HYDROLOGIC DATA FOR THE BIG SPRING BASIN,

CLAYTON COUNTY, IOWA, WATER YEAR 1988

By Stephen J. Kalkhoff

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CONVERSION FACTORS

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

Multiply inch-pound units	By	To obtain SI units
foot (ft)	0.3048	meter (m)
cubic foot per second (ft3/s)	0.02832	cubic meter per second (m3/s)
million gallons per day (Mgal/d)	0.0438	cubic meter per second (m3/s)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi2)	2.590	square kilometer (km2)

Temperature in degrees Fahrenheit (F) as follows:

$$F = (1.8 \times C) + 32$$

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ABSTRACT

Hydrologic data was collected during the 1988 water year in cooperation with the Iowa Department of Natural Resources Geological Survey Bureau in the Big Spring ground-water basin located in Clayton County, Iowa. Information on precipitation, streams, and ground water was collected in the basin.

Total rainfall at Big Spring was 24.08 inches. The greatest monthly rainfall was in September. Calcium and sulfate were the predominant ions in the rain and the median ammonia and nitrate concentrations as nitrogen were 0.40 and 0.37 mg/L (milligrams per liter),respectively.

Stream discharge, water temperature, specific conductance, and pH were monitored continuously and monthly water-quality samples were collected at three sites in the basin. In the streams, water temperature and pH vary diurnally and are greatest during the day. Specific conductance varies inversely with water temperature and pH. The predominant ions in the streams were calcium, magnesium, and bicarbonate. Nitrate plus nitrite as nitrogen concentrations ranged from 0.5 to 15 mg/L. Pesticide concentrations ranged from less than 0.10 μg/L (micrograms per liter) to 0.72 μg/L. Atrazine was detected in 12 of 13 stream samples and cyanazine was detected in 4 of 13 samples.

The daily mean temperature of the water in Big Spring ranged from 9.7 to 10.6 degrees Celsius, the daily mean specific conductance ranged from 698 to 735 microsiemens per centimeter at 25 degrees Celsius, and the daily median pH ranged from 6.7 to 7.1. Calcium, magnesium, and bicarbonate were the predominant ions in solution. Nitrate plus nitrite as nitrogen concentrations ranged from 7.5 to 11 mg/L. Atrazine was the only pesticide detected in the monthly samples from Big Spring. Atrazine concentrations were greater than the detection limit in six of seven samples and ranged from less than 0.10 to 0.26 μg/L.

During a baseflow seepage study, June 28 and 29, the discharge lost by streams in the basin was 5.57 cubic feet per second and the dissolved nitrogen load lost was 0.19 tons per day. The discharge and total dissolved nitrogen leaving the basin in streams was 2.93 cubic feet per second and 0.02 tons per day, respectively.

INTRODUCTION

There is a concern nationally, as well as within the State of Iowa, to understand, quantify, and minimize the occurrence of agricultural chemicals in surface water and ground water. In response to this concern, the Big Spring ground water basin in northeast Iowa, has been studied since 1980 and has become a nationally known demonstration area for improving ground-water quality through the modification of agricultural practices. Numerous multidisciplinary studies that deal with agronomy, geology, hydrology, biology, and socioeconomics of the basin are currently being conducted.

The unique ground-water-flow system within the Big Spring basin aids in studying the movement of agricultural chemicals in the ground water. Much of the ground water in the basin moves through a karst drainage system and is discharged at Big Spring. The extent of the ground-water drainage basin has been defined by dye tracing, potentiometric-surface mapping, and other hydrologic analyses. Nearly all land in the basin is farmed and a clear link between agricultural chemicals and ground-water contamination has been established (Hallberg and others, 1983, 1984 Libra and others, 1986).

Beginning in October 1987, the U.S. Geological Survey in cooperation with the Iowa Department of Natural Resources, Geological Survey Bureau began a study to collect water quality and quantity data in the Big Spring basin. These data are needed for a detailed understanding of the hydrologic cycle within the basin and for an understanding of agricultural chemical transport processes in the system. The dynamic nature of the surface water and ground-water flow within the basin requires that some facets of water quality and quantity be continuously monitored. Data collected in the study also will aid in interpreting the nature of the flow system. This work also includes determining a partial water budget for the ground-water basin by measuring the input (precipitation) into the basin and the outputs (stream discharge and spring discharge) from the basin.

In addition to the data presented in this report, the Iowa Department of Natural Resources, Geological Survey Bureau and other state and university investigators collected water-quality and discharge data in the study area. These data will be published in separate reports.

Purpose and Scope

The purpose of this report is to present the hydrologic data collected in the Big Spring basin in the 1988 water year, October 1987 to September 1988. These data include information on the quantity of precipitation and the quantity and quality of ground water, and surface water. Precipitation quality data from the NADP/NTN (National Atmospheric Deposition Program/ National Trends Network) site at Big Spring also are included.

The data are presented in two formats to aid the reader. Data recorded continuously are presented graphically and are summarized in tables showing mean daily values. The results of chemical analyses of samples collected monthly at the monitoring sites and of samples collected during the seepage run are listed in tables.

Study area

The study area is located in Clayton County in northeastern Iowa and corresponds with the ground-water basin draining through Big Spring (Hallberg and others, 1983). The basin includes 103 mi^2 (square miles). One monitoring site (RC2) is located on Roberts Creek above Saint Olaf, Iowa (fig. 1). Roberts Creek and its major tributary, Silver Creek drain approximately 69 percent (70.7 mi^2) of the study area overlying the ground-water basin. The remaining area is drained by Howard (approximately 18 mi^2) and Hatchery Creeks (8.8 mi^2) and several small intermittent streams. A monitoring site (BOOGD) is located on a small stream, Unnamed Creek near Luana, Iowa, that drains into a series of sinkholes. Station numbers for stream sites were the same as those assigned by the Iowa Department of Natural Resources, Geological Survey Bureau in previous studies (Hallberg and others, 1984). A stream-gaging site (L23) is located on Silver Creek. Additional sampling sites for a seepage study are given in table 1. Ground-water discharge is monitored at Big Spring.

Methodology

Precipitation is measured using standard rain gages at three sites. At two sites, RC2 and BOOGD, precipitation is recorded digitally by a datalogger every 15 minutes while at Big Spring it is recorded continuously on analog chart.

Precipitation quality samples obtained at Big Spring are collected automatically with an Aerochem Metrics Wet/Dry Precipitation Collector. 1/ During periods of rainfall, a bucket is exposed to catch the rain. Between rain events the bucket is covered to avoid the collection of particulate matter. Buckets are removed and the contents analyzed weekly. Site operations are described in detail in the NADP/NTN instruction manual (NADP/NTN, 1988).

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

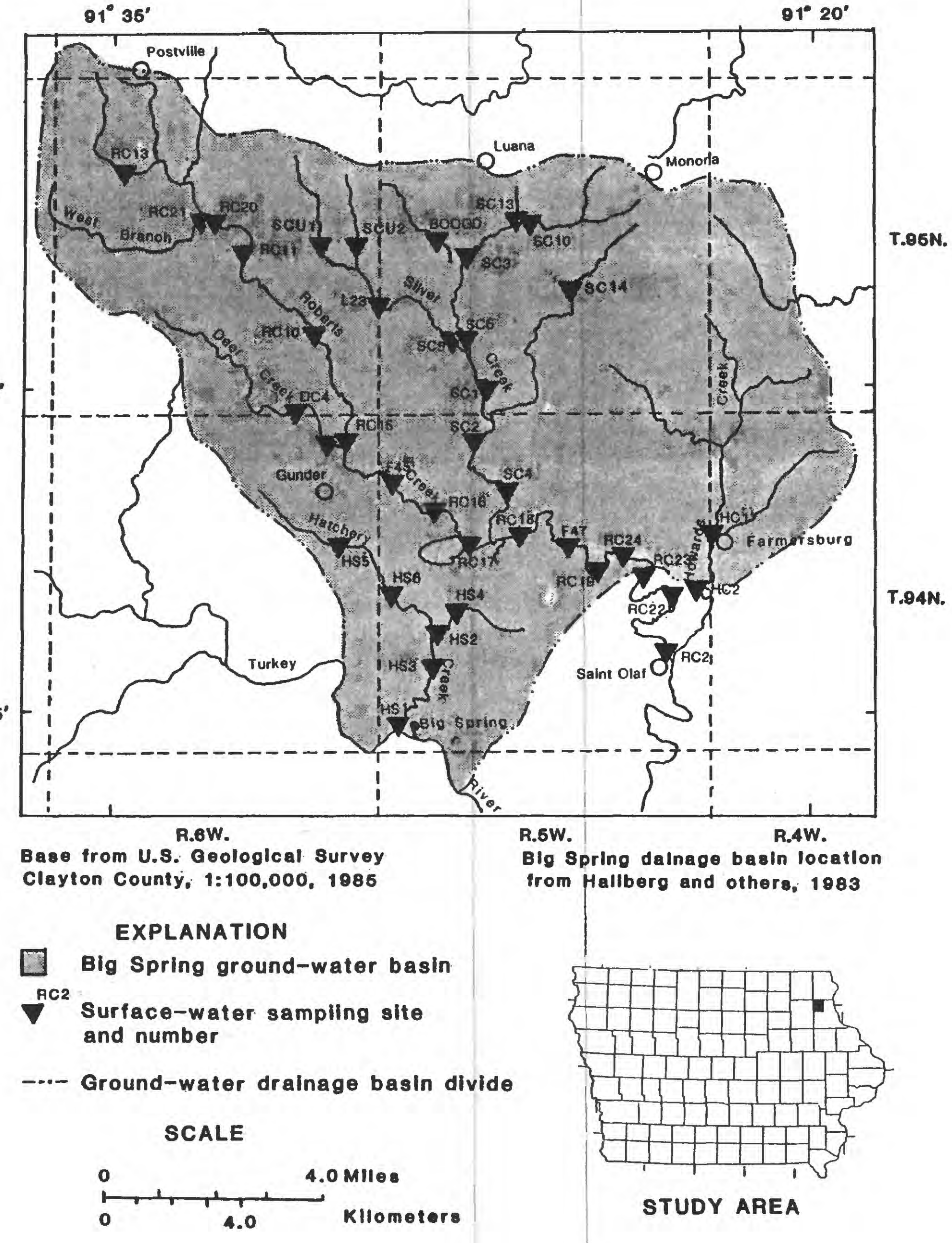

Figure 1.--Location of the study area and sampling sites.

