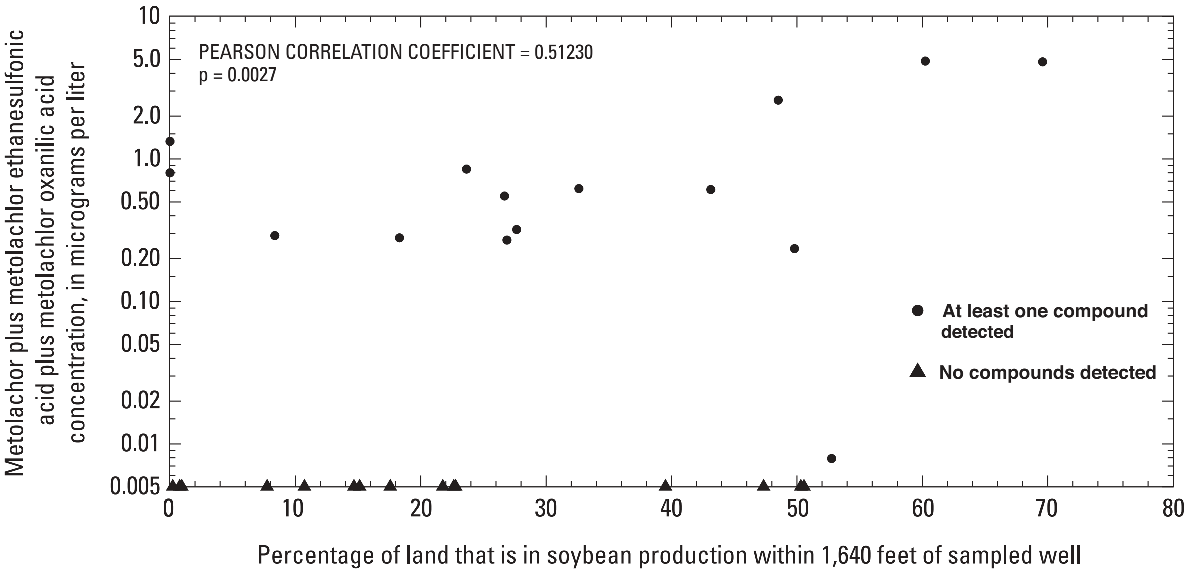

Figure 9. Relation between concentration of metolachlor plus metolachlor ethanesulfonic acid plus metolachlor oxanilic acid and percentage of land used for soybean production within 1,640 feet of sampled well.

Basins study unit and were completed in alluvial aquifers. Data from these 11 wells were combined with the data from the 32 domestic wells sampled during this study to make comparisons with municipal and monitoring wells completed in alluvial aquifers in the Eastern Iowa Basins study unit. Data from 58 municipal wells from the Iowa Ground-Water Monitoring network (GWM) (Detroy, 1985; Schaap and Linhart, 1998) and from 61 monitoring wells sampled in a NAWQA land-use study (Savoca and others, 2000) also were used in this comparison. Municipal wells from the GWM network have been sampled annually since 1982. Data from the GWM network used for the comparison described herein were collected from 1982 through 1996. Monitoring wells for the land-use study were installed by the USGS in agricultural and urban settings and were sampled during the summer of 1997. Results of the comparison of data from domestic, municipal, and monitoring wells are listed in table 6, and summary statistics are presented in table 7. The physical properties and chemical constituents in table 6 are those common to the three data sets. Wilcoxon rank-sum tests (SAS, 1990) were used to compare the data sets. Some of the data are displayed in the form of box plots in figure 10.

Well depth was significantly less for monitoring wells than for domestic wells ($p = 0.0001$) and municipal wells ($p = 0.0001$). There was a significant difference in pH between domestic- and municipal-well samples ($p = 0.0001$), and between municipal- and monitoring-well samples ($p = 0.0001$). The pH in the municipal-well samples was higher in both instances.

Calcium concentrations were significantly higher in municipal-well samples than in domestic-well samples ($p = 0.0010$). Sulfate concentrations were significantly higher in municipal-well samples than in domestic-well samples ($p = 0.0001$) and monitoring-well samples ($p = 0.0001$). Chloride concentrations were significantly lower in domestic-well samples than in municipal-well samples ($p = 0.0003$) and monitoring-well samples ($p = 0.0006$). Fluoride concentrations were significantly higher in domestic-well samples than in municipal-well samples ($p = 0.0200$).

Ammonia concentrations were significantly higher in domestic-well samples than in monitoring-well samples ($p = 0.0087$). Atrazine concentrations were significantly higher in municipal-well samples than in domestic-well samples ($p = 0.0361$).

The differences in the three types of wells may explain the differences in water quality. Generally, both domestic and municipal wells are deeper than monitoring wells. Major ion concentrations tend to increase with depth due to the greater residence time with increasing depth of ground water. This may explain the higher pH and concentrations of sulfate in the municipal wells. These had positive correlations with well depth ($p = 0.0001$ for pH and $p = 0.0417$ for sulfate). Chloride did not follow this pattern and had higher concentrations in ground-water samples from the monitoring wells than in samples from domestic wells. A possible explanation could be the application of road salt. Many of the monitoring wells were constructed on public rights-of-way alongside roads in both urban and rural areas.

Municipal wells have large screens and pumps that enable them to withdraw both deep and shallow water from a large area of the aquifer. This may explain the higher pH and concentrations of calcium, sulfate, chloride, and atrazine in ground-water samples from the municipal wells than in samples from the domestic wells. The reason for higher fluoride concentrations in samples from domestic wells than in samples from municipal wells is not known.

