WATER-QUALITY ASSESSMENTS OF GROUND WATER AND SURFACE WATER IN THE WARWICK AQUIFER AREA, FORT TOTTEN INDIAN RESERVATION, NORTH DAKOTA

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CONTENTS

FIGURES

TABLES

WATER-QUALITY ASSESSMENTS OF GROUND WATER AND SURFACE WATER IN THE WARWICK AQUIFER AREA, FORT TOTTEN INDIAN RESERVATION, NORTH DAKOTA

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Abstract

A data summary was prepared to assess the quality of ground water and surface water in the Warwick aquifer area. During 1967-93, a total of 205 samples were collected from 61 wells and 18 surface-water locations, and the samples were analyzed for various water-quality constituents. Overall, the quality of ground water in the Warwick aquifer is within the selected drinking water guidelines for North Dakota, and the quality of water from wells less than or equal to 25 feet deep and wells greater than 25 feet deep is similar. Only a few water-quality constituents had concentrations that exceeded the selected drinking water guidelines for North Dakota. Arsenic concentrations neared or exceeded North Dakota drinking water standards in samples collected from two wells greater than 133 feet deep located within the production well field area. Thus, arsenic may be a concern in deeper portions of the aquifer. The quality of the surface water in the Warwick aquifer area was similar to the quality of the ground water in the aquifer. However, specific conductance, pH values, and concentrations of common agricultural pesticides generally are greater in the surface water than in the ground water.

INTRODUCTION

Water withdrawals from the relatively shallow Warwick aquifer have increased in recent years and are expected to continue to increase in response to domestic and municipal demands of the city of Devils Lake and the Fort Totten Indian Reservation. Water for the city of Devils Lake is withdrawn from the Warwick aquifer by means of production wells. Water for the Fort Totten Indian Reservation is withdrawn from the Warwick, Tokio, and Spiritwood aquifers and small and localized glacial deposits by means of private wells. The Spiritwood aquifer is a deeper water source than the Warwick and Tokio aquifers and has poorer water quality.

In order to reduce dependence on private-well water and to provide water to locations where water is needed, the Spirit Lake Sioux Nation, in cooperation with the Bureau of Reclamation, developed a water-distribution system (HKM Associates, 1989) to serve a majority of the population on the Fort Totten Indian Reservation (Bureau of Reclamation, 1989). Water for the system is withdrawn from the Warwick aquifer by means of a number of production wells. These production wells are about 1,500 feet from the well field that serves the city of Devils Lake.

The Spirit Lake Sioux Nation plans to develop a water-management program that will be used to determine future water-use allocations. The Spirit Lake Sioux Nation is concerned about the quality of water in the Warwick aquifer and whether water will be available to meet demands. Of particular concern to the Spirit Lake Sioux Nation is the quality of water near the production well field. In order to address

these concerns, a study was conducted by the U.S. Geological Survey in cooperation with the Spirit Lake Sioux Nation. The purpose of the study was to assess the ground-water and surface-water resources of the Fort Totten Indian Reservation and, in particular, the ground-water resources of the Warwick aquifer.

Purpose and Scope

The purpose of this report is to summarize the quality of ground water and surface water in the Warwick aquifer area. Water quality is presented as descriptive statistics for ground-water and surface-water sites and are compared to the selected drinking water guidelines for North Dakota. The summary was prepared using water-quality data located in computer files of the U.S. Geological Survey.

Previous Studies

County ground-water reports for Benson, Eddy, Nelson, and Ramsey Counties (Bluemle, 1965, 1973; Carlson and Freers, 1975; Downey, 1971, 1973; Hutchinson, 1977; Hutchinson and Klausing, 1980; Randich, 1977; Trapp, 1966, 1968) provide substantial information on the Warwick aquifer. Paulson and Akin (1964) provided a specialized report on the Devils Lake area, Benson, Eddy, and Ramsey Counties. Pusc (1992, 1993) published investigations for the glacial aquifers in the Warwick aquifer area. Several lakes in the Warwick aquifer area were sampled during 1949 (Swenson and Colby, 1955) and during 1954, 1955, 1957, and 1960 (Mitten, Scott, and Rosene, 1968). During 1992, water samples from 15 surface-water locations on the Fort Totten Indian Reservation were collected and analyzed in order to document the water quality of small lakes and wetlands associated with the Warwick aquifer (Lent and others, 1993). During 1993, ground-water data and additional surface-water data were collected from the Warwick aquifer (Michael Strobel, U.S. Geological Survey, oral commun., 1996). Digital simulation modeling was used to investigate the hydraulic characteristics of the Warwick aquifer within the boundaries of the Fort Totten Indian Reservation (Thomas Reed, U.S. Geological Survey, oral commun., 1996).

Physical and Hydrological Setting

The Fort Totten Indian Reservation is located in northeastern North Dakota (fig. 1). The Reservation covers about 405 square miles in Benson, Eddy, Nelson, and Ramsey Counties and extends from Devils Lake on the north to the Sheyenne River on the south. A majority of the Warwick aquifer lies within the boundaries of the Reservation.

The Fort Totten Indian Reservation is located within the Drift Prairie section of the Central Lowland physiographic province (Randich, 1977, p. 2). The topography and relief of the Reservation are due to glacial processes. The land surface of the Reservation is mainly low-relief glacial deposits that are poorly drained and dotted by numerous lakes and wetlands. These lakes and wetlands are often ground-water discharge points and tend to focus runoff from rainfall and snowmelt for ground-water recharge. The Sheyenne River is incised about 60 feet below the prevailing land surface on the Reservation's southern border.