Table 1.--Location and drainage area of sampling sites
[nr, near; SE, southeast; N, north; SW, southwest; NW, northwest; W, west; E, east; NE, northeast; S, south; trib, tributary; Cr, Creek]

Station number	Site identi-cation number	Station name	Location Lat.	Location Long.	Drainage area(mi2)
HS5		Hatchery Creek nr Gunder	425734	0913012	1.28
HS6		Hatchery Creek SE of Gunder	425647	0912859	2.84
HS4		Hatchery Cr trib N of Big Spring	425629	0912737	1.36
HS2		Hatchery Cr trib nr Big Spring	425606	0912806	1.85
HS3		Hatchery Creek nr Big Spring	425536	0912806	7.02
HS1		Hatchery Creek at Big Spring	425446	0912853	8.80
RC13		Roberts Creek trib nr Postville	430327	0913440	2.28
RC21		West Branch Roberts Cr at mouth	430244	0913300	4.14
RC20		Roberts Creek nr Postville	430240	0913253	11.1
RC11		Roberts Creek SE of Postville	430211	0913216	13.2
RC10		Roberts Creek nr Luana	430057	0913042	15.9
RC15		Roberts Creek at Gunder	425908	0913002	18.2
DC4		Deer Creek nr Gunder	425942	0913107	4.37
DC2		Deer Creek at Gunder	425908	0913025	5.56
F45		Roberts Creek East of Gunder	425830	0912858	26.0
RC16		Roberts Creek north of Big Spring	425806	0912805	28.8
RC17		Roberts Creek near Big Spring	425735	0912722	30.4
SC10		East Fork Silver Cr nr Monona	430240	0912620	3.05
SC13		E Fork Silver Cr trib nr Monona	430240	0912606	.28
SC3		E Fork Silver Cr nr Luana	430203	0912730	4.28
BOOGD	05412070	Unnamed Creek near Luana	430224	0912807	1.15
SC6		E Fork Silver Creek S of Luana	430054	0912730	9.46
SCU1		Silver Creek SW of Luana	430210	0913033	1.36
SCU2		Silver Creek trib SW of Luana	430201	0912949	.70
L23	05412060	Silver Creek nr Luana	430119	0912921	4.39
SC5		Silver Creek South of Luana	430049	0912744	5.59
SC1		Silver Creek NE of Gunder	430002	0912653	17.3
SC14		Silver Creek trib nr Monona	430140	0912510	1.13
SC2		Silver Creek nr Gunder	425916	0912712	25.2
SC4		Silver Creek East of Gunder	425824	0912630	28.8
RC18		Roberts Creek NE of Big Spring	425736	0912603	61.8
RC19		Roberts Creek NW of Saint Olaf	425733	0912510	63.6
F47		Roberts Creek W of Farmersburg	425706	0912434	64.3
RC24		Roberts Creek nr Farmersburg	425724	0912358	65.2
RC23		Roberts Creek N of Saint Olaf	425710	0912328	66.0
RC22		Roberts Creek SW of Farmersburg	425641	0912226	66.6
RC2	05412100	Roberts Creek above Saint Olaf	425549	0912303	70.7
HC1		Howard Creek at Farmersburg	425744	0912209	13.8
HC2		Howard Creek nr Farmersburg	425648	0912223	17.8

Measurement of unstable constituents and stream discharge are made at the time of sample collection. Water temperatures and dissolved-oxygen concentrations are measured in the stream or spring pool. Water temperatures are measured with a standard mercury or alcohol thermometer that has been previously checked against a laboratory grade thermometer for accuracy. Dissolved-oxygen concentrations are measured with a dissolved-oxygen meter. Water to be analyzed is collected from a flowing section of the stream or the surface of the spring pool. Immediately after sample collection, the pH and specific conductance of the water are measured. Stream discharge normally is measured by current-meter methods (Buchanan and Somers, 1969). Because of low-flow conditions with shallow stream depths during most of 1988 water year, the 0.6-depth method generally is used. Where the channel is extremely narrow and the discharge is small, less than 0.50 ft^3/s (cubic feet per second), a portable Parshall flume (Kilpatrick and Schneider, 1983, p 13-15) is used to measure the flow. Stage is recorded continuously at stream sites RC2, L23, and BOOGD with bubble-gage sensors and digital recorders (Rantz and others, 1982a, p 32-39). Stream discharge is calculated from stage using stage-discharge relations developed for each site (Kennedy, 1983, p 30-32).

Samples for chemical analyses are prepared as described in table 2 for shipment to the laboratory. Analyses of water samples by the University Hygienics Laboratory in Iowa City and Des Moines, Iowa are by the methods listed in table 2. The U.S. Environmental Protection Agency's method 81.40 for the analyses of pesticides is modified to use capillary columns.

The water-quality constituents continuously monitored at two stream sites and at Big Spring are water temperature, specific conductance, and pH. These constituents are measured using a multiple parameter meter and recorded at 15 minute intervals with a Campbell datalogger. The data stored in the datalogger is retrieved weekly by computer through a phone modem in the U.S. Geological Survey's office in Iowa City. From the 15 minute observations, mean daily values are calculated and permanently stored in the U.S. Geological Survey National Water Data Storage and Retrieval System (WATSTORE) data base. Values determined by the multiple parameter field meter are checked weekly against pH buffer and conductance reference solutions. Temperature values are checked against a mercury thermometer. Water samples for the analyses of major ions, nutrients, and selected pesticides are collected the first week of each month at the monitoring sites starting in March 1988.

Suspended sediment samples are collected periodically by local observers. The observers collected depth integrated samples at one vertical using techniques described by Guy and Norman, (1970). Samples were collected five times per week at RC2, Roberts Creek above Saint Olaf, and three times per week at BOOGD, Unnamed Creek near Luana.

Table 2.--Sample preparation and chemical analysis procedures
[EPA methods from U.S. Environmental Protection Agency, 1983]
[USGS1 - Buchanan and Somers, 1969; USGS2 - Wood, 1976]
[um, micrometer; C, Carbon; N, nitrogen; P, phosporus]
[*, modified method see text]

Sample preparation method	Chemical constituent
Filtration through a 0.45um membrane	Calcium, magnesium, sodium, potassium sulfate, chloride, dissolved solids, silica, aluminum, iron, nitrate plus nitrite, organic nitrogen, ammonia
Acidification with nitric acid	Calcium, magnesium, sodium, potassium, iron, aluminum
Chill	Organic carbon, nitrate plus nitrite, ammonia, organic nitrogen, orthophosphate, atrazine, cyanazine, metolachlor, alachlor, metribuzin, butylate, trifluralin
Acidification with sulfuric acid	nitrate plus nitrite, ammonia, orthophosphate

Constituent	Analytical method
Field Measurements	
Stream discharge	USGS1
Water temperature	USGS2
Specific conductance	USGS2
pH	USGS2
Oxygen, dissolved	USGS2
Alkalinity	Incremental titration
Bicarbonate, dissolved	Incremental titration
Carbonate, dissoved	Incremental titration
Inorganic compounds, dissolved	
Calcium	EPA method 215.2
Magnesium	EPA method 200.7
Sodium	EPA method 273.1
Potassium	EPA method 258.1
Chloride	EPA method 325.3
Sulfate	EPA method 275.4
Silica	EPA method 370.1
Aluninum	EPA method 200.7
Iron	EPA method 200.7
Nutrients, dissolved	
Nitrate plus nitrite as N	EPA method 353.2
Ammonia as N	EPA method 350.1
Organic nitrogen as N	EPA method 415.1
Carbon, total organic as C	EPA method 415.1
Orthophosphate as P	EPA method 365.1
Pesticides, total recoverable	
Atrazine	*EPA method 81.40
Cyanazine	*EPA method 81.40
Metolachlor	*EPA method 81.40
Alachlor	*EPA method 81.40
Metribuzin	*EPA method 81.40
Butylate	*EPA method 81.40
Trifluralin	*EPA method 81.40

Acknowledgments

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HYDROLOGIC DATA

Precipitation

Quantity

Measurable precipitation of 0.01 in. (inch) or more fell 36 of 52 weeks during water year 1988 at Big Spring. Total rainfall for water year 1988 was 24.08 in. with a median weekly rainfall of 0.22 in.(table 3). The total rainfall at Big Spring was 9.25 in. less than the average for the nearby National Weather Service station in Elkader, Iowa (National Oceanic and Atmospheric Administration, 1988, p 3.). The greatest weekly rainfall (3.68 in.) occurred from September 18 to 24.

Precipitation was measured at site BOOGD from May 14 to the end of the water year and at site RC2 from June 1 to the end of the water year (table 4). During this period, the greatest monthly rainfall occurred in September when 4.89 and 4.82 in. fell at site BOOGD and RC2, respectively. The greatest daily rainfall at site BOOGD (2.37 in.) fell on September 19 and the greatest daily rainfall at site RC2 (2.26 in.) fell on September 22.

Quality

Weekly precipitation samples were collected for 33 of 36 weeks of measurable rainfall that occurred at Big Spring. Results of chemical analyses of these samples are summarized in table 3. The median concentration of the predominant cation, calcium, was 0.81 mg/L and the median concentration of the predominant anion, sulfate, was 2.0 mg/L. The median concentrations of nitrate and ammonia, were 0.40 an 0.37 mg/L as nitrogen, respectively. Maximum concentrations of all major ions were less than 10 mg/L.

Table 3.--Statistical summary of precipitation quantity and quality at Big Spring water year October 1987 to September 1988
[Chemical constituents in milligrams per liter]
[μS/cm, microsiemens per centimeter at 25 degrees Celsius; N, nitrogen]

Constituent	Number of weekly samples	Median	Minimum	Maximum
Precipitation (inches)	52	.22	0.0	3.68
Lab pH (units)	33	5.81	4.19	7.41
Lab conductance (μS/cm)	33	17	2.6	60
Calcium	33	.81	.07	4.4
Magnesium	33	.10	.02	.52
Sodium	33	.12	.02	4.5
Potassium	33	.04	<.01	.70
Sulfate	33	2.0	.03	9.2
Chloride	32	.16	.05	1.1
Nitrate as N	33	.40	<.01	1.8
Ammonia as N	33	.37	<.02	1.8

