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Riverbed Elevations and Water Quality of the Missouri River at Sioux City, Iowa, 2002-03

Scientific Investigations Report 2004-5079

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

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Conversion Factors, Abbreviations, Vertical and Horizontal Datum

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Abbreviated water-quality units used in this report: Chemical concentrations are reported in milligrams per liter (mg/L) and micrograms per liter (µg/L). A milligram per liter expresses the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. A microgram per liter expresses the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. Microsiemens per centimeter (µS/cm) at 25 degrees Celsius (°C) expresses the capability of a unit volume of water to conduct an applied electrical current.

Vertical Datum: Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 29). Elevation as used in this report, refers to distance above or below NGVD of 29. NGVD of 29 can be converted to the North America Vertical Datum of 1988 (NAVD of 88) by using the National Geodetic Survey conversion utility available at URL http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html

Horizontal datum: Horizontal datum information is referenced to the North American Datum of 1983 (NAD of 83).

Riverbed Elevations and Water Quality of the Missouri River at Sioux City, Iowa, 2002-03

By Daniel E. Christiansen

Abstract

The U.S. Geological Survey, in cooperation with the City of Sioux City, Iowa, conducted an investigation of the Missouri River, during 2002-2003, to assess changes in riverbed elevations from its confluence with the Big Sioux River, downstream to the area of the Sioux City municipal well field. Water-quality samples also were collected across the Missouri River to provide additional information on the differences between the water quality of the Missouri River and Big Sioux River in the well field area.

The water supply at Sioux City, Iowa, is withdrawn from fourteen vertical wells and one horizontal collector well. Twelve vertical wells and the collector well are completed in the alluvial sand and gravel aquifer adjacent to the Missouri River at Sioux City. The well field is located on the left bank (looking downstream) of the Missouri River about 0.5 mile upstream from USGS streamflow gage 06486000, and approximately 5,000 feet downstream from the confluence with the Big Sioux River.

The Missouri River, adjacent to the Sioux City alluvial well field, consists of the combined streamflows from the Missouri and the Big Sioux Rivers. The streamflows do not appear to be well mixed downstream from the confluence, and the streamflow directly adjacent to the well field could be predominately from the Big Sioux River. The U.S. Geological Survey measures streamflow on the Missouri River at Sioux City, Iowa (USGS streamflow gage 06486000). The riverbed of the Missouri River at Sioux City consists of a sequence of sands and gravels. The surface of the riverbed is undulatory, with continuously migrating riverbed forms, 5 to 8 feet in relief, of sand and gravel.

Measurements of riverbed elevations from October 1, 2002, to September 30, 2003, showed an annual change of as much as 8 feet with the majority of the riverbed change closer to 5 feet. The largest change occurred near a wing dike on the Nebraska side of the Missouri River. On the Iowa side, the annual change was close to 5 feet. The results showed that channel fill occurred in the winter months and scour occurred during the summer months.

Results of analyses of water samples collected at five locations across the Missouri River, near the municipal well field, were similar for most samples. Higher values of specific conductance and turbidity were recorded on the Iowa side of the Missouri River, the side from which the Big Sioux River enters upstream. Higher concentrations of chloride, ammonia nitrogen, nitrate nitrogen, and atrazine also were detected on the Iowa side of the Missouri River. Based on these results, there does not appear to be complete mixing of water from the Missouri and Big Sioux Rivers near the municipal well field.

Introduction

The City of Sioux City, Iowa, obtains part of its municipal water supply from the alluvial sand and gravel aquifer along the Missouri River (fig. 1). The well field consists of fourteen vertical wells, ranging in depth from 90 to 134 ft and one horizontal collector well 85 ft deep, located on the left bank of the Missouri River, completed in the alluvial aquifer (Iowa Department of Natural Resources, 2001) (fig. 2). The alluvial aquifer consists of sand and gravel deposits of glacial and fluvial origin (Prior, 1991).

Because of the proximity of the Sioux City municipal well field to the Missouri River, river-borne contaminants have the potential to affect the water quality of the municipal supply, both chemically and biologically. Ground-water gradients can be from the riverbed to the alluvial aquifer during times of well withdrawals, inducing flow from the river to the well field. Alluvial aquifer material of suitable thickness may function as an efficient filter of river-borne particulate material and mitigate the chemical effects of the river water. Information on the thickness of the alluvial aquifer material between the riverbed and municipal well intakes is needed, particularly if changes in this thickness occurs. Horizontal collector wells are constructed by installing laterals in the aquifer beneath or adjacent to the riverbed; and therefore, collector-well laterals would be most susceptible to changes in the thickness and filtration effectiveness of aquifer material. Additionally, if the municipal wells induce flow only from adjacent river bank areas and the river streamflow is not well mixed, then understanding the source of the induced recharge is needed to develop appropriate source-water protection programs.