The higher ammonia concentrations in samples from domestic wells than in samples from monitoring wells possibly could be due to the reduction of nitrate to ammonia in low-oxygen environments that occur in deeper wells. There was a positive correlation between concentrations of ammonia and well depth ($p = 0.0001$) and a negative correlation between well depth and concentrations of oxygen ($p = 0.0334$).

SUMMARY

Ground-water samples from 32 domestic wells completed in alluvial aquifers in the Eastern Iowa Basins were collected from June through July 1998 and analyzed to determine concentrations of major ions, trace metals, nutrients, DOC, tritium, radon, pesticides and pesticide metabolites, and VOC's. Onsite measurements of specific conductance, pH, water temperature, dissolved oxygen, and alkalinity were obtained for each well. Forty-five percent of ground water pumped in the Eastern Iowa Basins originates from alluvial aquifers. The alluvial aquifers consist of varying thicknesses of sand, gravel, silt, and clay deposits, and occur along most of the major streams and rivers.

There were significant increases in pH and alkalinity with increasing well depth. These increases can be attributed to longer ground-water residence time associated with the increased depths. The dominant major ions in most samples were calcium and bicarbonate, likely derived from the dissolution of carbonate minerals in the alluvial aquifer material. Concentrations of iron exceeded the USEPA SMCL (300 µg/L) in 53 percent of the samples, and 50 percent of the samples exceeded the SMCL for manganese (50 µg/L). Sulfate concentrations decreased significantly with increasing well depth, possibly through sulfate reduction.

Ammonia and orthophosphorus were the most commonly detected nutrients. Nitrite plus nitrate and ammonia plus organic nitrogen had the highest nutrient concentrations. Nitrite plus nitrate exceeded its MCL (10 mg/L) in 13 percent of the samples. There was a positive correlation between nitrite plus nitrate concentration and percentage of oxygen saturation, and a negative correlation between nitrite plus nitrate

Table 6. Results of Wilcoxon rank-sum tests comparing domestic-, municipal-, and monitoring-well ground-water-quality data collected from alluvial aquifers in eastern Iowa and southern Minnesota

[ns, not significantly different; p, probability that observed difference occurs by chance. p less than 0.05 indicates significant difference]

Physical property or chemical constituent	Comparison of Domestic and municipal wells	 Domestic and monitoring wells	 Monitoring and municipal wells
Physical properties			
Well depth	ns	$p = 0.0001^1$	$p = 0.0001^2$
Specific conductance	ns	ns	ns
pH	$p = 0.0001^2$	ns	$p = 0.0001^2$
Dissolved oxygen	ns	ns	ns
Major ions			
Calcium	$p = 0.0010^2$	ns	ns
Magnesium	ns	ns	ns
Sodium	ns	ns	ns
Potassium	ns	ns	ns
Sulfate	$p = 0.0001^2$	ns	$p = 0.0001^2$
Chloride	$p = 0.0003^2$	$p = 0.0006^3$	ns
Fluoride	$p = 0.0200^1$	ns	ns
Nutrients			
Nitrite plus nitrate	ns	ns	ns
Ammonia	ns	$p = 0.0087^1$	ns
Pesticides and pesticide metabolites			
Alachlor	ns	ns	ns
Atrazine	$p = 0.0361^2$	ns	ns
Deethylatrazine	ns	ns	ns
Metribuzin	ns	ns	ns

[1] Value of physical property or chemical constituent for domestic-well sample is significantly higher.

[2] Value of physical property or chemical constituent for municipal-well sample is significantly higher.

[3] Value of physical property or chemical constituent for monitoring-well sample is significantly higher.

Table 7. Percentile values of selected physical properties and chemical constituents in water samples from domestic, municipal, and monitoring wells completed in alluvial aquifers in eastern Iowa and southern Minnesota

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

Physical property or chemical constituent (unit of measurement)	Percentiles								
	Domestic wells			Municipal wells			Monitoring wells		
	10th	Median	90th	10th	Median	90th	10th	Median	90th
Physical properties									
Well depth (feet below land surface)	15	43	125	28	41	65	16	19	28
pH (standard units)	6.6	7.0	7.4	6.7	7.3	7.6	6.1	6.9	7.3
Major ions									
Calcium (mg/L)	42	67	101	65	82	110	48	77	121
Sulfate (mg/L)	.8	31	73	27	60	120	6.7	29	115
Chloride (mg/L)	.4	8.8	23	8.0	15	28	4.2	16	86
Fluoride (mg/L)	<.2	<.2	.3	<.2	<.2	.3	<.2	<.2	.3
Nutrient									
Ammonia (mg/L)	<.10	<.10	1.4	<.10	<.10	.30	<.10	<.10	.23
Pesticide									
Atrazine (µg/L)	<.10	<.10	.17	<.10	<.10	.32	<.10	<.10	.20

concentration and well depth. There was a positive correlation between ammonia plus organic nitrogen and well depth. The ratio of nitrite plus nitrate to ammonia had a positive correlation with percentage of oxygen saturation.

Tritium data indicate the majority of samples, 72 percent, contained water recharged since the early 1950's. Ground-water samples from greater well depths had lower concentrations of tritium due to longer residence time. Ground-water samples from younger water had higher concentrations of nitrite plus nitrate and total pesticides plus metabolites. These relations are due to recharge of young tritium-enriched water transporting pesticides and fertilizers to the ground water. Older ground water recharged before the 1950's would not contain pesticides or relatively high concentrations of nitrite plus nitrate. All samples had detectable concentrations of radon. Fifty-seven percent of the samples exceeded USEPA previously proposed drinking-water MCL for radon (300 pCi/L).