Table 4.--Accumulated daily rainfall, water year October 1987 to September 1988
[---, data not collected]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					BOOGD, Unnamed Creek at Luana							
1	---	---	---	---	---	---	---	---	0.07	0.00	0.00	0.00
2	---	---	---	---	---	---	---	---	.00	.00	.00	.00
3	---	---	---	---	---	---	---	---	.00	.00	.01	.05
4	---	---	---	---	---	---	---	---	.00	.00	.47	.00
5	---	---	---	---	---	---	---	---	.00	.00	.01	.00
6	---	---	---	---	---	---	---	---	.00	.00	.00	.00
7	---	---	---	---	---	---	---	---	.00	.00	.00	.00
8	---	---	---	---	---	---	---	---	.00	.00	.94	.00
9	---	---	---	---	---	---	---	---	.00	.38	.01	.00
10	---	---	---	---	---	---	---	---	.00	.38	.00	.00
11	---	---	---	---	---	---	---	---	.00	.00	.00	.00
12	---	---	---	---	---	---	---	---	.00	.00	.00	.00
13	---	---	---	---	---	---	---	---	.00	.10	.00	.00
14	---	---	---	---	---	---	---	0.00	.01	.00	.00	.00
15	---	---	---	---	---	---	---	.00	.00	.06	.00	.00
16	---	---	---	---	---	---	---	.00	.00	.21	.00	.08
17	---	---	---	---	---	---	---	.00	.02	.00	.00	.00
18	---	---	---	---	---	---	---	.01	.00	.00	.00	.45
19	---	---	---	---	---	---	---	.00	.31	.00	.00	2.37
20	---	---	---	---	---	---	---	.00	.00	.08	.00	.01
21	---	---	---	---	---	---	---	.00	.00	.00	.00	.45
22	---	---	---	---	---	---	---	.00	.04	.00	1.04	1.44
23	---	---	---	---	---	---	---	.00	.00	.00	.01	.00
24	---	---	---	---	---	---	---	.00	.15	.01	.00	.00
25	---	---	---	---	---	---	---	.00	.00	.00	.00	.00
26	---	---	---	---	---	---	---	.00	.00	.00	.00	.00
27	---	---	---	---	---	---	---	.02	.00	.00	.08	.00
28	---	---	---	---	---	---	---	.00	.18	.00	.00	.02
29	---	---	---	---	---	---	---	.00	.00	.00	.00	.02
30	---	---	---	---		---	---	.00	.00	.00	.03	.00
31	---		---	---		---		.00		.00	.00	
TOTAL	---	---	---	---	---	---	---	---	0.78	1.22	2.60	4.89
				RC2, Roberts Creek above Saint Olaf								
1	---	---	---	---	---	---	---	---	0.00	0.00	---	0.00
2	---	---	---	---	---	---	---	---	.00	.00	---	.00
3	---	---	---	---	---	---	---	---	.00	.00	---	.00
4	---	---	---	---	---	---	---	---	.00	.00	---	.05
5	---	---	---	---	---	---	---	---	.00	.00	---	.00
6	---	---	---	---	---	---	---	---	.00	.00	0.00	.00
7	---	---	---	---	---	---	---	---	.00	.00	.00	.00
8	---	---	---	---	---	---	---	---	.00	.00	.86	.00
9	---	---	---	---	---	---	---	---	.00	.47	.02	.00
10	---	---	---	---	---	---	---	---	.00	.43	.00	.00
11	---	---	---	---	---	---	---	---	.00	.00	.00	.00
12	---	---	---	---	---	---	---	---	.00	.00	.00	.00
13	---	---	---	---	---	---	---	---	.00	.09	.00	.00
14	---	---	---	---	---	---	---	---	.00	.00	.00	.00
15	---	---	---	---	---	---	---	---	.00	.00	.00	.00
16	---	---	---	---	---	---	---	---	.00	.30	.00	.01
17	---	---	---	---	---	---	---	---	.02	.00	.00	.00
18	---	---	---	---	---	---	---	---	.00	.01	.00	.00
19	---	---	---	---	---	---	---	---	.44	.00	.00	2.09
20	---	---	---	---	---	---	---	---	.00	.15	.00	.02
21	---	---	---	---	---	---	---	---	.00	.00	.00	.36
22	---	---	---	---	---	---	---	---	.21	.00	.79	2.26
23	---	---	---	---	---	---	---	---	.00	.00	.00	.00
24	---	---	---	---	---	---	---	---	.16	.07	.00	.00
25	---	---	---	---	---	---	---	---	.00	.00	.00	.00
26	---	---	---	---	---	---	---	---	.00	.00	.00	.00
27	---	---	---	---	---	---	---	---	.00	.00	.07	.00
28	---	---	---	---	---	---	---	---	.12	.00	.00	.02
29	---	---	---	---	---	---	---	---	.01	.00	.00	.01
30	---	---	---	---		---	---	---	.00	.00	.01	.00
31	---		---	---		---		---		.00	.00	
TOTAL	---	---	---	---	---	---	---	---	0.96	1.52	---	4.82

Surface water

Silver Creek

The drainage area upstream of site L23, Silver Creek near Luana, is 3.76 mi^2. Daily mean discharge at this site ranged from 0.05 ft^3/s on September 14 and 15 to 26 ft^3/s on March 1 during snowmelt (table 5). Mean discharge for the 1988 water year was 1.59 ft^3/s.

Unnamed Creek

Discharge

The daily mean discharge at site BOOGD, Unnamed Creek near Luana, ranged from 0.0 to 7.0 ft^3/s (table 6). The mean and median discharge for the 1988 water year were 0.21 and 0.02 ft^3/s, respectively. Unnamed Creek was dry in late December and most of January. The maximum discharge occurred in March during snowmelt. Streamflow again ceased during the last week of June and remained dry through the end of the water year.

Water quality

A limited amount of water-quality data was collected at Unnamed Creek near Luana because of the lack of streamflow due to the precipitation deficit in water year 1988. Water temperature, specific conductance, and pH were monitored continuously from the time of instrument installation (May 14) until the stream dried up on June 27. During this period, specific conductance ranged from 687 $\mu S/cm$ (microsiemens per centimeter at 25 degrees Celsius) on May 27 to 819 $\mu S/cm$ on June 20 (table 6). Overall, daily mean specific conductance increased during the month of June (fig. 2) and the daily the daily mean water temperature gradually increased. The minimum mean daily temperature was 10.5 °C (degrees Celsius) on May 16 and the maximum daily mean temperature was 23.8 °C on June 20. During this same period, the median pH declined. The maximum daily median pH was 8.21 units on May 15 and the minimum was 7.59 units on June 20 (table 7). Field measurements of instantaneous discharge, specific conductance, pH, water temperature, and dissolved oxygen collected March to September at monthly monitoring sites are given in table 8.

Chemical analyses of the dissolved constituents in three monthly samples show that calcium and magnesium were the dominant cations in solution (table 9). Concentrations of calcium ranged from 44 to 79 mg/L and concentrations of magnesium ranged from 19 to 33 mg/L. Concentrations of sodium and potassium were less than 10 mg/L. The dominant anion in solution was bicarbonate. Bicarbonate concentrations ranged from 182 to 366 mg/L. Other major anions, sulfate and chloride, were present in concentrations ranging from 12 to 32 mg/L. Silica concentrations ranged from 10 to 18 mg/L. Nitrate plus nitrite is the dominant nitrogen species in four samples collected from Unnamed Creek near Luana (table 10). Nitrate plus nitrite concentrations ranged from 7.6 to 14 mg/L as nitrogen. Concentrations in three of the four samples exceed the U.S. Environmental Protection Agency (1986) maximum contaminant level of 10 mg/L nitrate-nitrogen for drinking water. Ammonia nitrogen concentrations ranged from less than the detection level to 0.5 mg/L and organic nitrogen concentrations ranged from 0.1 to 0.8 mg/L.

Table 5.--Daily mean discharge at site L23, Silver Creek near Luana, Iowa
Water year October 1987 to September 1988

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Daily mean discharge, in cubic feet per second							
1	1.6	1.1	.88	.72	2.4	26	3.5	1.2	1.0	.58	.24	.12
2	1.5	1.4	.96	.70	2.0	17	5.5	1.1	1.0	.66	.22	.11
3	1.5	1.3	1.0	.68	2.0	7.4	7.3	1.0	.89	.66	.25	.20
4	1.4	1.1	.70	.58	1.2	6.0	5.8	.97	1.1	.58	.31	.16
5	1.4	1.1	.64	.49	.90	7.1	5.5	.94	1.0	.60	.31	.12
6	1.3	1.0	.78	.43	.76	17	5.1	.90	.95	.60	.24	.10
7	1.3	1.0	.97	.48	.68	13	4.4	.88	.99	.59	.21	.09
8	1.3	1.8	1.2	.52	.63	19	3.9	5.4	.98	.57	.33	.08
9	1.2	1.6	1.9	.49	.58	9.1	3.4	5.3	.95	.59	.26	.08
10	1.2	1.4	1.6	.45	.56	7.6	3.2	4.3	.97	.65	.21	.07
11	1.2	1.3	1.6	.47	.55	6.9	2.7	3.5	.95	.52	.22	.07
12	1.1	1.8	1.4	.58	.54	6.1	2.7	3.1	.97	.53	.17	.06
13	1.2	1.6	1.0	.52	.53	5.1	2.5	2.3	.96	.52	.15	.06
14	1.1	1.4	.80	.48	.58	4.9	2.1	2.2	.88	.55	.13	.05
15	1.1	1.3	.72	.54	.56	4.7	1.9	2.0	.88	.58	.13	.05
16	1.3	1.2	1.6	.68	.56	3.8	1.8	1.7	.85	.58	.12	.10
17	1.5	2.0	1.4	.64	.64	3.6	2.0	1.5	.91	.52	.13	.09
18	1.3	1.2	1.2	.56	.62	3.6	1.8	1.7	.86	.53	.10	.20
19	1.2	1.2	1.3	.51	.60	3.3	1.8	1.5	.89	.48	.09	.99
20	1.1	1.1	1.5	.48	.56	2.6	1.9	1.3	.88	.44	.10	.56
21	1.1	1.0	.90	.45	.54	2.5	1.5	1.2	.72	.41	.13	.32
22	1.0	1.1	1.0	.44	.58	2.8	1.4	1.1	.73	.40	.27	1.7
23	.96	.93	.95	.44	.58	2.9	1.6	1.0	.69	.40	.23	.56
24	.94	.76	.84	.45	.55	3.5	1.4	.96	.78	.38	.11	.33
25	.89	.76	.75	.44	.53	5.4	1.5	.94	.70	.37	.10	.31
26	.88	.75	.70	.43	.68	4.2	1.8	.94	.59	.35	.09	.28
27	3.0	.73	.68	.42	1.2	3.3	2.2	1.2	.58	.36	.18	.22
28	2.0	1.2	.79	.54	3.0	5.0	1.7	1.1	.57	.31	.15	.17
29	1.2	1.2	.76	.68	14	5.6	1.5	1.1	.57	.33	.13	.19
30	1.0	1.1	.80	2.0		5.1	1.3	1.0	.57	.28	.15	.21
31	.93		.80	6.0		4.0		1.0		.28	.14	