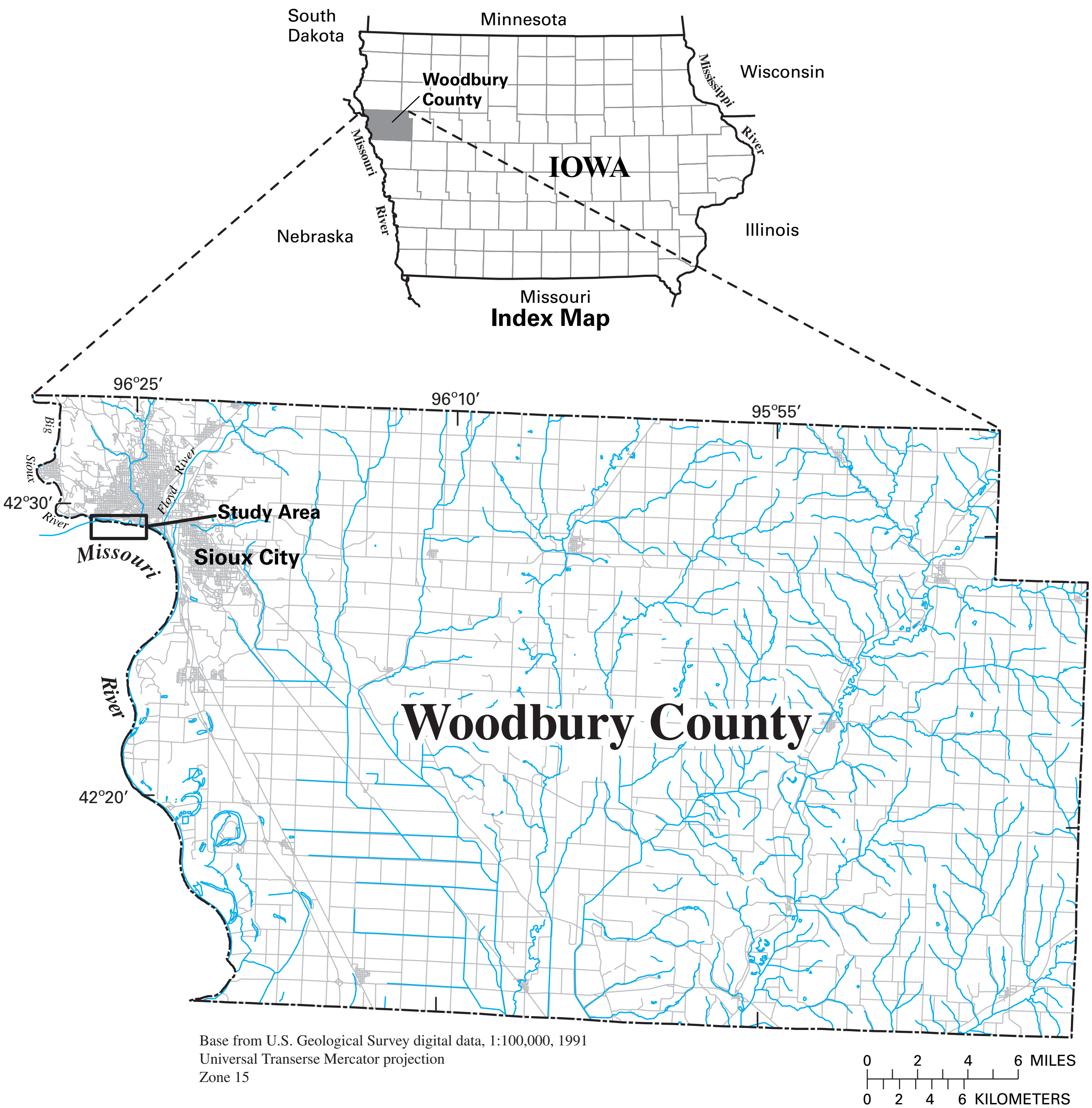
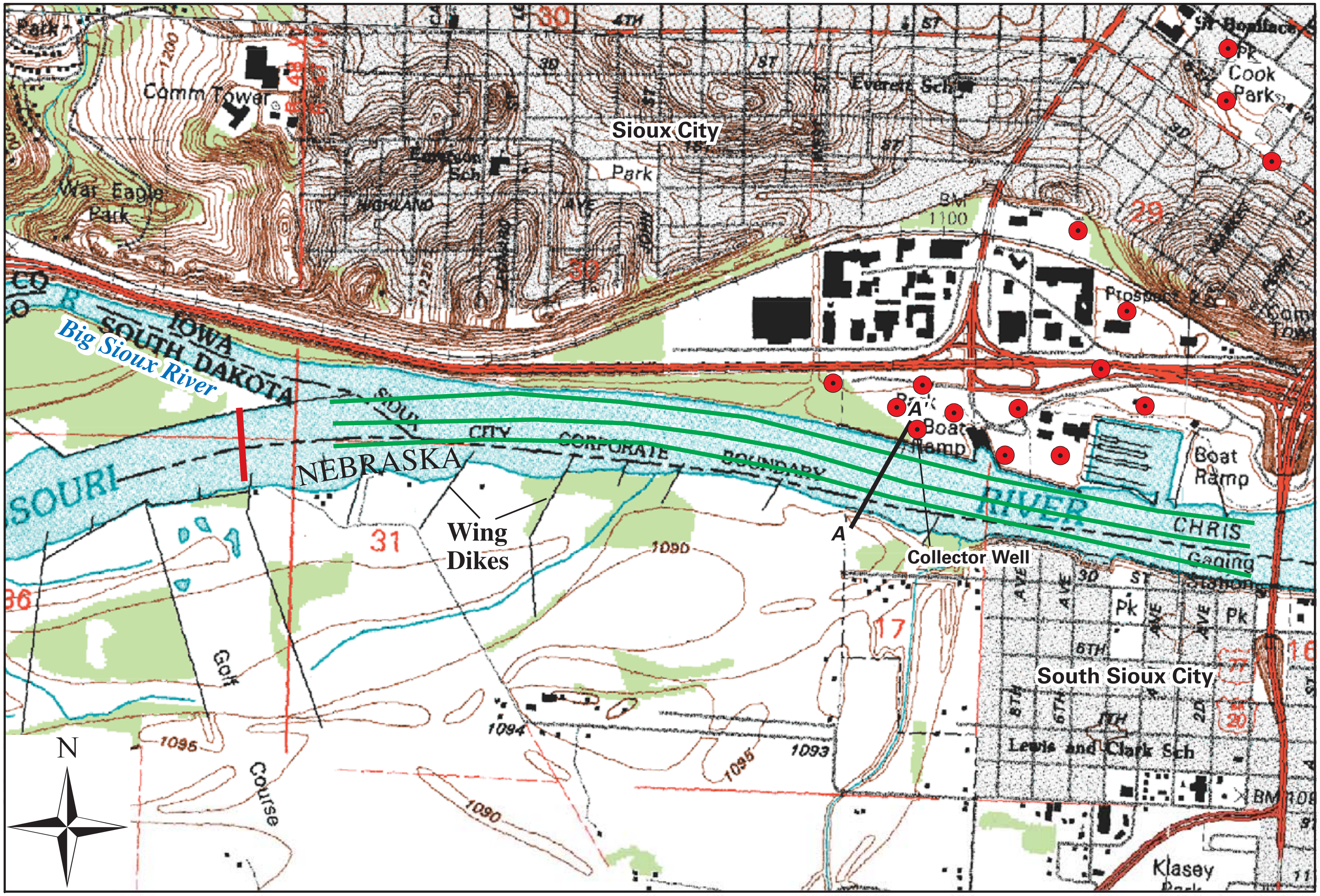


Figure 1. Location of Sioux City study area.

To help address concerns about protection of the municipal water supply from river-borne contaminants, the U.S. Geological Survey (USGS), in cooperation with the City of Sioux City, conducted a study of the Missouri River from 2002 to 2003, to provide information about the annual changes in riverbed elevations and water quality. The study focused on whether the Big Sioux River affects water quality at the riverbank area adjacent to the alluvial well field located about 5,000 ft downstream from the confluence of the Big Sioux River with the Missouri River.

The objectives of the study were to: 1) provide bathymetry data on changes in riverbed elevation, both across and along upstream/downstream traverses of the Missouri River, in the area of the Sioux City well field and 2) collect samples of selected water-quality constituents to determine the differences in water quality across the Missouri River in the well field area.



Base from U.S. Geological Survey, Sioux City South, 1:24,000, 1993
Universal Transerse Mercator projection
Zone 15

EXPLANATION

A′—A Cross section

Upstream/downstream bathymetric traverse

Upstream discharge measurment location

Sioux City municipal wells

0 0.25 0.5 MILES

0 0.25 0.5 KILOMETERS

Figure 2. Location of data-collection sites in study area on Missouri River, Sioux City, Iowa.