Atrazine and prometon, found in 38 and 16 percent of the samples, respectively, were the most common pesticides detected in ground-water samples. Median concentrations were higher for pesticide metabolites than for pesticides. Metolachlor ESA was the most commonly detected metabolite.

Carbon disulfide was the most common VOC detected in 9 percent of the samples. Dibromochloromethane, chloroform, dichlorobromomethane, and toluene were detected in 3 percent of the samples. No VOC exceeded its MCL.

There were positive correlations between percentage of land used for soybean production and metolachlor, metolachlor ESA, and metolachlor OA. Metolachlor is more commonly used for corn than soybeans. Perhaps landowners have rotated plantings of corn and soybeans on land near the sampled wells. Metolachlor may have been applied to these fields and later affected the underlying ground water.

A comparison was made using previously collected data and data from this study to determine differences in water quality between domestic, municipal, and monitoring wells completed in alluvial aquifers in the Eastern Iowa Basins study unit. Well depth was significantly greater for domestic and municipal wells than for monitoring wells. pH, calcium, sulfate, chloride, and atrazine concentrations were significantly higher in municipal-well samples than in domestic-well samples. pH values and sulfate concentrations were significantly higher in municipal-well samples than in monitoring-well samples. Ammonia concentrations were significantly higher in domestic-well samples than in monitoring-well samples, chloride concentrations were significantly higher in monitoring-well samples than in domestic-well samples, and fluoride concentrations were significantly higher in domestic-well samples than in municipal-well samples.

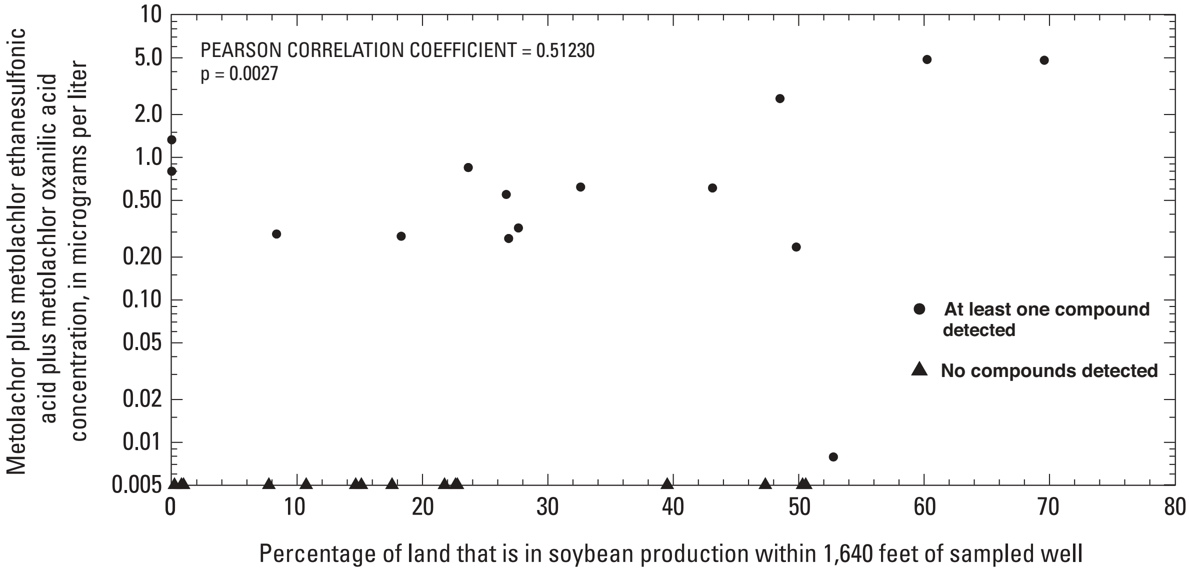

Figure 10. Relations between selected physical properties and chemical constituents in water samples and different well types completed in alluvial aquifers in eastern Iowa and southern Minnesota.

Major ion concentrations tend to increase with depth due to the greater residence time with increasing depth of ground water. This would explain the higher pH and concentrations of sulfate in the municipal wells. These had positive correlations with well depth. Chloride concentrations did not follow this pattern and had higher concentrations in ground-water samples from the monitoring wells than in samples from domestic wells. A possible explanation could be the application of road salt.

Municipal wells have large screens and pumps that enable them to withdraw both deep and shallow water from a large area of the aquifer. This can explain the higher pH and concentrations of calcium, sulfate, chloride, and atrazine in water samples from the municipal wells than in samples from the domestic wells.

The higher ammonia concentrations in ground-water samples from domestic wells than in samples from monitoring wells could possibly be due to the reduction of nitrate to ammonia in low oxygen environments that occur in deeper wells. There was a positive correlation between ground-water sample concentrations of ammonia and well depths and a negative correlation between well depths and ground-water sample concentrations of oxygen.