Table 6.--Daily mean discharge and specific conductance at site BOOGD, Unnamed Creek near Luana, Iowa
Water year October 1987 to September 1988
[---, data not available to calculate mean values]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Daily mean discharge, in cubic feet per second							
1	.19	.04	.04	.00	.11	7.0	.66	.14	.07	.00	.00	.00
2	.17	.03	.03	.00	.45	3.5	.93	.18	.06	.00	.00	.00
3	.16	.03	.02	.00	.53	.80	2.6	.16	.06	.00	.00	.00
4	.15	.02	.01	.00	.21	.40	2.3	.15	.05	.00	.00	.00
5	.14	.02	.01	.00	.10	1.0	1.8	.15	.05	.00	.00	.00
6	.13	.02	.01	.00	.05	2.5	1.3	.14	.05	.00	.00	.00
7	.12	.02	.02	.00	.03	6.0	1.1	.13	.06	.00	.00	.00
8	.11	.04	.04	.01	.02	4.0	.85	.35	.06	.00	.00	.00
9	.10	.03	.06	.01	.02	2.8	1.1	.20	.06	.00	.00	.00
10	.09	.02	.03	.01	.01	2.5	.95	.13	.06	.00	.00	.00
11	.09	.02	.04	.00	.01	2.1	.75	.10	.06	.00	.00	.00
12	.09	.03	.04	.00	.01	1.9	.81	.12	.05	.00	.00	.00
13	.08	.03	.03	.00	.01	1.2	.78	.12	.05	.00	.00	.00
14	.08	.02	.02	.01	.01	.98	.65	.13	.06	.00	.00	.00
15	.07	.02	.01	.01	.01	.78	.54	.12	.06	.00	.00	.00
16	.15	.02	.01	.00	.01	.67	.51	.13	.06	.00	.00	.00
17	.13	.06	.01	.00	.01	.60	.53	.11	.06	.00	.00	.00
18	.10	.02	.01	.00	.02	.46	.51	.12	.05	.00	.00	.00
19	.08	.01	.01	.00	.01	.42	.40	.22	.05	.00	.00	.00
20	.06	.02	.01	.00	.01	.29	.40	.21	.04	.00	.00	.00
21	.05	.01	.01	.00	.01	.25	.30	.21	.04	.00	.00	.00
22	.05	.02	.01	.00	.02	.31	.29	.20	.04	.00	.00	.00
23	.04	.02	.01	.00	.02	.32	.26	.14	.04	.00	.00	.00
24	.04	.02	.01	.00	.01	.91	.25	.08	.04	.00	.00	.00
25	.03	.03	.01	.00	.01	.77	.24	.07	.02	.00	.00	.00
26	.03	.04	.00	.00	.04	.54	.30	.07	.00	.00	.00	.00
27	.04	.04	.00	.01	.10	.47	.32	.11	.01	.00	.00	.00
28	.04	.10	.00	.01	.50	.99	.21	.13	.00	.00	.00	.00
29	.03	.07	.00	.02	6.0	.91	.14	.09	.00	.00	.00	.00
30	.03	.05	.00	.04		.65	.13	.07	.00	.00	.00	.00
31	.02		.00	.08		.71		.08		.00	.00	
			Daily mean specific conductance, in microsiemens per centimeter at 25 degrees Celsius									
1	---	---	---	---	---	---	---	---	---	a/	a/	a/
2	---	---	---	---	---	---	---	---	726	a/	a/	a/
3	---	---	---	---	---	---	---	---	728	a/	a/	a/
4	---	---	---	---	---	---	---	---	722	a/	a/	a/
5	---	---	---	---	---	---	---	---	735	a/	a/	a/
6	---	---	---	---	---	---	---	---	734	a/	a/	a/
7	---	---	---	---	---	---	---	---	742	a/	a/	a/
8	---	---	---	---	---	---	---	---	744	a/	a/	a/
9	---	---	---	---	---	---	---	---	724	a/	a/	a/
10	---	---	---	---	---	---	---	---	737	a/	a/	a/
11	---	---	---	---	---	---	---	---	748	a/	a/	a/
12	---	---	---	---	---	---	---	---	757	a/	a/	a/
13	---	---	---	---	---	---	---	---	782	a/	a/	a/
14	---	---	---	---	---	---	---	713	805	a/	a/	a/
15	---	---	---	---	---	---	---	708	793	a/	a/	a/
16	---	---	---	---	---	---	---	701	790	a/	a/	a/
17	---	---	---	---	---	---	---	699	791	a/	a/	a/
18	---	---	---	---	---	---	---	697	787	a/	a/	a/
19	---	---	---	---	---	---	---	694	775	a/	a/	a/
20	---	---	---	---	---	---	---	693	819	a/	a/	a/
21	---	---	---	---	---	---	---	692	---	a/	a/	a/
22	---	---	---	---	---	---	---	689	---	a/	a/	a/
23	---	---	---	---	---	---	---	692	---	a/	a/	a/
24	---	---	---	---	---	---	---	693	---	a/	a/	a/
25	---	---	---	---	---	---	---	690	---	a/	a/	a/
26	---	---	---	---	---	---	---	691	a/	a/	a/	a/
27	---	---	---	---	---	---	---	687	---	a/	a/	a/
28	---	---	---	---	---	---	---	689	a/	a/	a/	a/
29	---	---	---	---	---	---	---	---	a/	a/	a/	a/
30	---	---	---	---		---	---	---	a/	a/	a/	a/
31	---		---	---		---		---		a/	a/	

a/ No discharge

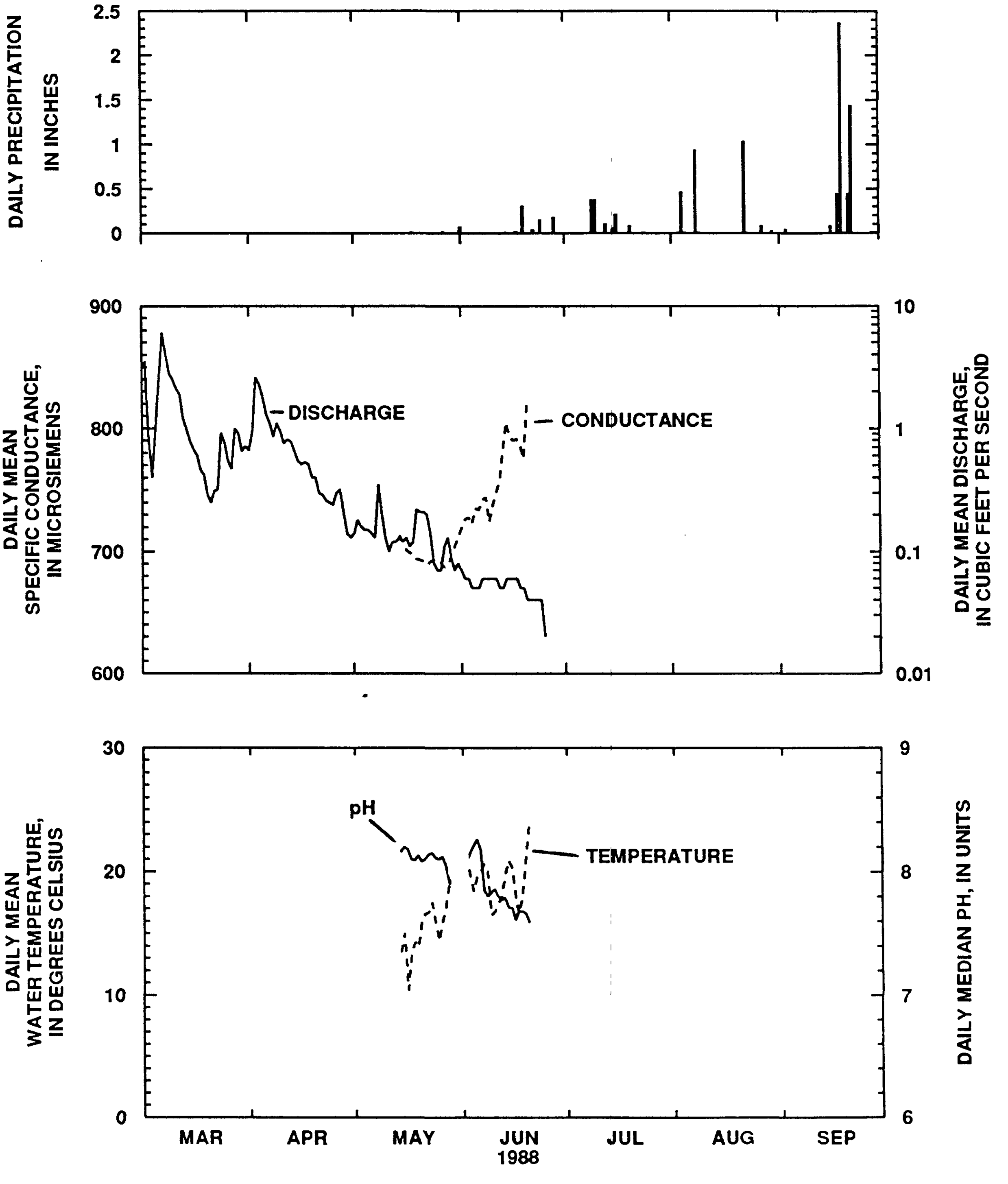

Figure 2.--Daily precipitation, daily mean specific conductance, discharge, water temperature, and daily median pH at site BOOGD, Unnamed Creek near Luana, March-September, 1988.

Table 7.--Daily mean water temperature and median pH at site BOOGD, Unnamed Creek near Luana, Iowa

Water year October 1987 to September 1988

[---, data not available to calculate mean values]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Daily mean water temperature, in degrees Celcius							
1	---	---	---	---	---	---	---	---	---	a/	a/	a/
2	---	---	---	---	---	---	---	---	21.4	a/	a/	a/
3	---	---	---	---	---	---	---	---	19.7	a/	a/	a/
4	---	---	---	---	---	---	---	---	18.4	a/	a/	a/
5	---	---	---	---	---	---	---	---	19.6	a/	a/	a/
6	---	---	---	---	---	---	---	---	20.0	a/	a/	a/
7	---	---	---	---	---	---	---	---	20.6	a/	a/	a/
8	---	---	---	---	---	---	---	---	20.1	a/	a/	a/
9	---	---	---	---	---	---	---	---	16.5	a/	a/	a/
10	---	---	---	---	---	---	---	---	16.7	a/	a/	a/
11	---	---	---	---	---	---	---	---	17.4	a/	a/	a/
12	---	---	---	---	---	---	---	---	17.9	a/	a/	a/
13	---	---	---	---	---	---	---	---	19.6	a/	a/	a/
14	---	---	---	---	---	---	---	13.5	20.9	a/	a/	a/
15	---	---	---	---	---	---	---	15.0	20.4	a/	a/	a/
16	---	---	---	---	---	---	---	10.4	18.3	a/	a/	a/
17	---	---	---	---	---	---	---	13.4	16.6	a/	a/	a/
18	---	---	---	---	---	---	---	14.3	17.9	a/	a/	a/
19	---	---	---	---	---	---	---	13.9	20.8	a/	a/	a/
20	---	---	---	---	---	---	---	16.0	23.8	a/	a/	a/
21	---	---	---	---	---	---	---	16.6	---	a/	a/	a/
22	---	---	---	---	---	---	---	16.7	---	a/	a/	a/
23	---	---	---	---	---	---	---	17.5	---	a/	a/	a/
24	---	---	---	---	---	---	---	15.8	---	a/	a/	a/
25	---	---	---	---	---	---	---	14.4	---	a/	a/	a/
26	---	---	---	---	---	---	---	16.1	a/	a/	a/	a/
27	---	---	---	---	---	---	---	17.2	---	a/	a/	a/
28	---	---	---	---	---	---	---	19.2	a/	a/	a/	a/
29	---	---	---	---	---	---	---	---	a/	a/	a/	a/
30	---	---	---	---		---	---	---	a/	a/	a/	a/
31	---		---	---		---		---		a/	a/	
					Daily median pH, in units							
1	---	---	---	---	---	---	---	---	---	a/	a/	a/
2	---	---	---	---	---	---	---	---	8.08	a/	a/	a/
3	---	---	---	---	---	---	---	---	8.15	a/	a/	a/
4	---	---	---	---	---	---	---	---	8.21	a/	a/	a/
5	---	---	---	---	---	---	---	---	8.26	a/	a/	a/
6	---	---	---	---	---	---	---	---	8.18	a/	a/	a/
7	---	---	---	---	---	---	---	---	7.85	a/	a/	a/
8	---	---	---	---	---	---	---	---	7.80	a/	a/	a/
9	---	---	---	---	---	---	---	---	7.83	a/	a/	a/
10	---	---	---	---	---	---	---	---	7.86	a/	a/	a/
11	---	---	---	---	---	---	---	---	7.80	a/	a/	a/
12	---	---	---	---	---	---	---	---	7.77	a/	a/	a/
13	---	---	---	---	---	---	---	---	7.79	a/	a/	a/
14	---	---	---	---	---	---	---	8.16	7.71	a/	a/	a/
15	---	---	---	---	---	---	---	8.20	7.71	a/	a/	a/
16	---	---	---	---	---	---	---	8.18	7.61	a/	a/	a/
17	---	---	---	---	---	---	---	8.10	7.68	a/	a/	a/
18	---	---	---	---	---	---	---	8.09	7.68	a/	a/	a/
19	---	---	---	---	---	---	---	8.13	7.66	a/	a/	a/
20	---	---	---	---	---	---	---	8.08	7.59	a/	a/	a/
21	---	---	---	---	---	---	---	8.10	---	a/	a/	a/
22	---	---	---	---	---	---	---	8.14	---	a/	a/	a/
23	---	---	---	---	---	---	---	8.15	---	a/	a/	a/
24	---	---	---	---	---	---	---	8.11	---	a/	a/	a/
25	---	---	---	---	---	---	---	8.10	---	a/	a/	a/
26	---	---	---	---	---	---	---	8.12	a/	a/	a/	a/
27	---	---	---	---	---	---	---	8.04	---	a/	a/	a/
28	---	---	---	---	---	---	---	7.90	a/	a/	a/	a/
29	---	---	---	---	---	---	---	---	a/	a/	a/	a/
30	---	---	---	---		---	---	---	a/	a/	a/	a/
31	---		---	---		---		---		a/	a/	