Purpose and Scope

This report describes results of the study of changes in riverbed elevation and water quality of the Missouri River in the Sioux City study area. Hydrologic and water-quality data were collected from October 2002 through September 2003 along the Missouri River near Sioux City's municipal well field (fig. 2). Hydrologic data collected consisted of twenty-four measurements along section A′–A of the Missouri River and quarterly measurements along three upstream/downstream traverses (fig. 2). Water-quality data were collected December 3, 2002, March 19, 2003, and June 25, 2003.

Information from this study will contribute to understanding the characterization of the Missouri River riverbed changes and the mixing of the streamflow below the confluence of the Missouri and Big Sioux Rivers near Sioux City. The hydrologic data from the Missouri River will furnish results needed by managers for planning and operation of public-water supply collection and treatment facilities, and provide information that is relevant to present and/or future public-water supplies utilizing alluvial-aquifer sources.

Description of Study Area

Sioux City, Iowa, is located in western Woodbury County, Iowa on the left bank of the Missouri River in northwest Iowa (fig. 1). The city extends east from the Missouri Alluvial Plain into the Loess Hills landform region (Prior, 1991). The topography of these two landform regions differs significantly; the Missouri Alluvial Plain is nearly level, with low relief ridges and swales that mark former positions of the river. The topography of the Loess Hills is sharp featured; with alternating peaks and saddles that trend along narrow, non-linear ridge crests (Prior, 1991). The boundary between the Missouri Alluvial Plain and the Loess Hills landform regions is abrupt.

The study area contains the Sioux City municipal water supply well field which is located about 0.5 mile upstream from the USGS streamflow gage 06486000 and approximately 5,000 ft downstream from the Missouri and Big Sioux Rivers confluence. Annual mean daily streamflow at this site is about 26,640 ft^3/s (October 2000 through September 2001)[1]. The land-surface elevation of the river valley in the study area varies from about 1,090 to 1,100 ft, and to the east, in the Loess Hills, the uplands rise to an elevation above 1,200 ft in some areas. Upstream from the study area, Missouri River streamflow is controlled by six mainstem dams constructed by the U.S. Army Corps of Engineers from 1940 to 1964. The Gavins Point Dam upstream from Sioux City controls the discharge of the Missouri River at Sioux City. Numerous wing dikes and other control structures also have been constructed to stabilize the navigation channel in the vicinity of Sioux City.

[1]Real-time stage and discharge data for this stream-gaging station can be accessed through the Internet at URL http://webdiaiwc.cr.usgs.gov/data.html

Acknowledgments

The author thanks the City of Sioux City Water Department staff for their assistance in gathering technical information. The author also thanks Kent Becher, Jim Caldwell, Joe Gorman, Rich Kopish, Matt Noon, Doug Schnoebelen, and James Sondag, USGS, for assisting with data collection and compilation.

Data-Collection Methods

Data-collection included riverbed elevation along one cross section and three upstream/downstream traverses. Quality-assurance procedures in the field included at least four transects for the riverbed-elevation data measurements and two sets of blanks for the water-quality data.

Riverbed-Elevation Data

Bathymetric data were collected from October 1, 2002, to September 30, 2003, on the Missouri River near the Sioux City municipal well field. The data consisted of 24 measurements at cross-section A′–A along with quarterly measurements of mid-channel, left-channel (Iowa), and right-channel (Nebraska) 8,500 ft upstream/downstream traverses (fig. 2). The bathymetric data were collected using a Bathy Pro 500® echo sounder (BPES) with a three-degree transducer. The sounder, which has a higher resolution and lower sensitivity to suspended sediment than the Acoustic Doppler Current Profiler (ADCP), was used due to the generally high suspended-sediment content of the Missouri River. Streamflow-discharge measurements were collected using an ADCP and completing four transects (two in each direction) under steady-flow conditions (Lipscomb, 1995). A Global Positioning Systems (GPS) receiver is integrated into the BPES and ADCP units to provide accurate position measurements. Individual cross-section measurements were then graphically merged to produce figures 3-6 showing the range of measured riverbed elevation change and measured water-surface elevation during the data-collection period. The elevations of the collector-well laterals below the riverbed also are shown for reference (figs. 3-6).

Water-Quality Data

Discrete water-quality samples were collected at five regularly spaced locations across the Missouri River at cross-section A′–A near the municipal well field (fig. 2). The distance between the sampling points was approximately 100 ft, depending on the width of the river at the time of sampling. Discharge measurements at cross-section A′–A and an upstream discharge measurement were made on the Missouri River using the ADCP each time water-quality samples were collected. The upstream discharge measurement allowed the comparison of the discharge contribution of the Big Sioux River to that of the Missouri River at cross-section A′–A to be determined by subtracting the discharge at cross-section A′–A from the upstream discharge.

Water-quality samples from the Missouri River were collected on December 3, 2002, during low-flow conditions, on March 19, 2003, following snowmelt, and on June 25, 2003, following a spring/summer precipitation event. The samples were collected using the isokinetic, depth-integrated, equal-width-increment (EWI) sampling method (U.S. Geological Survey, 1998). EWI is used frequently on streams that are sand riverbeds; the dominant Missouri River riverbed sediment is sand. Samples were analyzed in the field at the time of sample collection for dissolved oxygen, pH, specific conductance, and temperature (U.S. Geological Survey, 1998). Laboratory analyses consisted of major ions, nutrients, pesticides, and physical properties (Fishman, 1993; Zaugg and others, 1995). Laboratory analyses were performed at the USGS National Water Quality Laboratory in Lakewood, Colorado.

Quality Assurance

Discharge measurements were collected using the ADCP. To ensure quality of data collected with the ADCP, all USGS standard procedures were followed as prescribed in Lipscomb (1995).

Water-quality measurements followed collection procedures outlined in U.S Geological Survey National field manual for the collection of water-quality data, (U.S. Geological Survey, 1998). Two field blanks were collected for water-quality quality-assurance purposes. Both blanks had no detections for all constituents sampled indicating quality-assurance procedures were appropriate for the study.