The principal aquifers on the Fort Totten Indian Reservation are found in surficial outwash deposits or in buried-valley deposits. The largest of the outwash-deposit aquifers is the Warwick aquifer, which is located in the southeastern part of the Reservation. The Warwick aquifer forms a rough rectangle of about 9 miles from north to south and 12 miles from east to west. The geology under the aquifer is highly incised with numerous deep channels. Thickness of the Warwick aquifer varies from near zero at the edges to about 175 feet in the vicinity of the production wells. In certain areas, the Warwick aquifer is in contact

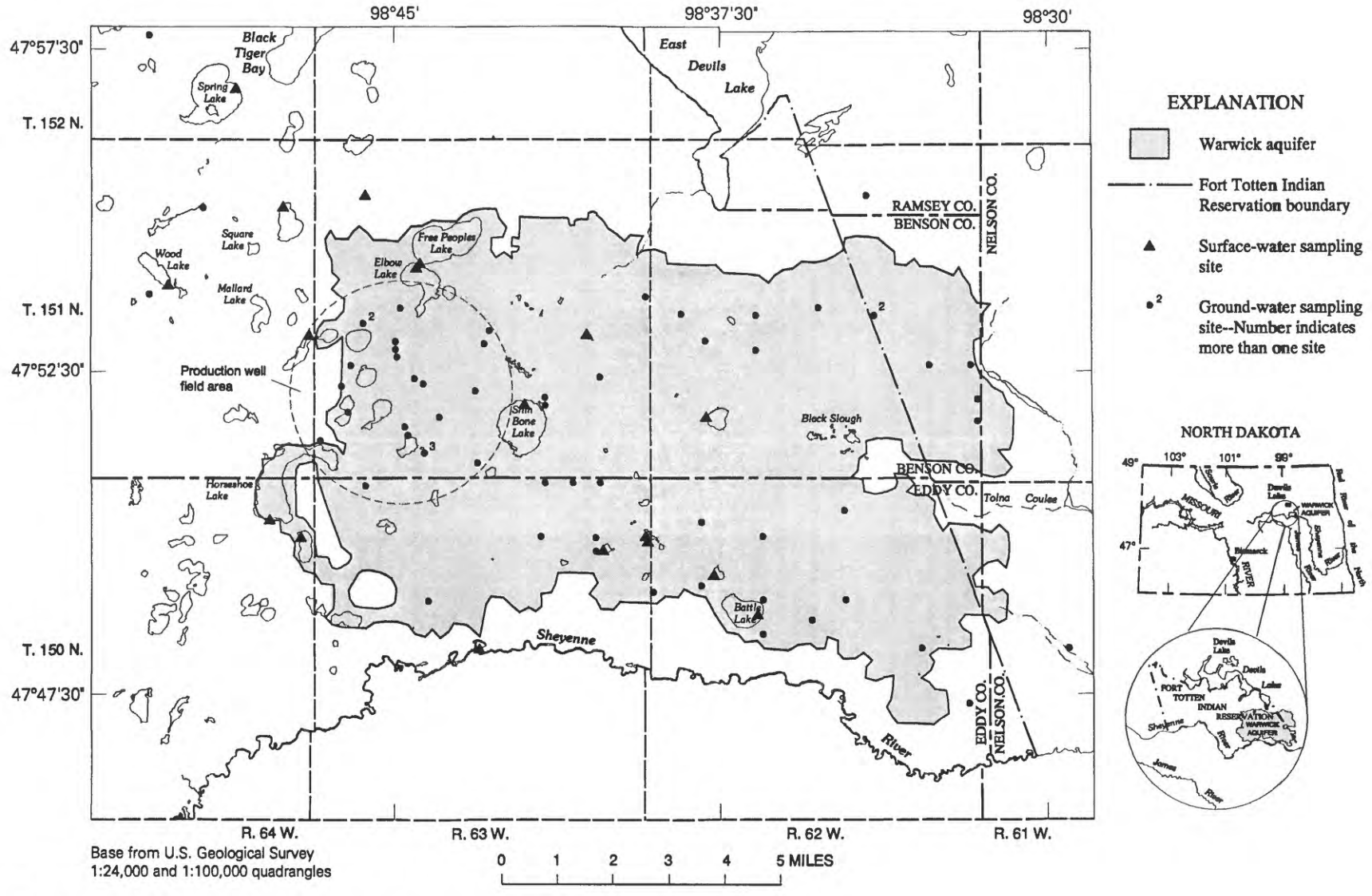

Figure 1. Locations of ground-water and surface-water sampling sites in the Warwick aquifer area.

with the underlying Pierre Shale. The Pierre Shale underlies other surficial glacial deposits throughout the Fort Totten Indian Reservation except along the Sheyenne River valley where the Pierre Shale is exposed at the land surface. The remainder of the Warwick aquifer is underlain by and is in contact with glacial till.

The Spiritwood aquifer, which is found in a buried-valley deposit, partially underlies the Warwick aquifer along the east boundary of the Fort Totten Indian Reservation. Within the Reservation, the Spiritwood and Warwick aquifers are separated by varying thicknesses of glacial till. However, east of the Reservation boundary, the two aquifers may be connected hydraulically (Pusc, 1992).