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SUPPLEMENTAL INFORMATION

Table 8. Physical properties or chemical constituents detected in blank samples, minimum reporting levels (MRL's), method detection limits (MDL's), and concentration ranges in blank and regular samples, June–July 1998

[mg/L, milligrams per liter; --, not available; µg/L, micrograms per liter; E, estimated]

Physical property or chemical constituent (unit of measurement)	MRL or MDL	Number of blank samples/ number of detections in blank samples	Concentration range	
			Blank sample range	Regular sample range
Physical properties				
Hardness as $CaCO_3$ (mg/L)	--	3/2	0.16 – 0.286	141 – 476
Major ions and trace metals				
Calcium (mg/L)	0.02	3/2	0.06 – 0.10	39 – 110
Magnesium (mg/L)	.01	3/2	0.005 – 0.007	8.6 – 49
Fluoride (mg/L)	.1	3/1	.10	<0.10 – 1.6
Silica (mg/L)	.1	3/1	.17	7.2 – 28
Iron (µg/L)	10	3/1	11	<10 – 9,710
Nutrients				
Nitrite plus nitrate (mg/L as N)	.01	3/1	.10	<0.05 – 22
Ammonia (mg/L as N)	.01	3/1	.04	<0.02 – 6.3
Phosphorus (mg/L as P)	.001	3/1	.01	<0.01 – 0.93
Orthophosphorus (mg/L as P)	.001	3/1	.02	<0.01 – 0.77
Carbon				
Dissolved organic carbon (mg/L as C)	.1	3/2	.4	0.5 – 5.8
Volatile organic compounds				
Acetone (µg/L)	4.9 – 20	3/1	E3.0	<4.9 – <20
Carbon disulfide (µg/L)	0.08 – 1.5	3/3	E0.02 – 0.14	<0.08 – 2.8
Dichlorodifluoromethane (µg/L)	0.01 – 0.56	3/2	E0.11 – E0.73	<0.10 – E0.73
Toluene (µg/L)	.04 – 0.22	3/3	E0.03 – E0.04	<0.04 – E0.07

Table 9. Chemical constituents with relative percentage differences greater than 10 percent in replicate samples, June–July 1998

[RPD, relative percentage differences; MRL, minimum reporting level; MDL, method detection limit; mg/L, milligrams per liter; µg/L, micrograms per liter]

Chemical constituent (unit of measurement)	Number of replicates/number of RPD's greater than 10 percent	Mean concentration	Difference in concentration	MRL or MDL	RPD
Major ions					
Fluoride (mg/L)	2/2	0.18 / 0.21	0.03 / 0.03	0.1	16 / 14
Bromide (mg/L)	2/1	.03	.01	.1	41
Nutrients					
Nitrite plus nitrate (mg/L)	2/1	.12[1]	.18[1]	.01	157[1]
Ammonia (mg/L)	2/1	.03	.01	.01	48
Ammonia plus organic nitrogen (mg/L)	2/1	.15	.11	.1	70
Phosphorus (mg/L)	2/1	.15	.02	.001	13
Orthophosphorus (mg/L)	2/1	.16	.06	.001	36
Carbon					
Dissolved organic carbon (mg/L)	2/1	1.5	.30	.1	19
Volatile organic compounds					
Carbon disulfide (µg/L)	2/2	0.05[2] /0.02[2]	0.04[2]/0.01[2]	0.08–1.5	76[2] / 52[2]
Chloroform (µg/L)	2/1	.02[1]	.02[1]	0.05–0.21	89[1]
Meta-paraxylene (µg/L)	2/1	.02[2]	.002[2]	0.06 – 0.26	12
Toluene (µg/L)	2/1	.04[2]	.005[2]	0.04–0.22	12[2]

[1] One value was less than detection limit; value set as one-half of detection limit.

[2] Both values were estimated values less than the MRL.

Table 10. Spike recovery percentages for pesticides and pesticide metabolites, with spike and sample concentrations, June–July 1998

[µg/L, microgram per liter; <, less than; E, estimated; --, not applicable]

Pesticide or pesticide metabolite	Number of field-spiked samples	Spike concentration (µg/L)	Sample concentration (µg/L)	Spike recovery (percent range)
Acetochlor	1	0.12	<0.002	102–103
Acifluorfen	1	E .86	<.035	71–74
Alachlor	1	.126	<.002	103–105
Aldicarb	1	<.55	<.55	--
Aldicarb sulfone	1	<.37	<.10	--
Aldicarb sulfoxide	1	<.021	<.021	--
Alpha-BHC	1	.0787	<.002	64–66
Atrazine	1	.268	.17	83
Benfluralin	1	.0695	<.002	56–58
Bentazon	1	<1.75	<.014	--
Bromocil	1	<.035	<.035	--
Bromoxynil	1	.67	<.035	55–58
Butylate	1	<.002	<.002	--
Carbaryl	1	E .581	<.003	50
Carbofuran	1	.08	<.12	0–67
Carbofuran	1	E .232	<.003	20
Chlopyrolid	1	E .26	<.23	3–23
Chloramben methyl ester	1	<.42	<.42	--
Chlorothalonil	1	E .38	<.48	0–41
Chlorpyrifos	1	<.004	<.004	--
cis-permethrin	1	.0635	<.005	49–53
Cyanazine	1	.0885	<.004	70–74
Dacthal (DCPA)	1	.0765	<.003	61–64
Deethylatrazine	1	E .0593	E .032	23
Diazinon	1	<.002	<.002	--
Dicamba	1	.96	<.035	80–83
Dichlorprop	1	.90	<.032	75–78
Dieldrin	1	.11	<.001	94–95
Dinoseb	1	<.035	<.035	--
Disulfoton	1	<.017	<.017	--
Diuron	1	.71	<.02	59–61
Eptam (EPTC)	1	<.002	<.002	--
Ethalfluralin	1	.04	<.004	34–37
Fenuron	1	<1.0	<.013	--
Fluometuron	1	.85	<.035	70–73

Table 10. Spike recovery percentages for pesticides and pesticide metabolites, with spike and sample concentrations, June–July 1998—Continued