a/ No discharge

Table 8.--Field measurements at monthly monitoring sites in the Big Spring Basin

[ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter; °C, degrees celsius; mg/L, milligrams per liter; --, missing data; >, greater than]

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH (units)	Temperature (°C)	Dissolved oxygen (mg/L)
			BOOGD, Unnamed Creek near Luana			
03-08-88	1130	9.6	410	7.31	4.5	10.6
04-04-88	1200	2.3	730	7.84	13.0	--
05-04-88	1330	.15	730	8.31	19.6	--
06-01-88	1015	.09	775	8.04	22.0	5.7
			RC2, Roberts Creek above St. Olaf			
03-08-88	1330	173	480	7.72	2.0	12.0
04-05-88	0900	80	650	8.30	13.0	9.8
05-04-88	1455	15	650	8.85	20.5	--
06-01-88	1510	5.7	700	8.60	28.0	14.2
07-01-88	1100	2.9	580	8.90	27.0	10.6
08-05-88	0810	.97	590	7.74	23.0	7.5
09-06-88	1000	.08	540	8.20	12.5	18.2
09-12-88	1350	.04	365	9.40	26.0	>20.0
09-20-88	0950	22	450	8.10	16.0	--
09-22-88	1340	78	504	7.64	17.5	--
			Big Spring			
03-08-88	0930	--	550	7.20	8.0	9.3
04-04-88	1330	--	730	7.24	9.0	9.2
05-04-88	1055	--	740	7.23	10.0	--
06-01-88	1230	--	780	7.24	10.0	8.9
07-01-88	1330	--	750	7.10	10.0	9.6
08-04-88	1545	--	750	7.22	11.0	10.2
09-06-88	1200	--	690	7.21	10.5	9.6
09-20-88	1230	--	--	--	--	--

Table 9.--Concentrations of major ions at the monthly monitoring sites in the Big Spring Basin

[Dissolved constituents are in milligrams per liter; --, data not collected]

Date	Time	Calcium	Magne-sium	So-dium	Pot-tas-sium	Bi-carbo-nate	Car-bo-nate	Sul-fate	Chlo-ride	Silica
				BOOGD, Unnamed Creek near Luana						
03-08-88	1130	44	19	5.4	5.1	182	0	22	12	10
04-04-88	1200	78	29	9.8	4.4	305	0	31	26	13
06-01-88	1015	79	33	8.4	2.2	366	0	32	24	18
				RC2, Roberts Creek above St. Olaf						
03-08-88	1330	53	22	7.5	5.1	220	0	26	16	11
04-05-88	0900	76	33	7.2	3.6	237	36	26	22	15
06-23-88	1800	52	34	10	3.8	--	--	37	23	9.0
06-24-88	0600	54	33	9.5	3.5	--	--	33	22	9.0
07-01-88	1100	51	36	10	4.0	251	30	38	26	7.5
08-05-88	0810	57	29	10	5.0	305	0	30	24	8.3
09-06-88	1000	85	30	8.2	4.8	354	0	24	23	--
09-20-88	0950	--	--	--	--	--	--	40	20	--
				Big Spring						
03-08-88	0930	64	25	6.5	4.7	264	0	23	14	13
04-04-88	1330	84	34	7.1	3.0	384	0	24	19	17
07-01-88	1330	83	37	13	2.6	384	0	35	24	5.8
09-06-88	1200	96	39	12	3.9	390	0	32	24	--
09-20-88	1230	--	--	--	--	--	--	37	23	--

Table 10.--Selected nitrogen, phosphorus and carbon species at monthly monitoring sites in the Big Spring Basin

[Dissolved constituents in milligrams per liter; N, nitrogen; P, phosphorus; C, carbon; --, data not collected; <, less than]

Date	Time	Nitrate plus nitrite, (as N)	Ammonia, (as N)	Organic nitrogen, (as N)	Ortho-phos-phorus, (as P)	Total Organic carbon (as C)
BOOGD Unnamed Creek near Luana						
03-08-88	1130	7.6	0.2	0.8	--	3.4
04-05-88	1200	11	.1	.7	--	2.8
05-04-88	1330	14	< .1	.1	<0.1	--
06-01-88	1015	13	.5	.4	.1	--
RC2 Roberts Creek above St. Olaf						
03-08-88	1330	7.2	0.4	1.1	--	3.1
04-05-88	0900	15	< .1	.3	--	1.7
05-04-88	1455	6.1	< .1	.4	0.2	--
06-01-88	1510	3.3	< .1	< .1	--	--
07-01-88	1100	.2	.2	.5	--	4.2
08-05-88	0810	1.5	< .1	.4	--	4.1
09-06-88	1000	2.2	< .1	< .1	< .1	--
09-20-88	0950	.5	.2	.7	.2	--
Big Spring						
03-08-88	0930	8.6	0.1	0.6	--	2.6
04-04-88	1330	11	.3	.3	--	1.2
05-04-88	1055	10	< .1	< .1	<0.1	--
06-01-88	1230	9.7	< .1	.2	--	--
07-01-88	1330	9.0	< .1	.2	--	1.2
08-04-88	1545	8.5	< .1	< .1	--	1.1
09-06-88	1200	8.1	< .1	< .1	.2	--
09-20-88	1230	7.5	< .1	.2	.2	--

Two pesticides were detected in samples from Unnamed Creek near Luana (table 11). Atrazine was detected in four samples and alachlor was detected in one sample. Total recoverable atrazine concentrations ranged from 0.16 to 0.34 μg/L. The greatest concentration occurred on March 8. The total recoverable alachlor concentration was 0.11 μg/L in a sample collected on June 1.

Sediment concentrations ranged from 22 mg/L on March 23 to 1,160 mg/L on May 8. During rainfall on May 8, sampled suspended-sediment concentrations increased from 76 mg/L at 0705 hours to 1,160 mg/L at 1740 hours (table 12).

Roberts Creek

Discharge

Daily mean discharge for site RC2, Roberts Creek above Saint Olaf, is listed in table 13 and illustrated graphically from March 1 to September 30 in figure 3. Maximum daily discharge (190 ft^3/s) occurred on March 2 and generally decreased through spring and summer reaching a minimum of 0.02 ft^3/s on September 17 and 18. The median discharge at site RC2 for the 1988 water year was 7.7 ft^3/s.

Water quality

Maximum specific conductance (691 μS/cm) was recorded the first day of monitor operation (June 1) at site RC2 and the minimum mean daily specific conductance (393 μS/cm) was on September 13 (table 13). The daily median pH at site RC2 varied from 7.23 to 8.82 units and daily mean water temperature varied from 15.3 to 30.2 degrees Celsius (table 14, fig. 3).

Analyses of water quality samples from site RC2 showed that calcium and magnesium were the predominant cations and bicarbonate was the predominant anion in solution (table 9). Sodium and potassium concentrations were 10 mg/L or less. Sulfate concentrations ranged from 24 to 40 mg/L and chloride concentrations ranged from 16 to 26 mg/L. Silica concentrations were 15 mg/L or less. Nitrate plus nitrite was the major nitrogen species present at site RC2 (table 10) and ranged from 0.2 to 15 mg/L as nitrogen. Ammonia nitrogen was detected in three of eight samples. The maximum concentration was 0.4 mg/L. Organic nitrogen was detected in six of eight samples and had a maximum concentration of 1.1 mg/L as nitrogen.

Atrazine was found in concentrations greater than the detection limit in seven of eight samples (table 11). Total recoverable atrazine concentrations ranged from 0.11 to 0.72 μg/L. Total recoverable cyanazine concentrations exceeded the detection limits in June to September. The maximum concentration (0.72 μg/L) was in July. Total recoverable metolachlor and alachlor concentrations both exceeded the detection limit in one sample. Total recoverable metribuzin, butylate, and trifluralin were not detected.

Suspended sediment concentrations at site RC2 ranged from less than 10.0 mg/L on April 23 and 24 to 810 mg/L on September 22 during a rainfall event (table 15). From April 1 to August 31, suspended sediment concentration generally were less than 100 mg/L (fig. 4). Occasionally concentrations exceeded 100 mg/L during this period of declining stream discharge. During September, suspended sediment concentrations generally exceeded 100 mg/L.