Drinking Water Guidelines

Much of the water withdrawn from the Warwick aquifer is for domestic use for the city of Devils Lake and the Spirit Lake Sioux Nation. Therefore, the quality of water in the aquifer will be compared to the selected drinking water guidelines for North Dakota (table 1). The North Dakota drinking water standards are concerned mostly with the health related issues of inorganic and organic chemical materials, and the Environmental Protection Agency secondary drinking water regulations are concerned with materials that affect the esthetic qualities of water.

Table 1. Selected drinking water guidelines for North Dakota (North Dakota Department of Health, 1994; U.S. Environmental Protection Agency, 1996)

Water-quality constituent	Maximum contaminant concentration
North Dakota drinking water standards	
Fluoride (milligrams per liter)	4
Nitrite (milligrams per liter as N)	1
Nitrate (milligrams per liter as N)	10
Nitrite plus nitrate (milligrams per liter as N)	10
Arsenic (micrograms per liter)	50
Lead (micrograms per liter)	15
Mercury (micrograms per liter)	2
Selenium (micrograms per liter)	50
Atrazine (micrograms per liter)	3
Carbofuran (micrograms per liter)	40
2,4-D (micrograms per liter)	70
Environmental Protection Agency secondary drinking water regulations	
pH (standard units)	6.5-8.5
Dissolved solids (milligrams per liter)	500
Sulfate (milligrams per liter)	250
Chloride (milligrams per liter)	250
Iron (micrograms per liter)	300
Manganese (micrograms per liter)	50

WATER-QUALITY DATA

Water-quality samples were collected for various projects during 1967-93. The earlier ground-water samples (1967-68) were collected in connection with county ground-water studies (Randich, 1977). Ground-water samples collected during 1969-91 were part of a general monitoring program by the U.S. Geological Survey and the North Dakota State Water Commission. Surface-water samples were collected

during 1992-93, and ground-water samples were collected during 1993. All samples collected during 1992-93 were part of a water-resources investigation by the U.S. Geological Survey for the Spirit Lake Sioux Nation.

Water-quality data consisting of physical properties, major ions, nutrients, trace metals, and selected pesticides are summarized in this report for ground-water sites located in the Warwick aquifer area, for ground-water sites located within the production well field area, and for surface-water sites located in the Warwick aquifer area (fig. 1). The production well field area for the city of Devils Lake and the Spirit Lake Sioux Nation was defined as the portion of the Warwick aquifer beneath an area encompassing a 2-mile radius from the center of sec. 29, T. 151 N., R. 63 W., based on results from a digital model of water redistribution within the aquifer caused by water withdrawals (Thomas Reed, U.S. Geological Survey, oral commun., 1996). The quality of water near the production well field is of particular concern to the Spirit Lake Sioux Nation because it is likely that this water will enter their water-distribution system. Water-quality data were compiled from analyses of 205 samples collected during 1967-93 from 61 wells and 18 surface-water sites (fig. 1). There are 23 ground-water sampling wells located within the well field area and 38 ground-water sampling wells located outside the well field area. The number of samples collected ranged from 1 to 21 per well and from 1 to 12 per surface-water site.

Observation wells completed in the Warwick aquifer were constructed of various materials including 3-inch galvanized steel, 1.25-inch steel, 1.25-inch polyvinyl chloride, and 2-inch polyvinyl chloride. Screens were made of either galvanized steel or polyvinyl chloride. Most of the wells were developed by air-lift pumping. The observation wells used to collect water-quality samples in the Warwick aquifer are owned by either HKM Associates, the North Dakota Geological Survey, the North Dakota State Water Commission, the Bureau of Reclamation, or the U.S. Geological Survey.

The production well field is located in a filled valley where the aquifer is the thickest. Production wells for both the city of Devils Lake and the Spirit Lake Sioux Nation were completed at depths greater than 130 feet. Four sampling wells have a depth of more than 130 feet. Within the production well field area, the median depth of all sampling wells is 30 feet with depths ranging from 10 to 170 feet. Outside the well field area, the median depth of all sampling wells is 26 feet with depths ranging from 10 to 65 feet.

The sampling methods used to improve the representativeness of ground-water samples have changed over time. During 1967-68, samples were collected using the air-lift method. Compressed air is pumped into the casing, lifting water to the top of the well. Water-quality samples are collected once the water becomes clear from turbidity. The disadvantage of the air-lift method is that it aerates the water, which causes potential oxidized conditions and changes in concentrations of some trace elements. During 1969-91, samples were collected using the bailing method, which reduces the potential of aerating. During 1992-93, samples were collected using a peristaltic pump.

WATER-QUALITY ASSESSMENTS

Tables of water-quality data are presented in this report. Data are reported as means, extremes, and percentiles for many water-quality constituents for which analyses were performed. Throughout this report, reference will be made occasionally to water quality at wells and surface-water sites of special interest. Complete tables of water-quality data are available in hardcopy format or on floppy disk from the U.S. Geological Survey.

Ground Water

Statistics are presented on data obtained from water samples collected from wells located in the Warwick aquifer area. Data were divided into two data sets for wells less than or equal to 25 feet deep and for wells greater than 25 feet deep to represent shallow and deep portions of the aquifer, respectively. Also, the division of data at 25 feet provided similar numbers of samples in each data set. No hydrologic considerations are implied by the division of data. Statistics also are presented on subsets of the two data sets from wells located within the production well field area.