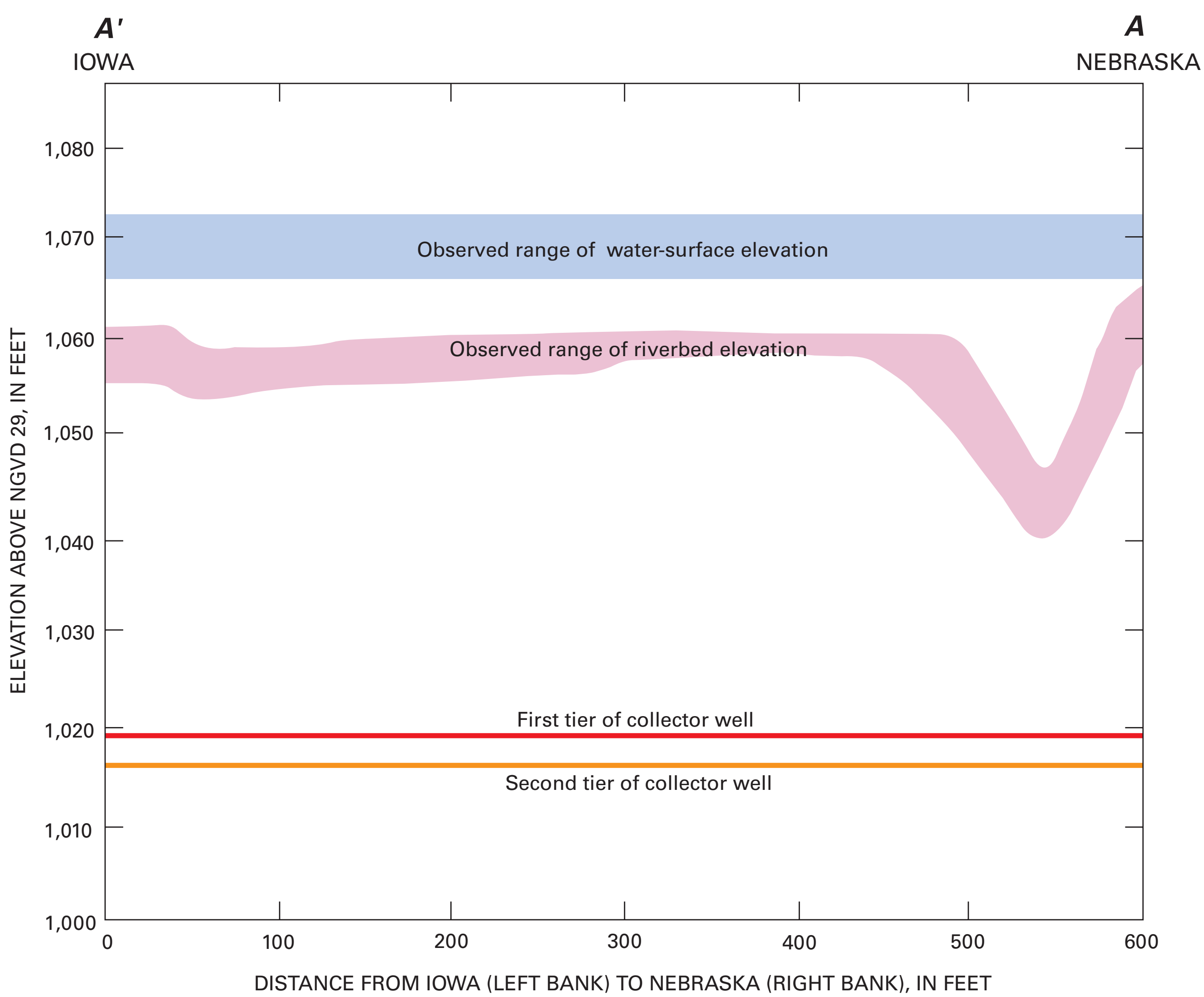


Figure 3. Cross-section A′–A located at Sioux City municipal well field.

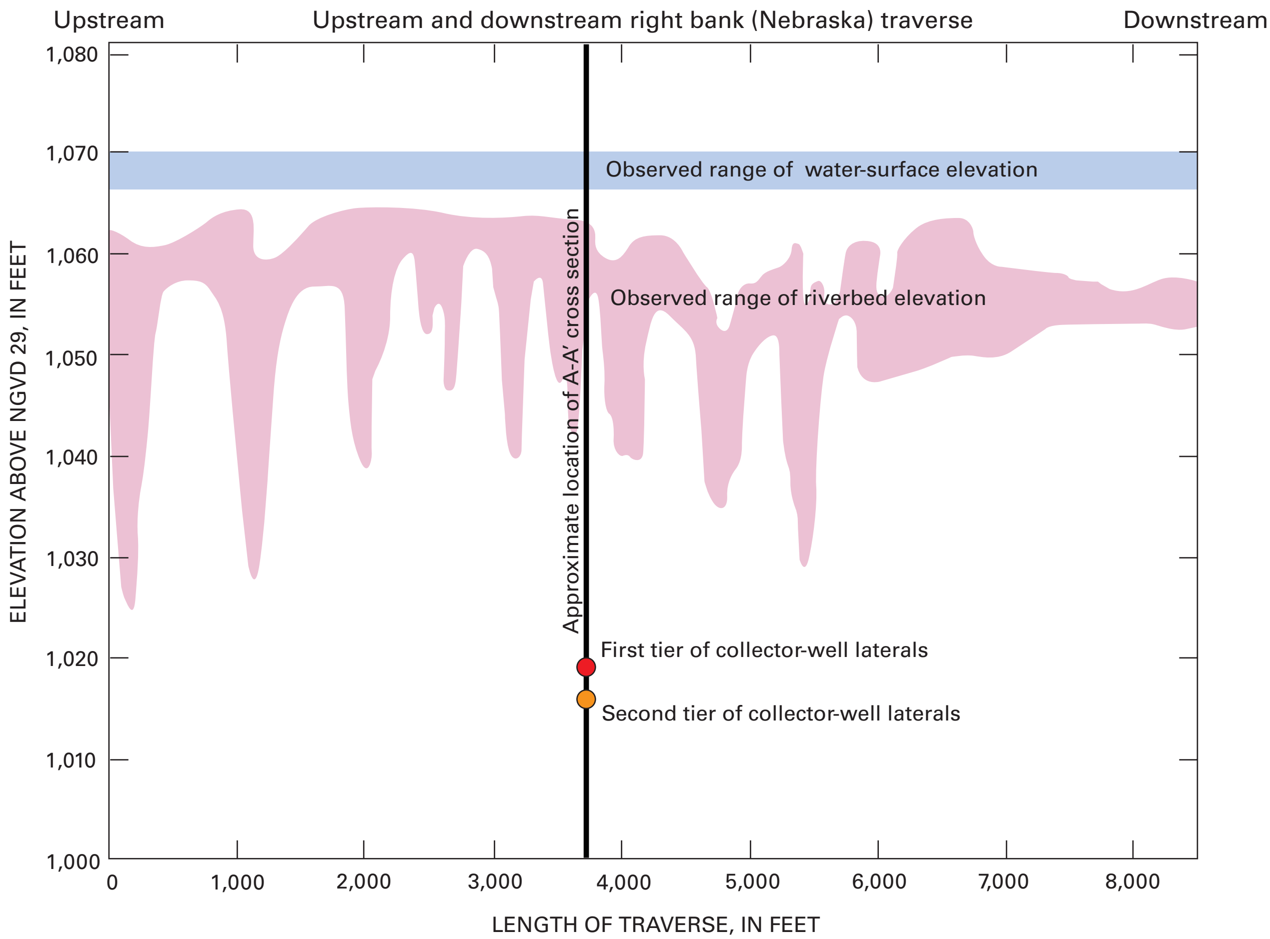


Figure 4. Upstream/downstream traverse on the right bank (Nebraska).