Table 11.--Selected pesticides at monthly monitoring sites in the Big Spring Basin

[Total recoverable constituents in micrograms per liter; <, less than]

Date	Time	Atrazine	Cyanazine	Metolachlor	Alachlor	Metribuzin	Butylate	Trifluralin
BOOGD, Unnamed Creek near Luana								
03-08-88	1130	0.34	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04-05-88	1200	.27	< .1	< .1	< .1	< .1	< .1	< .1
05-04-88	1015	.16	< .1	< .1	< .1	< .1	< .1	< .1
06-01-88	1015	.22	< .1	< .1	.11	< .1	< .1	< .1
RC2, Roberts Creek above St. Olaf								
03-08-88	1330	0.24	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04-05-88	0900	.11	< .1	< .1	< .1	< .1	< .1	< .1
05-04-88	1455	.40	< .1	< .1	< .1	< .1	< .1	< .1
06-01-88	1510	.72	.23	< .1	< .1	< .1	< .1	< .1
07-01-88	1100	.41	.72	< .1	< .1	< .1	< .1	< .1
08-05-88	0810	.42	.51	< .1	.55	< .1	< .1	< .1
09-06-88	1000	.19	< .1	< .1	< .1	< .1	< .1	< .1
09-20-88	0950	<.1	< .1	< .1	< .1	< .1	< .1	< .1
09-22-88	1340	.51	.12	.11	< .1	< .1	< .1	< .1
Big Spring								
03-08-88	0930	0.19	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04-05-88	1330	.11	< .1	< .1	< .1	< .1	< .1	< .1
05-04-88	1055	.26	< .1	< .1	< .1	< .1	< .1	< .1
06-01-88	1230	.24	< .1	< .1	< .1	< .1	< .1	< .1
07-01-88	1330	.12	< .1	< .1	< .1	< .1	< .1	< .1
08-04-88	1545	< .1	< .1	< .1	< .1	< .1	< .1	< .1
09-06-88	1200	.12	< .1	< .1	< .1	< .1	< .1	< .1

Table 12.--Instantaneous discharge and suspended sediment concentrations at site BOOGD, Unnamed Creek near Luana, Iowa

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; *, daily mean discharge]

Date	Time	Instantaneous discharge (ft^3/s)	Suspended sediment (mg/L)	Date	Time	Instantaneous discharge (ft^3/s)	Suspended sediment (mg/L)
3-01-88	1135	3.6	30	5-08-88	1740	1.8	1,160
3-08-88	1130	8.8	129	5-10-88	0903	.12	74
3-23-88	1200	.27	22	5-13-88	0915	.13	69
3-29-88	1100	.91	38	5-14-88	0735	.18	62
3-31-88	1230	.64	43	5-17-88	0925	.10	59
4-04-88	1145	*2.3	50	5-19-88	0720	.24	78
4-06-88	1230	*1.3	37	5-21-88	0755	.21	104
4-13-88	1345	.84	58	5-23-88	0725	.17	78
4-14-88	0950	.64	32	5-25-88	0710	.07	69
4-16-88	0930	.42	32	5-27-88	0740	.11	199
4-18-88	0840	.58	43	5-31-88	0825	.10	116
4-20-88	0845	.53	89	6-02-88	0712	.06	139
4-22-88	0825	.27	27	6-04-88	0705	.05	278
4-25-88	0905	.24	28	6-06-88	0715	.05	133
4-26-88	1650	.46	302	6-08-88	0730	.06	114
4-27-88	0800	.29	37	6-10-88	0725	.06	278
4-29-88	0919	.13	32	6-14-88	0700	.07	244
5-03-88	0843	.15	54	6-16-88	0720	.06	228
5-05-88	0835	.13	33	6-18-88	0835	.05	47
5-07-88	0817	.11	60	6-20-88	0850	.05	95
5-08-88	0705	.10	76	6-22-88	0835	.05	118
5-08-88	1614	.72	424	6-25-88	0825	.03	90

Table 13.--Daily mean discharge and specific conductance at site RC2, Roberts Creek above Saint Olaf, Iowa
Water year October 1987 to September 1988
[---, data not available to calculate mean values]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Daily mean discharge, in cubic feet per second							
1	13	8.5	15	5.7	50	160	45	17	6.0	2.7	.94	.11
2	12	9.1	14	6.0	37	190	42	16	6.4	2.7	.64	.05
3	11	8.6	13	6.2	44	70	99	16	6.0	2.6	.54	.03
4	11	7.9	9.0	6.3	24	45	79	15	5.6	2.4	.56	.05
5	11	6.8	9.7	5.2	16	25	65	14	5.2	2.1	1.4	.08
6	11	6.4	11	4.8	13	50	56	13	4.9	1.9	1.6	.10
7	10	7.2	12	6.3	9.9	100	46	13	4.7	1.8	.98	.08
8	10	9.3	12	7.4	9.6	130	41	16	4.6	1.8	2.4	.07
9	10	8.2	20	6.6	9.4	110	37	45	4.1	1.9	3.5	.06
10	9.7	7.1	21	5.8	7.4	70	35	27	4.0	3.4	2.3	.06
11	9.3	7.0	18	6.0	6.8	45	33	20	4.0	4.8	1.4	.05
12	9.4	7.3	17	7.0	6.4	36	32	19	3.9	3.1	1.1	.04
13	9.8	7.7	15	6.6	6.2	32	30	17	3.6	2.6	.83	.04
14	9.4	7.4	10	6.2	6.4	27	28	15	2.9	2.5	.73	.03
15	9.5	7.1	7.3	7.0	6.2	35	26	15	3.0	2.6	.80	.03
16	9.7	8.1	9.0	7.2	6.2	33	25	14	2.9	2.2	.65	.03
17	12	12	12	7.0	6.4	37	23	13	3.0	2.5	.55	.02
18	11	18	11	6.8	6.4	36	22	12	3.3	2.6	.39	.02
19	9.3	11	12	6.7	6.2	35	20	11	3.7	1.9	.34	6.1
20	8.6	9.1	15	6.6	6.0	34	21	11	3.7	1.9	.31	15
21	8.8	8.1	13	6.4	5.6	30	20	11	3.3	2.2	.26	5.6
22	8.7	9.1	12	6.4	5.8	30	21	9.9	2.9	2.0	.46	25
23	8.7	9.5	11	6.0	5.8	30	22	9.0	2.5	1.8	.86	23
24	8.4	9.0	9.6	6.0	5.4	30	22	8.3	2.4	1.7	1.2	6.9
25	8.1	8.5	8.6	6.3	5.5	75	19	7.9	2.6	1.8	.72	3.2
26	8.2	8.2	7.8	5.5	5.6	53	18	7.8	2.4	1.8	.32	2.0
27	8.1	7.9	8.6	5.8	6.2	40	31	7.8	2.1	1.4	.20	1.1
28	8.1	10	7.6	6.2	8.4	45	25	7.8	2.1	1.4	.18	.57
29	7.9	30	7.0	6.2	82	77	20	7.1	2.3	1.4	.15	.78
30	7.8	19	9.6	10		60	18	6.5	2.8	1.3	.12	.83
31	7.6		7.3	7.2		50		6.3		1.2	.11	
			Daily mean specific conductance, in microsiemens per centimeter at 25 degrees Celsius									
1	---	---	---	---	---	---	---	---	691	---	---	560
2	---	---	---	---	---	---	---	---	686	557	---	569
3	---	---	---	---	---	---	---	---	684	540	---	561
4	---	---	---	---	---	---	---	---	682	544	---	566
5	---	---	---	---	---	---	---	---	679	549	---	552
6	---	---	---	---	---	---	---	---	677	546	482	553
7	---	---	---	---	---	---	---	---	670	532	490	544
8	---	---	---	---	---	---	---	---	662	513	454	518
9	---	---	---	---	---	---	---	---	654	524	454	509
10	---	---	---	---	---	---	---	---	648	516	456	494
11	---	---	---	---	---	---	---	---	643	541	499	473
12	---	---	---	---	---	---	---	---	636	544	498	441
13	---	---	---	---	---	---	---	---	632	533	499	393
14	---	---	---	---	---	---	---	---	---	537	504	404
15	---	---	---	---	---	---	---	---	---	563	507	443
16	---	---	---	---	---	---	---	---	---	548	526	509
17	---	---	---	---	---	---	---	---	---	536	535	472
18	---	---	---	---	---	---	---	---	---	539	555	447
19	---	---	---	---	---	---	---	---	---	545	553	473
20	---	---	---	---	---	---	---	---	---	545	554	497
21	---	---	---	---	---	---	---	---	591	542	556	487
22	---	---	---	---	---	---	---	---	572	533	552	489
23	---	---	---	---	---	---	---	---	569	534	522	419
24	---	---	---	---	---	---	---	---	559	542	523	583
25	---	---	---	---	---	---	---	---	564	539	542	608
26	---	---	---	---	---	---	---	---	552	545	546	611
27	---	---	---	---	---	---	---	---	541	567	565	605
28	---	---	---	---	---	---	---	---	554	560	571	611
29	---	---	---	---	---	---	---	---	569	557	581	600
30	---	---	---	---		---	---	---	563	557	586	577
31	---		---	---		---		---		559	561	

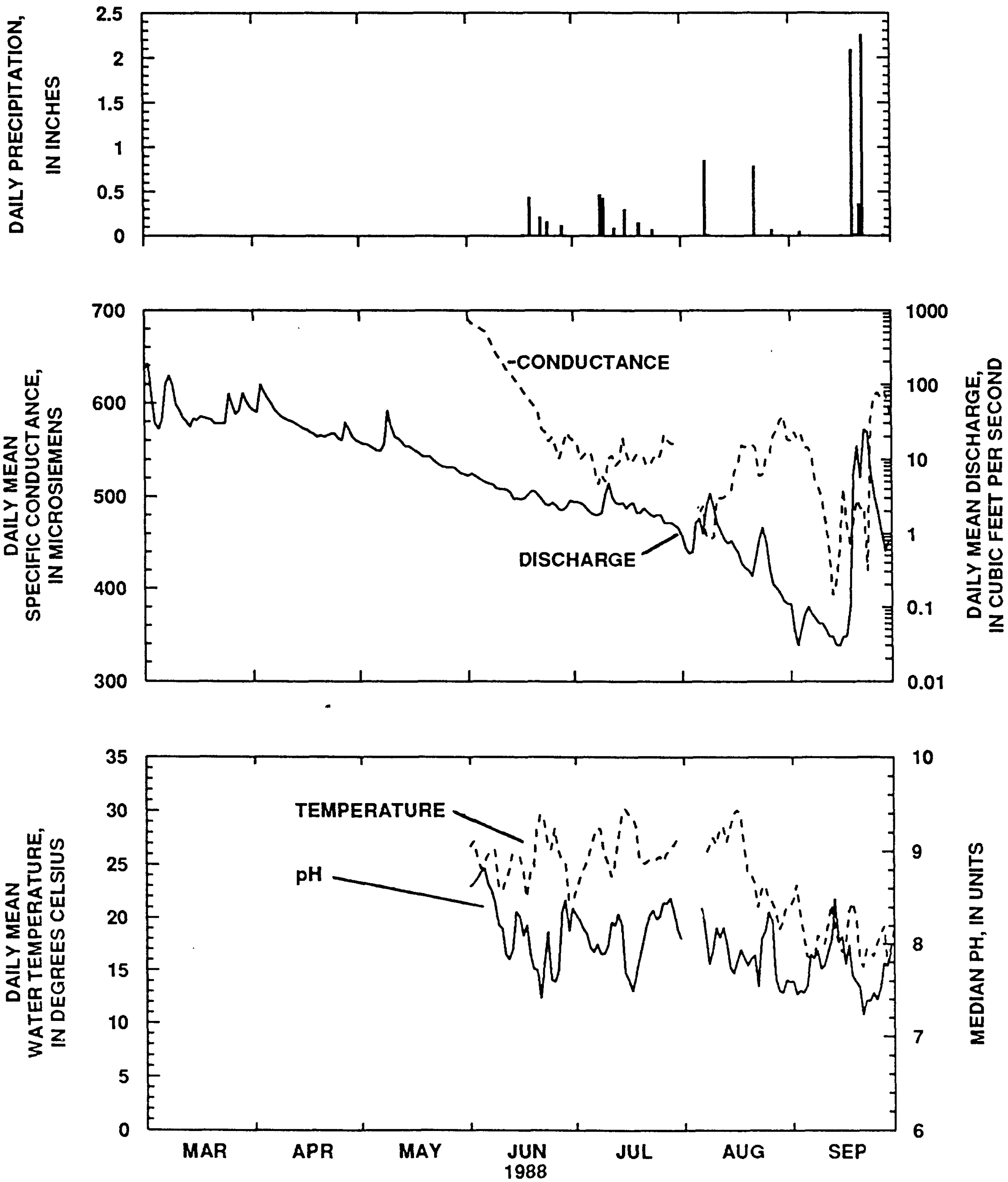

Figure 3.--Daily precipitation, daily mean specific conductance, discharge, water temperature, and daily median pH at site RC2, Roberts Creek above Saint Olaf, Iowa, March-September, 1988.