Warwick aquifer area

Statistics of water-quality constituents are summarized for samples collected from wells less than or equal to 25 feet deep (table 2) and from wells greater than 25 feet deep (table 3) located in the Warwick aquifer area. Overall, the quality of ground water in the aquifer area is within the selected drinking water guidelines for North Dakota, and the quality of water from the shallow and deep wells is similar. Values highlighted in tables 2 and 3 indicate that eight water-quality constituents had concentrations that exceeded the selected drinking water guidelines for North Dakota. Only manganese concentrations in samples collected from wells less than or equal to 25 feet deep and only manganese and iron concentrations in samples collected from wells greater than 25 feet deep had 25th percentile or median values that exceeded the Environmental Protection Agency secondary drinking water regulations. These statistics indicate that at least half of the manganese and iron analyses had concentrations greater than the drinking water regulations. The elevated manganese and iron concentrations occurred in samples collected from isolated wells of varying depths located throughout the aquifer area. Concentrations of the nitrogen constituents generally were higher in the shallow wells where surface runoff from agricultural lands could introduce fertilizers into ground water. The constituents p,p'DDE, carbofuran, and cyanazine were detected with concentrations above detection limits in water samples collected from 11 wells in the central and southeast portions of the aquifer. The depths of these wells ranged from 17 to 170 feet. The arsenic concentration exceeded North Dakota drinking water standards in one sample collected from a well 147 feet deep located in the west-central portion of the Warwick aquifer area.

Production well field area

Statistics of water-quality constituents are summarized for samples collected from wells less than or equal to 25 feet deep (table 4) and from wells greater than 25 feet deep (table 5) located within the production well field area. Results from the production well field area were similar to results from the Warwick aquifer area. Only manganese, iron, and dissolved-solids concentrations in samples collected from wells less than or equal to 25 feet deep and only manganese concentrations in samples collected from wells greater than 25 feet deep had 25th percentile or median values that exceeded the Environmental Protection Agency secondary drinking water regulations. Concentrations of the nitrogen constituents generally were higher in the shallow wells where surface runoff from agricultural lands could introduce fertilizers into ground water. The constituent p,p'DDE was detected with concentrations above detection limits in water samples collected from seven wells near the center of the production well field area. The depths of the wells ranged from 28 to 170 feet. Arsenic concentrations neared North Dakota drinking water standards in a sample collected from a well 133 feet deep and exceeded the standards in a sample collected from a well 147 feet deep. Both wells are located near the center of the production well field. These data indicate the possibility that arsenic may be a concern in deeper portions of the aquifer.

Table 2. Statistics of water-quality constituents in samples collected from wells less than or equal to 25 feet deep located in the Warwick aquifer area

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; <, less than; µg/L, micrograms per liter; --, no data]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Specific conductance (µS/cm)	78	595	260	1,430	382	478	639
pH, field (standard units)	80	na	6.6	8.2	7.4	7.5	7.7
pH, lab (standard units)	44	na	7.2	8.3	7.5	7.6	7.8
Hardness, total (mg/L as $CaCO_3$)	75	308	120	870	200	250	350
Noncarbonate hardness, total (mg/L as $CaCO_3$)	41	25.5	0	94	0	13	41
Alkalinity, dissolved (mg/L as $CaCO_3$)	26	298	131	858	218	253	289
Solids, dissolved, sum of constituents (mg/L)	74	361	171	**1,000**	227	300	393
Calcium, dissolved (mg/L as Ca)	75	67	31	130	54	67	78
Magnesium, dissolved (mg/L as Mg)	75	34	9.3	150	14	20	33
Sodium, dissolved (mg/L as Na)	75	14	1.8	94	3.2	4.5	14
Potassium, dissolved (mg/L as K)	75	4.6	0.3	24	0.9	2.2	3.2
Bicarbonate, dissolved (mg/L as HCO_3)	76	360	140	1,060	230	276	372
Carbonate, dissolved (mg/L as CO_3)	26	0	0	0	0	0	0
Sulfate, dissolved (mg/L as SO_4)	75	35	<0.1	220	11	20	55
Chloride, dissolved (mg/L as Cl)	75	3.6	0	22	0.9	1.8	3.8
Fluoride, dissolved (mg/L as F)	75	0.2	<0.1	0.8	0.2	0.2	0.3
Silica, dissolved (mg/L as SiO_2)	75	25	2.7	40	23	24	28
Nitrogen, nitrite, dissolved (mg/L as N)	27	0.02	<0.01	0.12	<0.01	<0.01	0.02
Nitrogen, nitrite, dissolved (mg/L as NO_2)	8	0.14	0.07	0.39	0.07	0.08	0.16
Nitrogen, nitrate, dissolved (mg/L as N)	8	7.5	0.2	**27**	0.24	3.0	**13**
Nitrogen, nitrate, dissolved (mg/L as NO_3)	14	19.2	<0.04	120	<0.04	1	23
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	69	2.75	<0.05	**76**	<0.05	0.1	0.5
Nitrogen, ammonia, dissolved (mg/L as N)	26	0.09	0.01	0.86	0.02	0.03	0.06
Phosphorus, dissolved (mg/L as P)	38	0.03	<0.01	0.11	<0.01	0.02	0.03
Phosphorus, orthophosphate, dissolved (mg/L as P)	64	0.02	<0.01	0.26	<0.01	0.01	0.03

Table 2. Statistics of water-quality constituents in samples collected from wells less than or equal to 25 feet deep located in the Warwick aquifer area—Continued