Riverbed Elevation

An annual change in riverbed elevation of as much as 8 ft was observed, with most of the range being less than 5 ft of change at the A′–A cross-section location near the municipal water supply (fig. 3). The deepest riverbed elevation measured was about 1,040 ft. This deep location was on the right-bank (Nebraska) side of the river, probably due to streamflow-induced scour behind the wing dike located at the site. The riverbed at an elevation of 1,040 ft is over 20 ft higher than the depth of the shallowest collector well lateral. The lowest riverbed elevation measured on the left bank (Iowa side) was 1,053 ft, which is greater than 30 ft above the elevation of the shallowest collector-well lateral.

The right-bank (Nebraska Side) traverses show variable riverbed elevations caused by scour (fig.4). The wing dikes along the right bank that can be seen in figure 2 probably cause this scour. The wing dikes in certain locations caused scour to within 5 ft of the depth of the collector-well laterals on the Iowa side of the Missouri River, although considerably upstream from the well-field area. The deepest riverbed elevation measured on the mid-channel traverse was 1,052 ft, about 33 ft above the shallowest collector-well lateral (fig. 5). The mid-channel traverse had a maximum change of 11 ft, with the range typically 7 ft or less. The deepest riverbed elevation measured on the left-bank (Iowa side) traverse was approximately 1,047 ft, about 27 ft above the elevation of the shallowest collector-well lateral (fig. 6), but located upstream from the well field area.

Water Quality

The Missouri and Big Sioux Rivers discharge measurements showed that the majority of the streamflow is contributed by the Missouri River. The Big Sioux River's largest proportion of the combined stream flow at cross-section A′–A was just over 14 percent on December 3, 2002, and the smallest proportion was 7 percent of the combined streamflow on June 25, 2003. During the winter, the Big Sioux River has a slightly larger proportion of streamflow passing the municipal well field than during the larger streamflows of the summer.

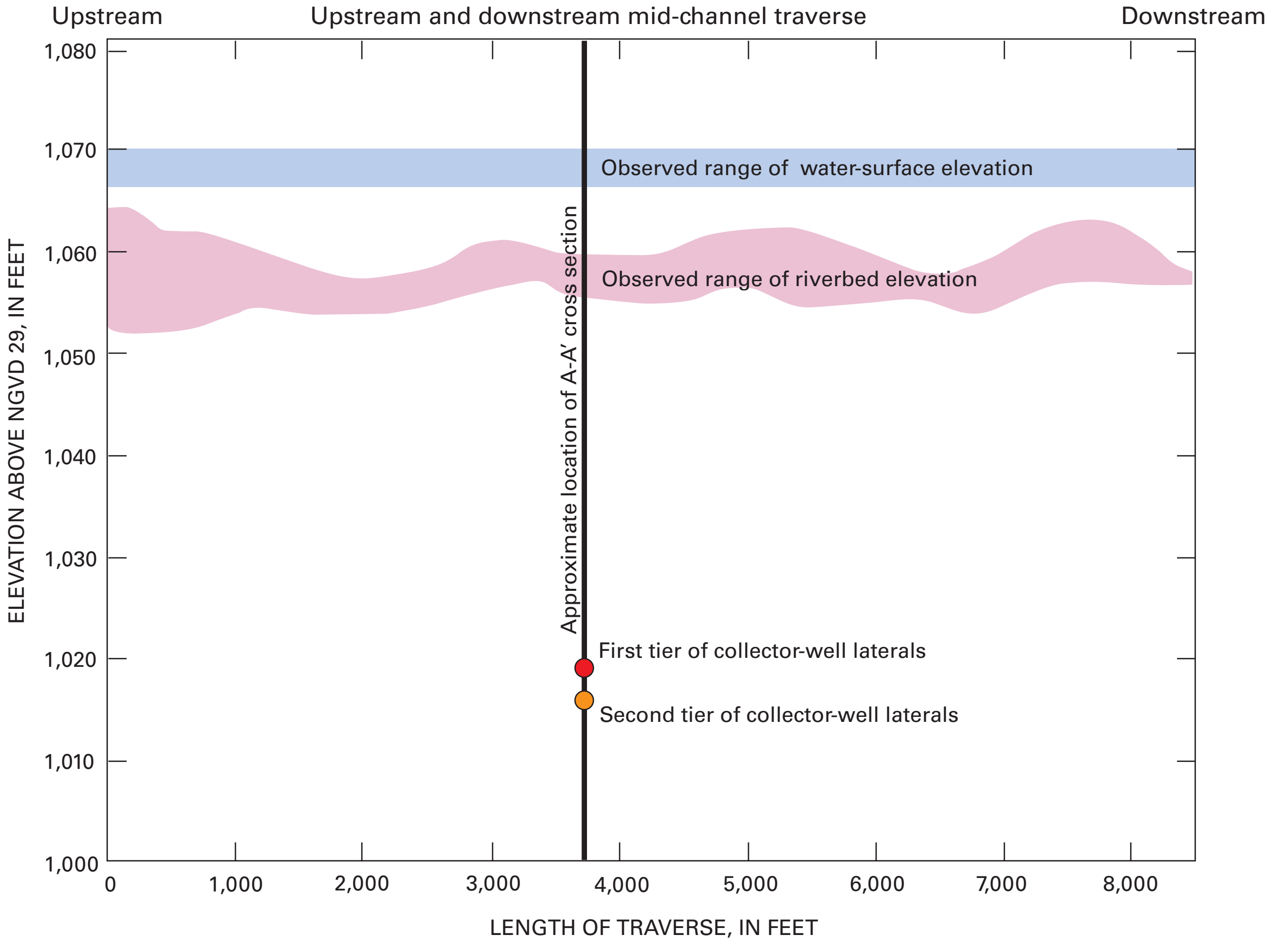


Figure 5. Upstream/downstream traverse on the mid channel.

The physical-properties data of Missouri River water samples are presented in table 1. Water temperature and pH values were consistent for each sampling date and location. There were seasonal changes measured in specific conductance, turbidity, and total dissolved solids (TDS) in all samples. Factors affecting turbidity in surface water include the physical properties of the surficial materials within the drainage basin, anthropogenic factors, land use, season, river stage, and discharge (American Society for Testing Materials, 1969).