Pesticide or pesticide metabolite	Number of field-spiked samples	Spike concentration (µg/L)	Sample concentration (µg/L)	Spike recovery (percent range)
Lindane	1	0.09	<0.004	72–75
Linuron	1	.84	<.018	71–72
Linuron	1	.17	<.002	138–140
Malathion	1	<.005	<.005	--
MCPA	1	.64	<.17	41–55
MCPB	1	.66	<.14	45–57
Methiocarb	1	<.026	<.026	--
Methomyl	1	<.017	<.017	--
Methyl azinphos	1	<.001	<.001	--
Methyl parathion	1	<.006	<.006	--
Metolachlor	1	.12	.010	90
Metribuzin	1	.04	<.004	30–34
Molinate	1	<.004	<.004	--
Napropamide	1	.06	<.003	52–54
Neburon	1	E .7	<.015	59–60
Norflurazon	1	<.024	<.024	--
Oryzalin	1	<1.25	<.91	--
Oxamyl	1	.62	<.018	52–53
Parathion	1	<.004	<.004	--
Pebulate	1	<.004	<.004	--
Phorate	1	<.002	<.002	--
Picloram	1	.55	<.05	43–47
Prometon	1	.26	.14	104
Pronamide	1	.08	<.003	66–68
Propachlor	1	.11	<.007	88–94
Propanil	1	.10	<.004	78–81
Propargite	1	.11	<.013	83–94
Propham	1	.23	<.035	17–20
Propoxur	1	<.87	<.035	--
Pendimethalin	1	.09	<.004	68–72
Simazine	1	.09	<.005	68–72
Tebuthiuron	1	.11	<.01	82–90
Terbacil	1	<.007	<.007	--
Terbufos	1	<.013	<.013	--
Thiobencarb	1	.02	<.002	11–13
Triallate	1	.04	<.001	36–37

Table 10. Spike recovery percentages for pesticides and pesticide metabolites, with spike and sample concentrations, June–July 1998—Continued

Pesticide or pesticide metabolite	Number of field-spiked samples	Spike concentration (µg/L)	Sample concentration (µg/L)	Spike recovery (percent range)
Triclopyr	1	0.84	<0.25	51–72
Trifluralin	1	.08	<.002	64–65
2,4-D	1	.74	<.15	51–64
2,4-DB acid	1	<.76	<.24	--
2,4,5-T	1	.78	<.035	64–67
2,6-Diethylaniline	1	<.003	<.003	--
3-Hydroxycarbofuran	1	.51	.07	38
p,p’-DDE	1	.06	<.006	43–48

Table 11. Spike recovery percentages for volatile organic compounds (VOC's), with spike and sample concentrations, June–July 1998

[µg/L, microgram per liter; <, less than; E, estimated]

VOC	Number of field-spiked samples	Spike concentration (µg/L)	Sample concentration (µg/L)	Spike recovery (percent range)
Bromodichloromethane	1	9.1	7.0	89
Bromoform	1	2.1	.30	79
Carbon tetrachloride	1	2.2	<.088	92–96
Dibromochloromethane	1	5.0	3.1	82
1,4-Dichlorobenzene	1	1.6	<.05	65–67
1,2-Dichloroethane	1	2.2	<.134	89–95
1,1-Dichloroethylene	1	1.4	<.044	67–69
Ethylbenzene	1	1.2	<.03	48–50
Methyl-tert-butyl-ether	1	2.0	<.166	80–87
Tetrachloroethene	1	1.9	<.102	85–90
1,1,1-Trichloroethane	1	2.2	<.032	95–96
Trichloroethylene	1	2.2	<.038	94–96
Vinyl chloride	1	E0.05	<.112	0–2

Table 12. Statistical summary of selected well measurements and ground-water-quality data from water samples collected from alluvial aquifers in the Eastern Iowa Basins, Iowa and Minnesota, June–July 1998

[MRL, minimum reporting level; MDL, method detection limit for pesticides and pesticide metabolites; --, not applicable; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; <, less than; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Constituent (unit of measurement)	Number of samples/ number of observations or detections	MRL or MDL	Minimum value	Maximum value	Median value
Well measurements and physical properties of water					
Well depth (feet below land surface)	32 / --	--	12	193	54
Water level (feet below land surface)	32 / --	--	2	81	11
Specific conductance (µS/cm at 25 °C)	32 / 32	1.0	331	1,150	559
pH (standard units)	32 / 32	.10	5.9	7.4	6.9
Water temperature (°C)	32 / 30	--	9.7	15.8	12.0
Dissolved oxygen (mg/L)	32 / 31	--	.1	8.3	1.6
Alkalinity (mg/L as $CaCO_3$)	32/ 32	1.0	58	423	262
Major ions, dissolved (mg/L)					
Calcium	32 / 32	.02	39	110	67
Magnesium	32 / 32	.01	8.6	49	21
Sodium	32 / 32	.2	4.6	77	9.3
Potassium	32 / 32	.1	.3	10	1.4
Chloride	32 / 32	.1	.2	113	7.5
Sulfate	32 / 29	.1	<.1	106	28
Fluoride	32 / 29	.1	<.1	1.6	.3
Bromide	32 / 31	.1	<.01	.49	.05
Silica	32 / 32	.1	7.2	28	19
Trace metals, dissolved (µg/L)					
Iron	32 / 22	10	<10	10,700	1,300
Manganese	32 / 21	1	<4	654	45
Nutrients, dissolved (mg/L)					
Nitrite as nitrogen	32 / 12	.01	<.01	.12	<.01
Nitrite plus nitrate as nitrogen	32 / 17	.01	<.05	22	.07
Ammonia as nitrogen	32 / 29	.01	<.02	6.3	.15
Ammonia plus organic nitrogen	32 / 23	.1	<.1	6.4	.4
Phosphorus	32 / 28	.001	<.01	.93	.05
Orthophosphorus as phosphorus	32 / 30	.001	<.01	.77	.04
Carbon, dissolved (mg/L)					
Organic carbon	32 / 32	.1	.5	5.8	1.5
Radiochemical isotopes (pCi/L)					
Radon-222	32 / 32	80	53	2,150	340
Trtitium	32 / 25	1.0	<1.0	60	28
Pesticides and pesticide metabolites, dissolved (µg/L)					
2,4,5-T	32 / 0	.035	<.035	<.035	<.035
2,4-D	32 / 0	.15	<.15	<.15	<.15