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; <, less than; µg/L, micrograms per liter; --, no data]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Phosphate, orthophosphate, dissolved (mg/L as PO_4)	56	0.063	<0.03	0.8	<0.03	0.03	0.09
Arsenic, dissolved (µg/L as As)	10	2.2	<1	8	<1	1.5	2
Boron, dissolved (µg/L as B)	50	64.6	<10	560	20	30	80
Iron, dissolved (µg/L as Fe)	75	**1,336**	<3	**9,800**	10	20	**1,200**
Lead, dissolved (µg/L as Pb)	1	--	--	<1	--	--	--
Lithium, dissolved (µg/L as Li)	1	--	--	9	--	--	--
Manganese, dissolved (µg/L as Mn)	68	**267**	1	**3,900**	30	**145**	**340**
Mercury, dissolved (µg/L as Hg)	1	--	--	<0.1	--	--	--
Molybdenum, dissolved (µg/L as Mo)	1	--	--	1	--	--	--
Selenium, dissolved (µg/L as Se)	1	--	--	1	--	--	--
Strontium, dissolved (µg/L as Sr)	1	--	--	140	--	--	--
Atrazine, water, dissolved, recoverable (µg/L)	9	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Carbofuran, dissolved (µg/L)	0	--	--	--	--	--	--
Carbofuran, total (µg/L)	15	0.07	<0.06	0.2	0.06	0.06	0.06
Cyanazine, dissolved (µg/L)	6	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyanazine, total (µg/L)	9	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dieldrin, dissolved (µg/L)	10	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
p,p'DDE, dissolved (µg/L)	9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Parathion, dissolved (µg/L)	10	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2,4-D, dissolved (µg/L)	6	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
2,4-D, total (µg/L)	9	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7

Table 3. Statistics of water-quality constituents in samples collected from wells greater than 25 feet deep located in the Warwick aquifer area

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; --, no data; <, less than; µg/L, micrograms per liter]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Specific conductance (µS/cm)	47	627	304	1,490	435	531	682
pH, field (standard units)	46	na	6.8	8.3	7.3	7.6	7.8
pH, lab (standard units)	33	na	7.2	8.2	7.6	7.6	7.7
Hardness, total (mg/L as $CaCO_3$)	43	270	100	670	210	230	310
Noncarbonate hardness, total (mg/L as $CaCO_3$)	10	37	0	150	0	32	45
Alkalinity, dissolved (mg/L as $CaCO_3$)	30	270	159	541	207	226	322
Solids, dissolved, sum of constituents (mg/L)	41	410	158	**1,000**	281	337	454
Calcium, dissolved (mg/L as Ca)	43	71	25	170	57	63	78
Magnesium, dissolved (mg/L as Mg)	43	22	6.7	72	15	18	29
Sodium, dissolved (mg/L as Na)	43	36	2.2	210	8.1	16	39
Potassium, dissolved (mg/L as K)	43	4.7	1.4	13	2.5	4.5	6.2
Bicarbonate, dissolved (mg/L as HCO_3)	44	325	200	666	250	283	395
Carbonate, dissolved (mg/L as CO_3)	30	0	0	0	0	0	0
Sulfate, dissolved (mg/L as SO_4)	43	81	<0.1	**360**	18	53	94
Chloride, dissolved (mg/L as Cl)	43	7.1	0.3	54	1.8	3.3	7.7
Fluoride, dissolved (mg/L as F)	43	0.4	<0.1	**5.4**	0.2	0.2	0.3
Silica, dissolved (mg/L as SiO_2)	43	26.9	5.8	38	25	27	29
Nitrogen, nitrite, dissolved (mg/L as N)	30	<0.01	<0.01	0.01	<0.01	<0.01	0.01
Nitrogen, nitrite, dissolved (mg/L as NO_2)	0	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N)	3	0.23	0.23	0.23	0.23	0.23	0.23
Nitrogen, nitrate, dissolved (mg/L as NO_3)	10	0.45	<0.04	1	<0.04	0.25	1
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	30	0.4	<0.05	5.8	<0.05	0.05	0.05
Nitrogen, ammonia, dissolved (mg/L as N)	30	0.43	0.02	2.5	0.11	0.26	0.53
Phosphorus, dissolved (mg/L as P)	0	--	--	--	--	--	--
Phosphorus, orthophosphate, dissolved (mg/L as P)	30	0.05	<0.01	0.32	0.01	0.025	0.06

Table 3. Statistics of water-quality constituents in samples collected from wells greater than 25 feet deep located in the Warwick aquifer area—Continued

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; --, no data; <, less than; µg/L, micrograms per liter]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Phosphate, orthophosphate, dissolved (mg/L as PO_4)	23	0.19	<0.03	0.98	0.06	0.12	0.31
Arsenic, dissolved (µg/L as As)	17	11	<1	**56**	1	6	10
Boron, dissolved (µg/L as B)	14	146	<10	490	0	80	290
Iron, dissolved (µg/L as Fe)	43	**1,450**	<3	**8,700**	68	**320**	**2,800**
Lead, dissolved (µg/L as Pb)	3	3	<1	8	<1	1	8
Lithium, dissolved (µg/L as Li)	3	25.7	7	62	7	8	62
Manganese, dissolved (µg/L as Mn)	34	**533**	2	**1,800**	**280**	**465**	**590**
Mercury, dissolved (µg/L as Hg)	3	0.2	<0.01	0.5	<0.1	0.1	0.5
Molybdenum, dissolved (µg/L as Mo)	3	2	1	5	1	1	5
Selenium, dissolved (µg/L as Se)	3	<1	<1	1	<1	1	1
Strontium, dissolved (µg/L as Sr)	3	190	50	390	50	130	390
Atrazine, water, dissolved, recoverable (µg/L)	11	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Carbofuran, dissolved (µg/L)	4	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Carbofuran, total (µg/L)	17	0.08	<0.06	0.27	0.06	0.06	0.06
Cyanazine, dissolved (µg/L)	9	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyanazine, total (µg/L)	11	0.04	<0.04	0.07	0.04	0.04	0.04
Dieldrin, dissolved (µg/L)	12	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
p,p'DDE, dissolved (µg/L)	11	0.02	<0.01	0.02	0.01	0.02	0.02
Parathion, dissolved (µg/L)	12	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2,4-D, dissolved (µg/L)	9	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
2,4-D, total (µg/L)	11	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7