During low-flow conditions (December 3, 2002), turbidity values of samples collected at all five sampling locations were low. Turbidity in water is due to the presence of suspended and dissolved solids and colloidal materials of various origins (IHO-WHO, 1978). The low turbidity values from samples collected in December 2002 are interpreted to be the absence of suspended solids, due to lack of surface runoff, and minimal amounts of algae and other microorganisms.

An increase in turbidity after snowmelt on March 19, 2003, was observed at the left bank and left-mid channel sample locations, which correlate with the side that water from the Big Sioux River enters the Missouri River. The increase in turbidity is attributed to a rise in river stage due to snowmelt, surface runoff, and the resulting increase in suspended sediment.

The turbidity in samples collected on June 25, 2003, was the highest in samples collected from the center channel to the right bank and lowest in samples collected from the left bank. During the summer months, water is released from upstream dams along the Missouri River. The increase in turbidity in the Missouri River at the sampling locations is attributed to the increase in stage and discharge from releases and from runoff following precipitation events and resulting increase in suspended sediment. Turbidity in surface water is generally larger in summer months due to an increase in suspended and dissolved mineral and organic material as shown by USGS streamflow gage 06610000 Missouri River at Omaha, NE (Nalley and others, 2001). The heterogeneity of turbidity observed in samples collected at this sampling point indicates that water in the Missouri River is not well mixed about 5,000 ft downstream from its confluence with the Big Sioux River.

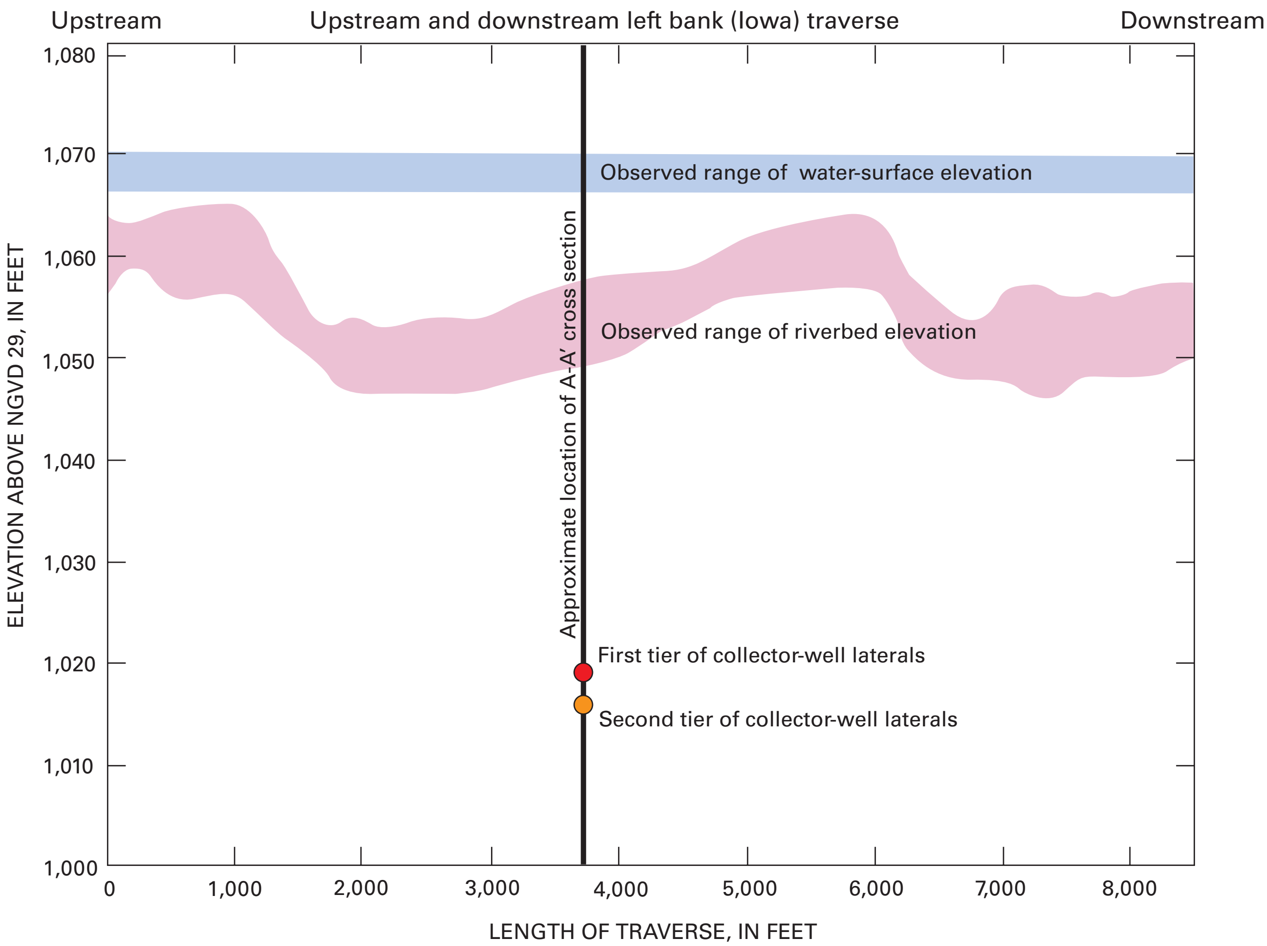


Figure 6. Upstream/downstream traverse on the left bank (Iowa).

Specific conductance was larger in samples from the left bank and left-mid channel than from the mid channel to right bank. Chemical analyses show that samples from the left side of the Missouri River have larger concentrations of dissolved ions compared to samples from the right side, which indicates that the water on the left side of the Missouri River is affected by discharge from the Big Sioux River. Specific conductance and TDS were the highest during the December 2003 samples, probably reflecting ground-water discharges during low-flow conditions or lack of dilution from runoff.

Concentrations of calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, silica, iron, and manganese vary in samples collected at each sampling location as well as seasonally (table 2). Sulfate was present in all samples with concentrations ranging from 141 to 211 mg/L. Chloride concentrations were larger in samples collected on the left bank of the river compared to the mid channel and along the right bank of the river in all samples. The largest concentration of chloride, 23 mg/L, was detected in the March 19, 2003, left-bank sample. This may indicate that the possible sources of chloride in the Missouri River are from the Big Sioux River. Sources of chloride in streamflow can include human or animal waste, or deicing agents used on roadways (IHD-WHO, 1978; U.S. Environmental Protection Agency, 1995).