Table 12. Statistical summary of selected well measurements and ground-water-quality data from water samples collected from alluvial aquifers in the Eastern Iowa Basins, Iowa and Minnesota, June– July 1998—Continued

Constituent (unit of measurement)	Number of samples/ number of observations or detections	MRL or MDL	Minimum value	Maximum value	Median value
Pesticides and pesticide metabolites, dissolved (µg/L)—Continued					
2,4-DB	32 / 0	0.24	<0.24	<0.24	<0.24
3-hydroxyarbofuran	32 / 1	.014	<.014	.07	<.014
Acetochlor	32 / 0	.002	<.002	<.002	<.002
Acetochlor ethanesulfonic acid	31 / 3	.20	<.20	.50	<.20
Acetochlor oxanilic acid	31 / 0	.20	<.20	<.20	<.20
Acifluorfen	32 / 0	.035	<.035	<.035	<.035
Alachlor	32 / 0	.002	<.002	<.002	<.002
Alachlor ethanesulfonic acid	31 / 9	.20	<.20	7.7	<.20
Alachlor oxanilic acid	31 / 2	.20	<.20	3.2	<.20
Aldicarb	32 / 0	.55	<.55	<.55	<.55
Aldicarb sulfone	32 / 0	.10	<.10	<.10	<.10
Aldicarb sulfoxide	32 / 0	.021	<.021	<.021	<.021
Atrazine	32 / 12	.001	<.001	.26	<.001
Atrazine, deethyl-	31 / 6	.05	<.05	.34	<.05
Atrazine, deisopropyl-	31 / 4	.05	<.05	.21	<.05
Atrazine, hydroxy-	31 / 0	.20	<.20	<.20	<.20
Azinphos, methyl-	32 / 0	.001	<.001	<.001	<.001
Benfluralin	32 / 0	.002	<.002	<.002	<.002
Bentazon	32 / 2	.014	<.014	.22	<.014
Bromacil	32 / 0	.035	<.035	<.035	<.035
Bromoxynil	32 / 0	.035	<.035	<.035	<.035
Butylate	32 / 0	.002	<.002	<.002	<.002
Carbaryl	32 / 0	.003	<.003	<.003	<.003
Carbofuran	32 / 0	.12	<.12	<.12	<.12
Chloramben	32 / 0	.42	<.42	<.42	<.42
Chlorothalonil	32 / 0	.48	<.48	<.48	<.48
Chlorpyrifos	32 / 0	.004	<.004	<.004	<.004
Clopyralid	32 / 0	.23	<.23	<.23	<.23
Cyanazine	32 / 0	.004	<.004	<.004	<.004
Cyanazine amide	31 / 1	.05	<.05	.44	<.05
Dacthal, mono-acid-	32 / 0	.017	<.017	<.017	<.017
DCPA	32 / 0	.002	<.002	<.002	<.002
p,p’-DDE	32 / 0	.006	<.006	<.006	<.006
Diazinon	32 / 0	.002	<.002	<.002	<.002
Dicamba	32 / 0	.035	<.035	<.035	<.035

Table 12. Statistical summary of selected well measurements and ground-water-quality data from water samples collected from alluvial aquifers in the Eastern Iowa Basins, Iowa and Minnesota, June– July 1998—Continued

Constituent (unit of measurement)	Number of samples/ number of observations or detections	MRL or MDL	Minimum value	Maximum value	Median value
Pesticides and pesticide metabolites, dissolved (µg/L)—Continued					
Dichlobenil	32 / 0	1.2	<1.2	<1.2	<1.2
Dichlorprop	32 / 1	.032	<.032	.10	<.032
Dieldrin	32 / 0	.001	<.001	<.001	<.001
2,6-Diethylaniline	32 / 0	.003	<.003	<.003	<.003
Dinoseb	32 / 0	.035	<.035	<.035	<.035
Disulfoton	32 / 0	.017	<.017	<.017	<.017
Diuron	32 / 0	.020	<.020	<.020	<.020
DNOC	32 / 0	.020	<.020	<.020	<.020
EPTC	32 / 0	.002	<.002	<.002	<.002
Ethalfluralin	32 / 0	.004	<.004	<.004	<.004
Ethoprop	32 / 0	.003	<.003	<.003	<.003
Fenuron	32 / 0	.013	<.013	<.013	<.013
Fluometuron	32 / 0	.035	<.035	<.035	<.035
Fonofos	32 / 0	.003	<.003	<.003	<.003
alpha-HCH	32 / 0	.002	<.002	<.002	<.002
Lindane	32 / 0	.004	<.004	<.004	<.004
Linuron	32 / 0	.002	<.002	<.002	<.002
Malathion	32 / 0	.005	<.005	<.005	<.005
MCPA	32 / 0	.17	<.17	<.17	<.17
MCPB	32 / 0	.14	<.14	<.14	<.14
Methiocarb	32 / 0	.026	<.026	<.026	<.026
Methomyl	32 / 0	.017	<.017	<.017	<.017
Metolachlor	32 / 3	.002	<.002	.02	<.002
Metolachlor ethanesulfonic acid	31 / 14	.20	<.20	20	<.20
Metolachlor oxanilic acid	31 / 2	.20	<.20	1.7	<.20
Metribuzin	32 / 0	.004	<.004	<.004	<.004
Molinate	32 / 0	.004	<.004	<.004	<.004
1-Naphthol	32 / 0	.007	<.007	<.007	<.007
Napropamide	32 / 0	.003	<.003	<.003	<.003
Neburon	32 / 0	.015	<.015	<.015	<.015
Norflurazon	32 / 0	0.024 – 0.150	<.024	<.150	<.024
Oryzalin	32 / 0	0.310 – 1.06	<.310	<1.06	<.310
Oxamyl	32 / 0	0.018 – 0.210	<.018	<.210	<.018
Parathion	32 / 0	.004	<.004	<.004	<.004
Parathion, methyl-	32 / 0	.006	<.006	<.006	<.006