Table 4. Statistics of water-quality constituents in samples collected from wells less than or equal to 25 feet deep located within the production well field area

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; µg/L, micrograms per liter; --, no data; <, less than]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Specific conductance (µS/cm)	20	919.8	272	1,400	548	975	1,265
pH, field (standard units)	20	na	6.9	7.9	7.1	7.25	7.6
pH, lab (standard units)	13	na	7.2	8	7.4	7.6	7.8
Hardness, total (mg/L as $CaCO_3$)	19	449	120	740	260	440	630
Noncarbonate hardness, total (mg/L as $CaCO_3$)	8	2.88	0	23	0	0	0
Alkalinity, dissolved (mg/L as $CaCO_3$)	9	316	131	858	234	261	289
Solids, dissolved, sum of constituents (mg/L)	18	**537**	175	**898**	327	**531**	**751**
Calcium, dissolved (mg/L as Ca)	19	65.7	31	98	51	70	74
Magnesium, dissolved (mg/L as Mg)	19	69.6	9.3	120	21	77	110
Sodium, dissolved (mg/L as Na)	19	33.46	2.8	55	8.2	40	49
Potassium, dissolved (mg/L as K)	19	11.9	0.6	24	1.6	17	20
Bicarbonate, dissolved (mg/L as HCO_3)	19	599	160	1,060	320	620	880
Carbonate, dissolved (mg/L as CO_3)	9	0	0	0	0	0	0
Sulfate, dissolved (mg/L as SO_4)	19	34.9	<0.1	220	8	15	52
Chloride, dissolved (mg/L as Cl)	19	7.72	0.6	22	1.6	8.7	9.1
Fluoride, dissolved (mg/L as F)	19	0.34	<0.1	0.6	0.3	0.3	0.4
Silica, dissolved (mg/L as SiO_2)	19	29.4	8.1	40	27	29	35
Nitrogen, nitrite, dissolved (mg/L as N)	9	0.016	<0.01	0.03	<0.01	<0.01	0.02
Nitrogen, nitrite, dissolved (mg/L as NO_2)	4	0.078	0.07	0.1	0.07	0.07	0.085
Nitrogen, nitrate, dissolved (mg/L as N)	4	6.75	0.2	**21**	0.21	2.9	**13.3**
Nitrogen, nitrate, dissolved (mg/L as NO_3)	4	30	0.89	93	0.91	13	59
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	19	1.64	<0.05	**21**	<0.05	0.1	0.24
Nitrogen, ammonia, dissolved (mg/L as N)	9	0.13	0.01	0.86	0.03	0.06	0.06
Phosphorus, dissolved (mg/L as P)	10	0.053	<0.01	0.11	0.03	0.045	0.08
Phosphorus, orthophosphate, dissolved (mg/L as P)	18	0.019	<0.01	0.12	<0.01	0.01	0.03

Table 4. Statistics of water-quality constituents in samples collected from wells less than or equal to 25 feet deep located within the production well field area—Continued

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; µg/L, micrograms per liter; --, no data; <, less than]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Phosphate, orthophosphate, dissolved (mg/L as PO_4)	14	0.067	<0.03	0.37	<0.03	0.03	0.09
Arsenic, dissolved (µg/L as As)	7	2.57	<1	8	<1	2	3
Boron, dissolved (µg/L as B)	10	136	80	190	100	145	160
Iron, dissolved (µg/L as Fe)	19	**3,218**	<3	**6,000**	12	**5,000**	**5,500**
Lead, dissolved (µg/L as Pb)	0	--	--	--	--	--	--
Lithium, dissolved (µg/L as Li)	0	--	--	--	--	--	--
Manganese, dissolved (µg/L as Mn)	18	**332**	3	**760**	**230**	**340**	**390**
Mercury, dissolved (µg/L as Hg)	0	--	--	--	--	--	--
Molybdenum, dissolved (µg/L as Mo)	0	--	--	--	--	--	--
Selenium, dissolved (µg/L as Se)	0	--	--	--	--	--	--
Strontium, dissolved (µg/L as Sr)	0	--	--	--	--	--	--
Atrazine, water, dissolved, recoverable (µg/L)	6	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Carbofuran, dissolved (µg/L)	0	--	--	--	--	--	--
Carbofuran, total (µg/L)	7	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Cyanazine, dissolved (µg/L)	6	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyanazine, total (µg/L)	1	--	--	0.04	--	--	--
Dieldrin, dissolved (µg/L)	6	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
p,p'DDE, dissolved (µg/L)	6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Parathion, dissolved (µg/L)	6	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2,4-D, dissolved (µg/L)	6	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
2,4-D, total (µg/L)	1	--	--	<0.7	--	--	--

Table 5. Statistics of water-quality constituents in samples collected from wells greater than 25 feet deep located within the production well field area