Ammonia nitrogen, nitrite plus nitrate, phosphorus, and ortho-phosphorus were present in all samples collected during at least one of the collection dates (table 3). Measured concentrations of ammonia nitrogen were between 0.02 mg/L and 0.50 mg/L. Ammonia nitrogen had a larger concentration in the March 19, 2003, collection date in samples collected along the left bank of the river. Ammonia nitrogen also was slightly larger on March 19, 2003, and June 25, 2003, in the left-bank samples compared to the right-bank samples. The presence of ammonia in water can be the result of decomposition of wastes, and from agricultural runoff. Concentrations of nitrite plus nitrate nitrogen were composed primarily of nitrate nitrogen, and were detected in all samples. No sample exceeded the U.S. Environmental Protection Agency (USEPA) maximum contaminant level for nitrate (10 mg/L as N) (U.S. Environmental Protection Agency, 1996). Samples collected along the left bank of the river had larger concentrations of nitrate nitrogen compared to the samples on the right bank in all samples collected in 2002-2003. This also is evidence of Big Sioux and Missouri River waters not being well mixed.

Table 1. Physical properties determined in samples from the Missouri River at Sioux City, Iowa, 2002-2003.

[M/D/YY, month/day/year; ft^3/s, cubic feet per second, mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; NTU, nephelonetric turbidity units; --, no data available]

Date (M/D/YY)	Time	Missouri River discharge at 06486000 (ft^3/s)	Big Sioux River discharge (ft^3/s)	Oxygen, dissolved (mg/L)	pH water whole field (standard units)	Specific conductance (µS/cm)	Temperature water (deg C)	Turbidity (NTU)	Total dissolved solids (mg/L)
Left bank (Iowa)									
12/3/2002	15:10	14,300	2,100	13.7	8.4	836	1.0	11.8	541
3/19/2003	11:25	24,000	3,158	10.7	8.2	673	4.5	71.3	438
6/25/2003	11:45	34,700	2,465	5.9	8.0	701	24.0	603.0	443
Left-mid channel									
12/3/2002	15:05	14,300	2,100	13.6	8.4	832	1.0	11.1	--
3/19/2003	11:35	24,000	3,158	11.5	8.4	724	5.0	24.9	--
6/25/2003	12:25	34,700	2,465	6.8	8.1	671	23.5	798.0	--
Mid channel									
12/3/2002	15:00	14,300	2,100	13.6	8.5	813	1.0	10.4	--
3/19/2003	11:40	24,000	3,158	11.8	8.4	739	5.5	14.2	--
6/25/2003	12:30	34,700	2,465	6.7	8.1	662	23.5	915.0	--
Right-mid channel									
12/3/2002	14:55	14,300	2,100	13.5	8.5	803	1.0	11.8	--
3/19/2003	11:50	24,000	3,158	11.8	8.4	733	5.5	12.5	--
6/25/2003	12:45	34,700	2,465	6.9	8.1	656	23.5	873.0	--
Right bank (Nebraska)									
12/3/2002	14:50	14,300	2,100	13.4	8.5	804	1.0	12.5	518
3/19/2003	11:55	24,000	3,158	11.8	8.4	735	5.5	16.9	481
6/25/2003	12:50	34,700	2,465	6.8	8.1	654	23.5	876.0	414

Table 2. Major ion concentrations in samples from Missouri River at Sioux City, Iowa, 2002-2003.

[M/D/YY, month/day/year; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Date (M/D/YY)	Time	Hardness (mg/L as $CaCO_3$)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Sodium (mg/L as Na	Potassium (mg/L as K)	Chloride (mg/L as CL)	Sulfate (mg/L as SO_4)	Fluoride (mg/L as F)	Silica (mg/L as SiO_2)	Iron (µg/L as Fe)	Manga-nese (µg/L as Mn)
Left bank (Iowa)												
12/3/2002	15:10	270	64	26	68	5.2	14	211	0.56	7.1	<10	50
3/19/2003	11:25	230	59	21	46	7.9	23	141	0.40	9.5	13	125
6/25/2003	11:45	240	56	24	51	6.0	14	162	0.50	8.0	<8	0.23
Left-mid channel												
12/3/2002	15:05	280	66	26	66	4.5	13	210	0.50	7.4	<10	46
3/19/2003	11:35	240	61	22	57	5.7	12	176	0.51	10	<10	35
6/25/2003	12:25	210	51	19	58	6.1	9.8	163	0.51	7.6	<8	0.40
Mid channel												
12/3/2002	15:00	270	64	26	69	4.7	11	210	0.56	7.4	<10	34
3/19/2003	11:40	250	62	23	62	4.9	9.2	189	0.51	11	<10	7.4
6/25/2003	12:30	200	51	18	57	6.2	9.4	161	0.51	7.6	<8	0.40
Right-mid channel												
12/3/2002	14:55	260	61	25	72	4.6	10	209	0.53	7.4	<10	20
3/19/2003	11:50	240	60	23	64	5.2	9.0	185	0.50	11	<10	7.8
6/25/2003	12:45	200	50	18	56	6.2	9.4	159	0.50	7.6	<8	0.40
Right bank (Nebraska)												
12/3/2002	14:50	240	57	23	69	5.0	10	208	0.57	7.0	<10	23
3/19/2003	11:55	240	61	22	62	5.0	9.4	186	0.48	11	<10	7.7
6/25/2003	12:50	200	51	18	56	6.2	9.4	159	0.50	7.5	<8	0.40

Table 3. Nutrient, concentrations in samples from Missouri River at Sioux City, Iowa, 2002-2003.

[M/D/YY, month/day/year; mg/L, milligrams per liter; <, less than]

Date (M/D/YY)	Time	Nitrogen, ammonia dissolved (mg/L as A)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, ammonia + organic dissolved (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Phosphorus, total (mg/L)	Phosphorus, dissolved (mg/L as P)	Ortho-phosphorus, total (mg/L as P)
Left bank (Iowa)									
12/3/2002	15:10	0.03	0.01	0.24	0.53	0.39	0.05	0.01	<0.02
3/19/2003	11:25	0.50	0.06	1.4	1.5	1.8	0.54	0.22	0.21
6/25/2003	11:45	0.13	0.02	0.57	1.2	3.2	1.0	0.07	0.05
Left-mid channel									
12/3/2002	15:05	0.03	0.01	0.22	0.49	0.39	0.05	0.01	<0.02
3/19/2003	11:35	0.13	0.02	0.43	0.54	0.68	0.16	0.01	0.05
6/25/2003	12:25	0.06	0.02	0.35	0.35	3.9	1.4	0.06	0.05
Mid channel									
12/3/2002	15:00	0.02	0.00	0.23	0.31	0.34	0.04	0.01	<0.02
3/19/2003	11:40	0.03	<0.01	0.24	0.24	0.40	0.07	0.01	<0.02
6/25/2003	12:30	0.06	0.02	0.33	0.35	4.1	1.4	0.06	0.05
Right-mid channel									
12/3/2002	14:55	0.02	<0.01	0.22	0.12	0.29	0.03	0.01	<0.02
3/19/2003	11:50	0.03	<0.01	0.22	0.25	0.41	0.08	0.01	<0.02
6/25/2003	12:45	0.06	0.02	0.38	0.38	4.1	1.4	0.06	0.05
Right bank (Nebraska									
12/3/2002	14:50	<0.04	<0.01	0.19	0.12	0.29	0.03	0.01	<0.02
3/19/2003	11:55	0.03	<0.01	0.24	0.26	0.45	0.09	0.01	<0.02
6/25/2003	12:50	0.06	0.02	0.41	0.37	4.2	1.4	0.06	0.05