Table 14.--Daily mean water temperature and median pH at site RC2, Roberts Creek above Saint Olaf, Iowa
Water year October 1987 to September 1988
[---, data not available to calculate mean or median values]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Daily mean water temperature, in degrees Celcius							
1	---	---	---	---	---	---	---	---	26.7	---	---	21.6
2	---	---	---	---	---	---	---	---	27.2	23.6	---	23.1
3	---	---	---	---	---	---	---	---	25.8	24.5	---	20.8
4	---	---	---	---	---	---	---	---	24.6	25.2	---	18.3
5	---	---	---	---	---	---	---	---	25.2	26.2	---	16.3
6	---	---	---	---	---	---	---	---	25.9	27.5	26.1	16.2
7	---	---	---	---	---	---	---	---	26.3	28.4	25.9	16.1
8	---	---	---	---	---	---	---	---	26.4	28.3	26.6	18.3
9	---	---	---	---	---	---	---	---	23.0	26.1	27.6	18.0
10	---	---	---	---	---	---	---	---	22.5	25.3	26.9	17.5
11	---	---	---	---	---	---	---	---	23.5	23.9	28.1	19.4
12	---	---	---	---	---	---	---	---	24.5	25.0	28.6	21.3
13	---	---	---	---	---	---	---	---	26.0	27.2	27.1	18.9
14	---	---	---	---	---	---	---	---	26.0	29.6	28.3	17.6
15	---	---	---	---	---	---	---	---	25.7	30.2	29.7	16.7
16	---	---	---	---	---	---	---	---	24.5	29.7	30.1	17.4
17	---	---	---	---	---	---	---	---	21.9	29.3	29.7	20.6
18	---	---	---	---	---	---	---	---	24.2	28.8	26.9	21.5
19	---	---	---	---	---	---	---	---	24.4	25.8	24.2	20.3
20	---	---	---	---	---	---	---	---	28.5	25.1	24.1	16.3
21	---	---	---	---	---	---	---	---	29.7	25.2	23.3	15.3
22	---	---	---	---	---	---	---	---	29.2	25.5	21.0	17.0
23	---	---	---	---	---	---	---	---	27.0	25.6	22.7	16.9
24	---	---	---	---	---	---	---	---	26.4	25.5	23.1	16.3
25	---	---	---	---	---	---	---	---	28.4	25.8	21.7	17.5
26	---	---	---	---	---	---	---	---	26.3	25.3	21.5	18.4
27	---	---	---	---	---	---	---	---	25.5	26.1	20.7	19.2
28	---	---	---	---	---	---	---	---	25.1	26.7	18.9	15.5
29	---	---	---	---	---	---	---	---	21.7	26.8	19.6	17.2
30	---	---	---	---		---	---	---	21.5	27.4	21.0	19.1
31	---		---	---		---		---		27.2	21.1	
					Daily median ph, in units							
1	---	---	---	---	---	---	---	---	8.62	---	---	7.60
2	---	---	---	---	---	---	---	---	8.66	8.26	---	7.45
3	---	---	---	---	---	---	---	---	8.71	8.17	---	7.50
4	---	---	---	---	---	---	---	---	8.78	8.11	---	7.47
5	---	---	---	---	---	---	---	---	8.82	7.96	---	7.55
6	---	---	---	---	---	---	---	---	8.65	7.91	8.39	7.89
7	---	---	---	---	---	---	---	---	8.58	8.00	8.11	7.84
8	---	---	---	---	---	---	---	---	8.45	7.89	7.78	7.93
9	---	---	---	---	---	---	---	---	8.21	7.89	7.92	7.73
10	---	---	---	---	---	---	---	---	8.17	7.98	8.18	7.77
11	---	---	---	---	---	---	---	---	7.89	8.24	8.07	7.91
12	---	---	---	---	---	---	---	---	7.83	8.20	8.18	8.05
13	---	---	---	---	---	---	---	---	7.94	8.33	8.01	8.49
14	---	---	---	---	---	---	---	---	8.35	8.20	7.75	8.03
15	---	---	---	---	---	---	---	---	8.30	7.68	7.68	8.08
16	---	---	---	---	---	---	---	---	8.09	7.60	7.81	7.78
17	---	---	---	---	---	---	---	---	8.21	7.49	7.94	7.99
18	---	---	---	---	---	---	---	---	7.89	---	7.85	7.65
19	---	---	---	---	---	---	---	---	7.73	---	7.77	7.59
20	---	---	---	---	---	---	---	---	7.72	8.01	7.84	7.53
21	---	---	---	---	---	---	---	---	7.41	8.20	7.88	7.23
22	---	---	---	---	---	---	---	---	---	8.31	7.54	7.39
23	---	---	---	---	---	---	---	---	8.13	8.37	8.06	7.38
24	---	---	---	---	---	---	---	---	7.61	8.27	8.15	7.47
25	---	---	---	---	---	---	---	---	7.59	8.30	8.35	7.39
26	---	---	---	---	---	---	---	---	7.71	8.45	8.25	7.53
27	---	---	---	---	---	---	---	---	8.34	8.44	7.62	7.79
28	---	---	---	---	---	---	---	---	8.48	8.50	7.49	7.76
29	---	---	---	---	---	---	---	---	8.14	8.36	7.47	7.91
30	---	---	---	---		---	---	---	8.39	8.16	7.61	---
31	---		---	---		---		---		8.06	7.59	

Table 15.--Instantaneous discharge and suspended sediment concentrations at site RC2, Roberts Creek above Saint Olaf, Iowa

[ft^3/s, cubic feet per second; mg/L, milligrams per liter]

Date	Time	Instantaneous discharge (ft^3/s)	Suspended sediment (mg/L)	Date	Time	Instantaneous discharge (ft^3/s)	Suspended sediment (mg/L)
3-08-88	1320	232	458	6-25-88	1635	2.7	29
3-23-88	1115	31	60	6-26-88	1620	2.4	39
3-23-88	1415	31	40	6-28-88	1645	2.0	34
3-25-88	1330	105	458	6-29-88	1645	2.4	80
3-29-88	1030	80	145	7-01-88	1615	2.4	201
3-31-88	1330	50	42	7-03-88	1640	2.7	51
4-13-88	1630	30	54	7-04-88	1640	2.4	47
4-14-88	1645	28	70	7-06-88	1840	1.9	68
4-15-88	1710	26	72	7-07-88	1645	1.7	64
4-16-88	1645	25	69	7-08-88	1640	1.8	101
4-17-88	1645	22	70	7-09-88	1635	2.0	139
4-19-88	1635	21	20	7-10-88	1845	4.1	11
4-20-88	1655	21	49	7-10-88	2045	4.1	19
4-21-88	1645	21	23	7-10-88	2245	5.3	71
4-23-88	1305	22	5.8	7-11-88	0045	5.7	42
4-24-88	1630	21	4.2	7-11-88	0245	5.7	42
4-25-88	1650	18	18	7-11-88	0445	5.7	112
4-26-88	1650	20	39	7-11-88	0645	5.3	30
4-27-88	1640	37	57	7-11-88	0845	5.1	12
4-28-88	1650	22	20	7-11-88	1045	4.9	13
4-29-88	1655	19	13	7-12-88	1641	2.8	21
5-01-88	1705	17	24	7-13-88	1720	2.5	27
5-03-88	1640	16	24	7-15-88	1505	2.8	52
5-04-88	1455	15	41	7-16-88	1530	2.4	142
5-06-88	1600	13	28	7-17-88	1705	2.8	28
5-07-88	1650	14	29	7-19-88	1720	1.8	170
5-08-88	1750	19	29	7-20-88	1640	1.8	83
5-10-88	1640	25	46	7-21-88	1640	2.1	31
5-11-88	1635	20	16	7-22-88	1635	1.9	60
5-13-88	1710	16	51	7-23-88	1635	1.7	37
5-14-88	1640	15	66	7-24-88	1630	1.7	52
5-15-88	1605	15	16	7-25-88	1828	1.7	176
5-17-88	1645	13	24	7-26-88	1753	1.8	40
5-18-88	1630	12	35	7-29-88	1100	1.4	12
5-20-88	1930	11	70	8-01-88	1115	.82	44
5-21-88	1835	11	46	8-05-88	750	.97	23
5-22-88	1840	9.6	62	8-08-88	1832	1.2	84
5-24-88	1815	8.2	49	8-09-88	1842	2.5	75
5-25-88	1830	8.2	83	8-10-88	1330	2.2	24
5-27-88	1825	7.9	79	8-10-88	1746	1.8	70
5-28-88	1820	7.9	50	8-11-88	1740	1.2	39
5-31-88	1820	6.2	81	8-12-88	1837	.97	56
6-01-88	1820	6.0	81	8-13-88	1505	.89	43
6-02-88	1150	6.4	93	8-15-88	1747	.75	62
6-04-88	1720	5.3	58	8-16-88	1100	.54	9.9
6-05-88	1650	4.9	50	8-17-88	1747	.48	75
6-07-88	1645	4.3	28	8-19-88	1632	.35	149
6-10-88	1745	3.9	31	8-20-88	1810	.30	118
6-11-88	1800	3.9	50	8-21-88	1745	.25	80
6-12-88	1655	3.7	35	8-22-88	1315	.60	36
6-14-88	1720	2.4	69	8-22-88	1637	.60	133
6-15-88	1825	2.9	27	8-23-88	1750	.75	70
6-17-88	1650	3.1	22	8-24-88	1812	1.3	44
6-18-88	1645	3.4	29	8-25-88	1222	.67	83
6-19-88	1645	3.9	110	8-25-88	1640	.41	30
6-21-88	1635	2.9	26	8-26-88	1615	.30	28
6-22-88	1640	3.1	32	8-28-88	1625	.12	90
6-23-88	1600	2.4	20	8-29-88	1645	.01	115
6-24-88	830	2.3	165	8-30-88	1635	.17	75
6-24-88	1930	2.7	54	8-31-88	1630	.12	64