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; --, no data; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; <, less than; µg/L, micrograms per liter]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Specific conductance (µS/cm)	17	634	310	1,490	482	555	675
pH, field (standard units)	16	na	7.4	8.3	7.55	7.7	7.85
pH, lab (standard units)	14	na	7.6	8.1	7.6	7.7	7.8
Hardness, total (mg/L as $CaCO_3$)	15	225	100	470	170	210	250
Noncarbonate hardness, total (mg/L as $CaCO_3$)	1	--	--	35	--	--	--
Alkalinity, dissolved (mg/L as $CaCO_3$)	12	288	198	518	212	250	300
Solids, dissolved, sum of constituents (mg/L)	15	419	158	**1,000**	298	361	454
Calcium, dissolved (mg/L as Ca)	15	58.5	25	130	46	57	68
Magnesium, dissolved (mg/L as Mg)	15	19.2	6.7	35	13	17	22
Sodium, dissolved (mg/L as Na)	15	54.6	3.5	210	8.1	28	48
Potassium, dissolved (mg/L as K)	15	5.35	1.8	13	3.4	4.7	6.6
Bicarbonate, dissolved (mg/L as HCO_3)	16	343	200	639	254	290	376
Carbonate, dissolved (mg/L as CO_3)	12	0	0	0	0	0	0
Sulfate, dissolved (mg/L as SO_4)	15	74.6	0.4	**330**	40	45	96
Chloride, dissolved (mg/L as Cl)	15	7.95	0.4	54	1.8	2.9	7.2
Fluoride, dissolved (mg/L as F)	15	0.22	<0.1	0.5	0.2	0.2	0.3
Silica, dissolved (mg/L as SiO_2)	15	25.2	5.8	38	25	26	29
Nitrogen, nitrite, dissolved (mg/L as N)	12	0.01	<0.01	0.01	<0.01	<0.01	0.01
Nitrogen, nitrite, dissolved (mg/L as NO_2)	0	--	--	--	--	--	--
Nitrogen, nitrate, dissolved (mg/L as N)	1	--	--	0.23	--	--	--
Nitrogen, nitrate, dissolved (mg/L as NO_3)	1	--	--	<0.04	--	--	--
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	12	0.8	<0.05	5.8	<0.05	0.05	0.52
Nitrogen, ammonia, dissolved (mg/L as N)	12	0.34	0.02	0.92	0.03	0.28	0.72
Phosphorus, dissolved (mg/L as P)	0	--	--	--	--	--	--
Phosphorus, orthophosphate, dissolved (mg/L as P)	12	0.072	<0.01	0.32	<0.01	0.04	0.1

Table 5. Statistics of water-quality constituents in samples collected from wells greater than 25 feet deep located within the production well field area—Continued

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; mg/L, milligrams per liter; --, no data; values highlighted indicate constituents with concentrations exceeding the North Dakota drinking water guidelines; <, less than; µg/L, micrograms per liter]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Phosphate, orthophosphate, dissolved (mg/L as PO_4)	8	0.32	0.06	0.98	0.12	0.26	0.37
Arsenic, dissolved (µg/L as As)	11	14.5	<1	**56**	1	7	20
Boron, dissolved (µg/L as B)	4	205	<10	460	10	180	400
Iron, dissolved (µg/L as Fe)	15	**995**	<3	**5,200**	56	170	**1,600**
Lead, dissolved (µg/L as Pb)	2	4	<1	8	<1	4	8
Lithium, dissolved (µg/L as Li)	2	7.5	7	8	7	7.5	8
Manganese, dissolved (µg/L as Mn)	14	**362**	20	**780**	**130**	**410**	**520**
Mercury, dissolved (µg/L as Hg)	2	0.3	<0.1	0.5	0.1	0.3	0.5
Molybdenum, dissolved (µg/L as Mo)	2	1	1	1	1	1	1
Selenium, dissolved (µg/L as Se)	2	0.5	<1	1	<1	0.5	1
Strontium, dissolved (µg/L as Sr)	2	90	50	130	50	90	130
Atrazine, water, dissolved, recoverable (µg/L)	9	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Carbofuran, dissolved (µg/L)	4	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Carbofuran, total (µg/L)	7	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Cyanazine, dissolved (µg/L)	9	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyanazine, total (µg/L)	1	--	--	<0.04	--	--	--
Dieldrin, dissolved (µg/L)	9	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
p,p'DDE, dissolved (µg/L)	9	0.018	<0.01	0.02	0.02	0.02	0.02
Parathion, dissolved (µg/L)	9	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2,4-D, dissolved (µg/L)	9	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
2,4-D, total (µg/L)	1	--	--	<0.7	--	--	--

Surface Water

Statistics of water-quality constituents in samples collected from surface-water sites located in the Warwick aquifer area are summarized in table 6. Values highlighted in table 6 indicate constituents with concentrations that exceed the selected drinking water guidelines for North Dakota, even though surface water is rarely used for domestic or municipal purposes. Overall, the quality of the surface water is similar to the quality of the ground water because of the hydraulic connection of lakes and wetlands to the Warwick aquifer. However, specific conductance, pH values, and concentrations of common agricultural pesticides generally are greater in the surface water than in the ground water.