Pesticide samples were collected for analysis at the left- and right-bank locations along cross-section A′–A. Analytical results of all pesticides that had at least one detection on a specific sample date are listed in table 4, and pesticides that had no detection are listed in table 5. Atrazine and deethylatrazine were detected on all sample dates in all samples. Deethlyatrazine was detected by the laboratory on 5 out of 6 samples, but at a low concentration (<0.08 µg/L). The presence of deethylatrazine would be expected because it is a degredate of atrazine. The concentrations of atrazine were the largest in samples on the left bank of the river, but still were below the drinking-water regulation of 3 µg/L set by the USEPA (U.S. Environmental Protection Agency, 1996). The larger concentrations occurred in the March 19, 2003, and June 25, 2003, samples, which could indicate snowmelt runoff in the spring and agricultural runoff in the summer as a source (Schnoebelen and others, 2003). The larger concentration of atrazine in samples on the left bank of the river would correlate to intense agricultural use of the Big Sioux River basin, and might possibly delineate a separation of streamflow between the Missouri and Big Sioux Rivers. Acetochlor, alachlor, metolachlor, promenton, and trifluralin were detected in several samples but at extremely low concentrations. Carbofuran was detected at estimated concentrations in the June 25, 2003, sample on both sides of the river; this would follow the pattern observed in previous studies that large carbofuran concentrations occur in the month of June (Schnoebelen and others, 2003). Carbofuran is a pesticide that is applied in the summer months for agricultural insect control.

Table 4. Selected dissolved pesticides in samples from Missouri River at Sioux City, Iowa, 2002-2003.

[All data in micrograms per liter. M/D/YY, month/day/year; E, estimated value; N, presumptive evidence of presence; T, below the long-term method detection limit, MDL; <, less than]

Date (M/D/YY)	Time	Acetochlor	Alachlor	Atrazine	Carbofuran	Deethyl-atrazine	Metolachlor	Promenton	Trifluralin
				Left bank (Iowa)					
12/3/2002	15:10	<0.006	<0.005	0.018	<0.020	E 0.007	E,T 0.002	E,T 0.005	<0.009
3/19/2003	11:25	0.023	<0.005	0.051	<0.020	E 0.020	0.157	<0.015	<0.009
6/25/2003	11:45	0.439	0.022	2.11	E 0.014	E 0.088	0.283	E,N 0.013	<0.009
				Right bank (Nebraska)					
12/3/2002	14:50	<0.006	0.005	0.017	<0.020	0.006	0.001	E,T 0.004	<0.009
3/19/2003	11:55	<0.006	<0.005	0.017	<0.020	E 0.009	0.014	<0.015	<0.009
6/25/2003	12:50	0.657	0.029	1.22	E 0.027	E 0.076	0.248	E,N 0.076	E,N 0.007

Table 5. Pesticide constituents not detected in surface-water samples from Missouri River at Sioux City, Iowa, 2002-2003.

[µg/L, micrograms per liter]

Constituent	Method detection limit (µg/L)	Constituent	Method detection limit (µg/L)	Constituent	Method detection limit (µg/L)
Alpha-HCH	0.046	Ethlfluralin	0.009	p.p'-DDE	0.0025
2,6-Diethylanline	0.006	Ethoprophos	0.005	Parathion	0.010
Azinphos-mthyl	0.050	Desulfinyfipronil amide	0.009	Pebulate	0.0041
Benfluralin	0.010	Fipronil sulfide	0.005	Pendimethalin	0.022
Butylate	0.002	Fipronil sulfone	0.005	Phorate	0.011
Carbaryl	0.041	Desulfinyfipronil	0.004	Propyzamide	0.0041
Chlorpyrifos	0.005	Fipronil	0.007	Propachlor	0.010
Cis-Permethrin	0.006	Fonofos	0.100	Propanil	0.011
Cyanizine	0.018	Lindane	0.004	Propargite	0.023
Dacthal	0.003	Linuron	0.035	Simazine	0.005
Diazinon	0.005	Malathion	0.027	Tebuthiuron	0.016
Diazinon-d10	0.100	Parathion-methyl	0.006	Terbacil	0.034
Dieldrin	0.0048	Metribuzin	0.006	Terbufos	0.017
Disulfoton	0.021	Molinate	0.0016	Thiobencarb	0.0048
EPTC	0.002	Napropamide	0.007	Tri-allate	0.0023

Summary

The City of Sioux City, Iowa obtains part of its municipal water supply from the Missouri River alluvial aquifer. The U.S. Geological Survey, in cooperation with City of Sioux City, conducted a study to provide information about the riverbed elevation and water quality of the Missouri River at Sioux City.

The alluvial aquifer along the Missouri River at Sioux City consists of sand and gravel deposits of glacial and fluvial origin. The Missouri River riverbed consists predominately of sand and gravel throughout the study area. The thickness of sediments overlying the municipal collector-well laterals are of concern for the filtration of drinking water being obtained by Sioux City. A consistent thickness of 20 to 30 ft of sediment overlies the collector-well laterals to provide a filter for the water supply. The cross-section data show scour and fill over the period from October 1, 2002, to September 30, 2003, but a thickness of 20 to 30 ft of sediment overlying the laterals was maintained. These changes appear to coincide with rising and lowering Missouri River discharge that is controlled by the U.S. Army Corps of Engineer's Gavins Point Dam upstream from the study location.

Results of water-quality analyses of the Missouri River were similar across the width of the river. However, somewhat higher concentrations of chloride, ammonia nitrogen, nitrite plus nitrate nitrogen, deethylatrazine, and atrazine were detected along the left bank (Iowa side) of the Missouri River compared to the right bank (Nebraska side). The left bank is the side of the Missouri River where the Big Sioux River enters upstream from the sampling cross section. Water-quality results indicate that water from the two rivers is not well mixed and that water from the Big Sioux River potentially has a greater influence on water quality at the municipal well field than does the Missouri River. Therefore, understanding the water quality of the Big Sioux River may be crucial to understand variations in water quality at the municipal well field and to protect the supply source.

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