Table 12. Statistical summary of selected well measurements and ground-water-quality data from water samples collected from alluvial aquifers in the Eastern Iowa Basins, Iowa and Minnesota, June– July 1998—Continued

Constituent (unit of measurement)	Number of samples/ number of observations or detections	MRL or MDL	Minimum value	Maximum value	Median value
Pesticides and pesticide metabolites, dissolved (µg/L)—Continued					
Pebulate	32 / 0	0.004	<0.004	<0.004	<0.004
Pendimethalin	32 / 0	.004	<.004	<.004	<.004
cis-Permethrin	32 / 0	.005	<.005	<.005	<.005
Phorate	32 / 0	.002	<.002	<.002	<.002
Picloram	32 / 1	.05	<.05	.17	<.05
Prometon	32 / 5	.018	<.018	.19	<.018
Pronamide	32 / 0	.003	<.003	<.003	<.003
Propachlor	32 / 0	.007	<.007	<.007	<.007
Propanil	32 / 0	.004	<.004	<.004	<.004
Propargite	32 / 0	.013	<.013	<.013	<.013
Propham	32 / 0	.035	<.035	<.035	<.035
Propoxur	32 / 0	.035	<.035	<.035	<.035
Silvex	32 / 0	.021	<.021	<.021	<.021
Simazine	32 / 0	.005	<.005	<.005	<.005
Tebuthiuron	32 / 1	.01	<.01	.01	<.01
Terbacil	32 / 0	.007	<.007	<.007	<.007
Terbufos	32 / 0	.013	<.013	<.013	<.013
Thiobencarb	32 / 0	.002	<.002	<.002	<.002
Triallate	32 / 0	.001	<.001	<.001	<.001
Triclopyr	32 / 0	.25	<.25	<.25	<.25
Trifluralin	32 / 0	.002	<.002	<.002	<.002
Volatile organic compounds, total (µg/L)					
1,1,1,2-Tetrachloroethane	32 / 0	0.132 – 0.528	<.132	<.176	<.132
1,1,1-Trichloroethane	32 / 0	0.032 – 0.256	<.032	<.256	<.032
1,1,2,2-Tetrachloroethane	32 / 0	0.132 – 0.528	<.132	<.528	<.132
1,1-Dichloroethane	32 / 0	0.066 – 0.264	<.066	<.264	<.066
1,1-Dichloroethylene	32 / 0	0.044 – 0.176	<.044	<.176	<.044
1,1-Dichloropropene	32 / 0	0.026 – 0.104	<.026	<.104	<.026
1,2,3-Trichlorobenzene	32 / 0	0.266 – 1.06	<.266	<1.06	<.266
1,2,3-Trichloropropane	32 / 0	0.070 – 0.648	<.070	<.648	<.070
1,2,4-Trichlorobenzene	32 / 0	0.188 – 0.752	<.188	<.752	<.188
1,2,4-Trimethylbenzene	32 / 0	0.056 – 0.224	<.056	<.224	<.056
1,2-Dichloroethane	32 / 0	0.134 – 0.536	<.134	<.536	<.134
cis-1,2-Dichloroethene	32 / 0	0.038 – 0.152	<.038	<.152	<.038
trans-1,2-Dichloroethene	32 / 0	0.032 – 0.128	<.032	<.128	<.032

Table 12. Statistical summary of selected well measurements and ground-water-quality data from water samples collected from alluvial aquifers in the Eastern Iowa Basins, Iowa and Minnesota, June– July 1998—Continued