The range of values for most water-quality constituents in samples collected from the Warwick aquifer area is greater in surface water than in the ground water. The variation is due to the degree of hydraulic connection to the aquifer. Wetlands that contain water with specific conductance values greater than about 2,000 µS/cm are often supplied with water from aquifers. These discharge wetlands act like evaporation ponds, concentrating dissolved materials upon evaporation. Wetlands that contain water with specific conductance values less than about 500 µS/cm may be recharge sites to the aquifer and may be points for contaminants to enter the aquifer.

SUMMARY

The Spirit Lake Sioux Nation, in cooperation with the Bureau of Reclamation, developed a municipal and rural water-distribution system to serve a majority of the population on the Fort Totten Indian Reservation. Water for the water-distribution system and for the city of Devils Lake is withdrawn from the Warwick aquifer. Of particular concern to the Spirit Lake Sioux Nation is the quality of water near the production well field.

A data summary was prepared to assess the quality of ground water and surface water in the Warwick aquifer area. During 1967-93, a total of 205 samples were collected from 61 wells and 18 surface-water locations. Samples were analyzed for physical properties, major ions, nutrients, trace metals, and pesticides. Statistics were presented on data obtained from water samples collected from wells less than or equal to 25 feet deep and from wells greater than 25 feet deep to represent shallow and deep portions of the Warwick aquifer. No hydrologic considerations were implied by the division of data. Statistics also were presented on subsets of the two data sets from wells located within the production well field area.

Overall, the quality of water in the Warwick aquifer area is good with little difference in the quality of water from wells less than or equal to 25 feet deep and wells greater than 25 feet deep. Only eight water-quality constituents had concentrations that exceeded the selected drinking water guidelines for North Dakota. Results from the production well field area were similar to results from the Warwick aquifer area with the exception of arsenic. Arsenic concentrations neared or exceeded North Dakota drinking water standards in samples collected from two wells greater than 130 feet deep located within the production well field area. Thus, arsenic may be a concern in deeper portions of the aquifer.

The quality of the surface water in the Warwick aquifer area is similar to the quality of the ground water in the aquifer. However, specific conductance, pH values, and concentrations of common agricultural pesticides generally are greater in the surface water than in the ground water. Wetlands that contain water with specific conductance values less than about 500 µS/cm may be recharge sites to the aquifer and may be points for contaminants to enter the aquifer.

Table 6. Statistics of water-quality constituents in samples collected from surface-water sites located in the Warwick aquifer area

[Numbers have not been rounded according to U.S. Geological Survey water-quality standards; µS/cm, microsiemens per centimeter at 25 degrees Celsius; na, mean of logarithmic values is not accurate; values highlighted indicate constituents with concentrations exceeding the drinking water guidelines; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Water-quality constituents	Descriptive statistics				Percent of samples in which values were less than or equal to those shown		
	Sample size	Mean	Minimum	Maximum	25	Median	75
Specific conductance (µS/cm)	58	3,070	7	15,700	530	1,120	4,080
pH, field (standard units)	58	na	7.4	**9.6**	8	**8.95**	**9.3**
pH, lab (standard units)	47	na	7.5	**9.8**	8.2	**9.1**	**9.3**
Alkalinity, dissolved (mg/L as $CaCO_3$)	31	890.7	214	4,300	319	606	1,380
Calcium, dissolved (mg/L as Ca)	47	29.7	3	270	7.6	14	31
Magnesium, dissolved (mg/L as Mg)	47	113.1	14	1,000	39	51	100
Sodium, dissolved (mg/L as Na)	47	765	8.3	2,900	24	220	1,100
Potassium, dissolved (mg/L as K)	47	60.5	1.8	210	14	27	110
Bicarbonate, dissolved (mg/L as HCO_3)	31	847.3	98	5,280	299	683	1,250
Carbonate, dissolved (mg/L as CO_3)	31	126	0	336	0	144	216
Sulfate, dissolved (mg/L as SO_4)	47	**1,106**	0.8	**9,200**	15	90	**2,000**
Chloride, dissolved (mg/L as Cl)	47	247	1.7	**990**	8.8	33	**440**
Fluoride, dissolved (mg/L as F)	44	0.53	0.2	**5.5**	0.3	0.3	0.6
Silica, dissolved (mg/L as SiO_2)	44	11.1	0.5	37	3.8	8.1	17.5
Nitrogen, nitrite, dissolved (mg/L as N)	44	0.011	0.01	0.04	0.01	0.01	0.01
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	44	0.059	0.05	0.2	0.05	0.05	0.05
Nitrogen, ammonia, dissolved (mg/L as N)	44	0.04	0.01	0.17	0.03	0.04	0.04
Nitrogen, ammonia plus organic, total (mg/L as N)	18	2.87	0.91	8.9	1.6	2.55	3.8
Phosphorus, total (mg/L as P)	18	0.21	<0.01	2.4	0.05	0.07	0.11
Phosphorus, orthophosphate, dissolved (mg/L as P)	47	0.16	<0.01	2.9	0.01	0.01	0.03
Iron, dissolved (µg/L as Fe)	47	49.8	3	**560**	10	10	46
Manganese, dissolved (µg/L as Mn)	47	**55.8**	1	**480**	8	10	40
Atrazine, dissolved (µg/L)	11	0.031	<0.02	0.05	0.02	0.03	0.04
Cyanazine, dissolved (µg/L)	11	<0.04	<0.04	0.05	<0.04	<0.04	<0.04
Metribuzin, dissolved (µg/L)	11	0.018	<0.01	0.05	0.01	0.01	0.03
2,4-D, dissolved (µg/L)	5	<0.7	<0.7	0.95	<0.7	<0.7	<0.7

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