Constituent (unit of measurement)	Number of samples/ number of observations or detections	MRL or MDL	Minimum value	Maximum value	Median value
Volatile organic compounds, total (mg/L)—Continued					
1,2-Dichloropropane	32 / 0	0.068 – 0.272	<0.068	<0.272	<0.068
1,3,5-Trimethylbenzene	32 / 0	0.044 – 0.176	<.044	<.176	<.044
1,3-Dichlorobenzene	32 / 0	0.054 – 0.216	<.054	<.216	<.054
1,3-Dichloropropane	32 / 0	0.116 – 0.464	<.116	<.464	<.116
cis-1,3-Dichloropropene	32 / 0	0.092 – 0.368	<.092	<.368	<.092
trans-1,3-Dichloropropene	32 / 0	0.134 – 0.536	<.134	<.536	<.134
1,4-Dichlorobenzene	32 / 0	0.050 – 0.20	<.050	<.20	<.050
2,2-Dichloropropane	32 / 0	0.078 – 0.312	<.078	<.312	<.078
2-Hexanone	32 / 0	0.746 – 2.98	<.746	<2.98	<.746
3-Chloropropene	32 / 0	0.196 – 0.784	<.196	<.784	<.196
Acetone	32 / 0	4.9 – 19.6	<4.9	<19.6	<4.9
Acrolein	32 / 0	1.432	<1.432	<1.432	<1.432
Acrylonitrile	32 / 0	1.23 – 4.90	<1.23	<4.90	<1.23
Benzene	32 / 0	0.032 – 0.40	<.032	<.40	<.032
Bromobenzene	32 / 0	0.036 – 0.144	<.036	<.144	<.036
Bromochloromethane	32 / 0	0.044 – 0.176	<.044	<.176	<.044
Bromoethene	32 / 0	0.100 – 0.400	<.100	<.400	<.100
Bromoform	32 / 0	0.104 – 0.416	<.104	<.416	<.104
n-Butylbenzene	32 / 0	0.186 – 0.192	<.186	<.192	<.186
sec-Butylbenzene	32 / 0	0.048 – 0.192	<.048	<.192	<.048
tert-Butylbenzene	32 / 0	0.096 – 0.384	<.096	<.384	<.096
Carbon disulfide	32 / 3	0.080 – 1.48	.017	2.780	.125
Carbon tetrachloride	32 / 0	0.088 – 0.352	<.088	<.352	<.088
Chlorobenzene	32 / 0	0.028 – 0.112	<.028	<.112	<.028
Chloroethane	32 / 0	0.120 – 0.480	<.120	<.480	<.120
Chloroform	32 / 1	0.052 – 0.208	<.052	17	<.052
o-Chlorotoluene	32 / 0	0.042 – 0.168	<.042	<.168	<.042
p-Chlorotoluene	32 / 0	0.056 – 0.224	<.056	<.224	<.056
Dibromochloromethane	32 / 1	0.182 – 0.728	<.182	3.1	<.182
Dibromochloropropane	32 / 0	0.214 – 1.00	<.214	<1.00	<.214
Dibromomethane	32 / 0	0.05 – 0.20	<.05	<.20	<.05
O-Dichlorobenzene	32 / 0	0.048 – 0.192	<.048	<.192	<.048
Dichlorobromomethane	32 / 1	0.048 – 0.192	<.048	7.0	<.048
Dichlorodifluoromethane	32 / 0	0.096 – 0.552	<.096	<.552	<.096
Diisopropyl ether	32 / 0	0.098 – 0.392	<.098	<.392	<.098

Table 12. Statistical summary of selected well measurements and ground-water-quality data from water samples collected from alluvial aquifers in the Eastern Iowa Basins, Iowa and Minnesota, June– July 1998—Continued

Constituent (unit of measurement)	Number of samples/ number of observations or detections	MRL or MDL	Minimum value	Maximum value	Median value
Volatile organic compounds, total (µg/L)—Continued					
Ethylbenzene	32 / 0	0.030 – 0.120	<0.030	<0.120	<0.030
Ethyl ether	32 / 0	0.170 – 0.680	<.170	<.680	<.170
o-Ethyl toluene	32 / 0	0.100 – 0.400	<.100	<.400	<.100
Freon-113	32 / 0	0.032 – 0.12	<.032	<.120	<.032
Hexachlorobutadiene	32 / 0	0.142 – 0.568	<.142	<.568	<.142
Hexachloroethane	32 / 0	0.362 – 1.45	<.362	<1.45	<.362
Isodurene	32 / 0	0.24 – 0.96	<.24	<.96	<.24
Isopropylbenzene	32 / 0	0.032 – 0.128	<.032	<.128	<.032
p-Isopropyltoluene	32 / 0	0.110 – 0.440	<.110	<.440	<.110
Methyl acrylate	32 / 0	0.612 – 5.43	<.612	<5.43	<.612
Methyl acrylonitrite	32 / 0	0.57 – 2.28	<.57	<2.28	<.57
Methyl bromide	32 / 0	0.148 – 0.592	<.148	<.592	<.148
Methyl chloride	32 / 0	0.254 – 1.11	<.254	<1.11	<.254
Methylene chloride	32 / 0	0.382 – 1.53	<.382	<1.53	<.382
Methyl ethyl ketone	32 / 0	1.65 – 6.60	<1.65	<6.60	<1.65
Methyl iodine	32 / 0	0.076 – 0.832	<.076	<.832	<.076
Methyl iso-butyl ketone	32 / 0	0.374 – 1.50	<.374	<1.50	<.374
Methyl methacrylate	32 / 0	0.350 – 1.40	<.350	<1.40	<.350
Methyl tert-butyl ether	32 / 0	0.112 – 0.664	<.112	<.664	<.166
Naphthalene	32 / 0	0.25 – 1.00	<.25	<1.00	<.25
Prehnitene	32 / 0	0.23 – 0.92	<.23	<.92	<.23
n-Propylbenzene	32 / 0	0.042 – 0.168	<.042	<.168	<.042
Styrene	32 / 0	0.042 – 0.168	<.042	<.168	<.042
Tetrachloroethylene	32 / 0	0.038 – 0.408	<.038	<.408	<.038
Tetrahydrofuran	32 / 0	1.15 – 35.2	<.142	<35.2	<1.15
Toluene	32 / 1	0.038 – 0.216	<.054	.18	<.054
Trichloroethylene	32 / 0	0.038 – 0.152	<.038	<.152	<.038
Trichlorofluoromethane	32 / 0	0.092 – 0.368	<.092	<.368	<.092
Vinyl chloride	32 / 0	0.112 – 0.448	<.112	<.448	<.112
m- and p-Xylene	32 / 0	0.064 – 0.256	<.064	<.256	<.064
o-Xylene	32 / 0	0.064 – 0.256	<.064	<.256	<.064