Table 15.--Instantaneous discharge and suspended sediment concentrations at site RC2, Roberts Creek above Saint Olaf, Iowa--continued

[ft³/s, cubic feet per second; mg/L, milligrams per liter]

Date	Time	Instantaneous discharge (ft^3/s)	Suspended sediment (mg/L)	Date	Time	Instantaneous discharge (ft^3/s)	Suspended sediment (mg/L)
9-01-88	1630	.12	103	9-21-88	1100	5.3	30
9-02-88	1630	.04	62	9-21-88	1300	4.9	22
9-04-88	1635	.04	244	9-21-88	1625	4.1	84
9-05-88	1630	.08	106	9-22-88	715	30	152
9-06-88	1000	.08	29	9-22-88	920	12	263
9-06-88	1635	.12	47	9-22-88	1115	15	256
9-07-88	1625	.17	129	9-22-88	1145	20	347
9-09-88	1625	.12	135	9-22-88	1215	22	442
9-10-88	1630	.17	181	9-22-88	1245	24	418
9-11-88	1700	.12	113	9-22-88	1307	39	683
9-12-88	1630	.04	120	9-22-88	1315	52	810
9-16-88	1625	.12	220	9-22-88	1325	66	692
9-17-88	1700	.17	182	9-22-88	1335	76	598
9-19-88	945	1.9	90	9-22-88	1345	80	556
9-19-88	1635	1.3	109	9-22-88	1400	83	482
9-19-88	1700	2.2	116	9-22-88	1415	81	407
9-19-88	1900	25	333	9-22-88	1445	73	339
9-19-88	2300	14	176	9-22-88	1515	65	275
9-20-88	100	13	244	9-22-88	1545	57	230
9-20-88	300	12	271	9-22-88	1615	51	266
9-20-88	500	11	298	9-22-88	1630	48	779
9-20-88	700	14	206	9-22-88	1645	45	231
9-20-88	900	22	164	9-22-88	1715	40	256
9-20-88	935	22	123	9-22-88	1745	36	280
9-20-88	1100	22	163	9-22-88	1815	32	293
9-20-88	1300	21	118	9-22-88	1845	27	303
9-20-88	1500	18	123	9-22-88	1915	28	311
9-20-88	1625	16	227	9-22-88	1945	27	302
9-20-88	1700	16	127	9-22-88	2015	25	279
9-20-88	1900	13	138	9-22-88	2045	23	266
9-20-88	2100	11	148	9-22-88	2115	23	246
9-20-88	2300	9.6	116	9-22-88	2145	23	234
9-21-88	100	8.5	99	9-22-88	2215	23	211
9-21-88	300	7.9	90	9-22-88	2245	23	213
9-21-88	500	7.0	74	9-23-88	1635	17	194
9-21-88	700	6.8	55	9-24-88	1625	5.3	106
9-21-88	900	6.0	56	9-26-88	1820	1.8	106

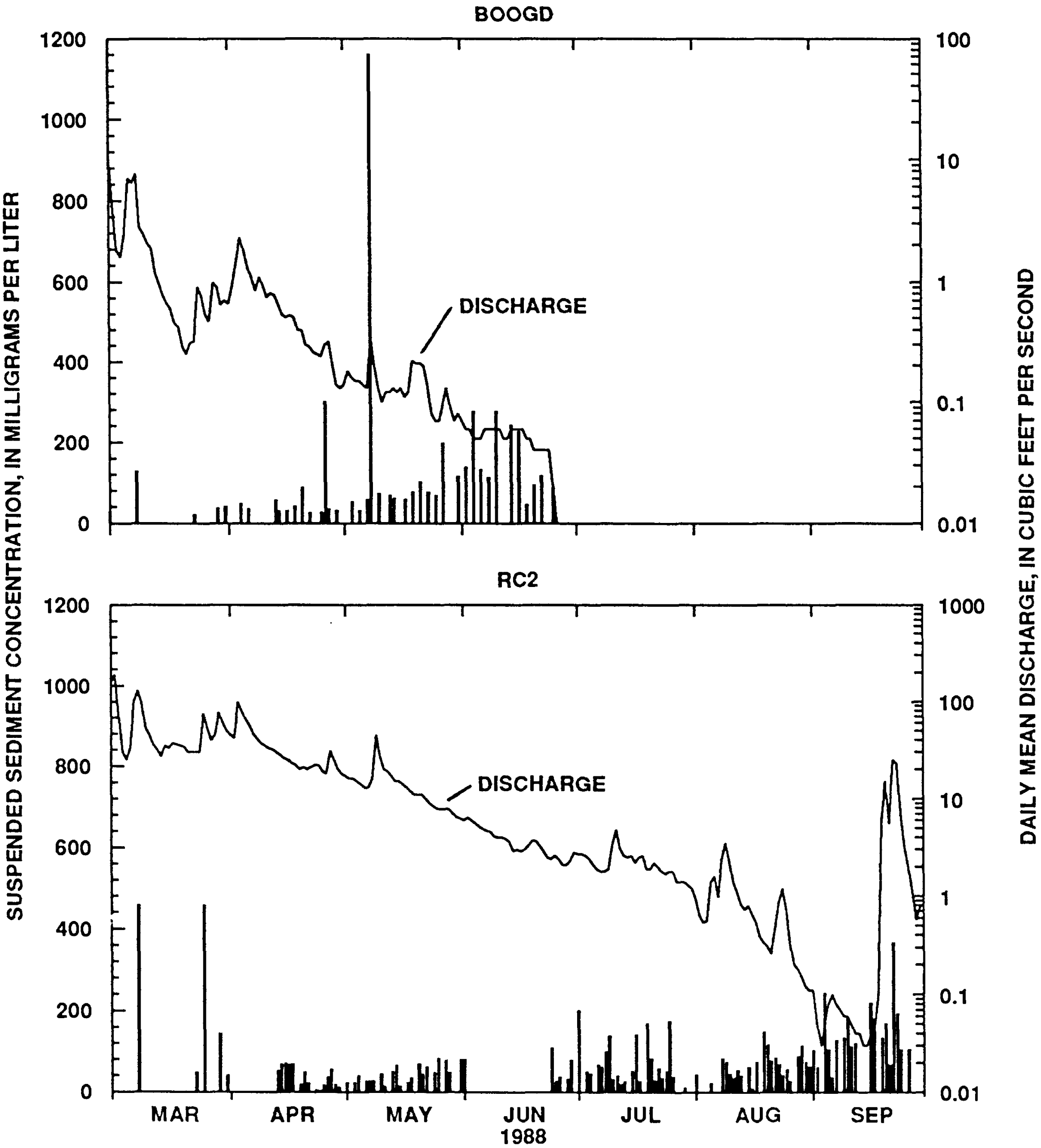

Figure 4.--Discharge and suspended sediment concentrations at sites BOOGD, Unnamed Creek near Luana, and RC2, Roberts Creek above Saint Olaf, Iowa, March-September 1988.

To define the diurnal variation in water quality at site RC2 during a period of low streamflow, water-quality samples were collected at three hour intervals from 0900 hours on June 23 to 0600 hours on June 24, 1988. Concentrations of selected constituents are listed in table 16 and are shown in figure 5. Stream discharge varied slightly from 2.1 to 2.5 ft^3/s. Specific conductance was lowest, 540 µS/cm, in the afternoon of June 23 and greatest, 600 µS/cm,the following morning. Water temperature, pH, and dissolved oxygen varied inversely in relation to specific conductance. Water temperature and pH reached maximum values during mid-afternoon and were at minimum values in mid-morning. The maximum pH and water temperature were 8.80 units and 31.3° C, respectively and the minimum pH and water temperature were 7.34 units and 21.9 °C, respectively. Dissolved-oxygen concentrations increased through the morning and early afternoon and peaked at 14.0 mg/L at mid-afternoon. Dissolved-oxygen concentrations are supersaturated at this point. Concentrations decrease during the late afternoon and evening and reached a minimum of 4.0 mg/L during the middle of the night.

Concentrations of most dissolved nutrients were constant during this 24-hour period (table 16). Nitrite plus nitrate concentrations were 0.5 to 0.6 mg/L as nitrogen. Ammonia was detected (0.2 mg/L as nitrogen) only at 0600 hours on June 24. Ortho-phosphorus concentrations were constant at 0.3 mg/L. Organic nitrogen concentrations generally were lowest from 1200 hours to 1800 hours and greatest during the night.

Four samples for pesticide analyses were collected during the diurnal sampling. Two pesticides were detected (table 16). Atrazine was detected in all samples and cyanazine in one sample. The total recoverable atrazine concentration was 0.25 µg/L in one sample and 0.26 µg/L in the other three samples. The total recoverable cyanazine concentration was 0.12 µg/L at 1800 hours on June 23.

Table 16.--Diurnal variation of selected physical and chemical constituents at site RC2, Creek above St. Olaf, Iowa

[ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter; C, degrees celsius; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; C, carbon; µg/L, micrograms per liter; --, data not collected]

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH (units)	Temperature (C)	Dissolved oxygen (mg/L)
6-23-88	0900	2.4	590	8.1	23.5	6.0
6-23-88	1200	2.5	560	8.4	28.0	11.5
6-23-88	1500	2.4	550	8.8	30.0	14.0
6-23-88	1800	2.4	540	8.8	29.0	12.6
6-23-88	2100	2.4	555	8.5	27.0	7.8
6-23-88	2400	2.4	580	8.1	24.0	4.4
6-24-88	0300	2.1	600	7.8	22.5	4.0
6-24-88	0600	2.1	580	7.7	21.0	4.2

Date	Time	Nitrite plus nitrate (as N) (mg/L)	Ammonia (as N) (mg/L)	Organic nitrogen (as N) (mg/L)	Orthophosphorus (as P) (mg/L)	Organic carbon, total (as C) (mg/L)
6-23-88	0900	0.6	<0.1	1.1	0.3	4.5
6-23-88	1200	.6	< .1	.6	.3	5.0
6-23-88	1500	.5	< .1	.7	.3	5.3
6-23-88	1800	.5	< .1	.5	.3	4.9
6-23-88	2100	.5	< .1	.7	.3	4.4
6-23-88	2400	.5	< .1	.8	.3	4.5
6-24-88	0300	.5	< .1	.9	.3	5.1
6-24-88	0600	.5	.2	.7	.3	4.3

Date	Time	Atrazine (µg-L)	Cyanazine (µg-L)	Metolachlor (µg-L)	Alachlor (µg-L)	Metribuzin (µg-L)	Butylate (µg-L)	Trifluralin (µg-L)
6-23-88	0900	--	--	--	--	--	--	--
6-23-88	1200	0.26	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-23-88	1500	--	--	--	--	--	--	--
6-23-88	1800	.26	.12	< .1	< .1	< .1	< .1	< .1
6-23-88	2100	--	--	--	--	--	--	--
6-23-88	2400	.25	< .1	< .1	< .1	< .1	< .1	< .1
6-23-88	0300	--	--	--	--	--	--	--
6-24-88	0600	.26	< .1	< .1	< .1	< .1	< .1	< .1

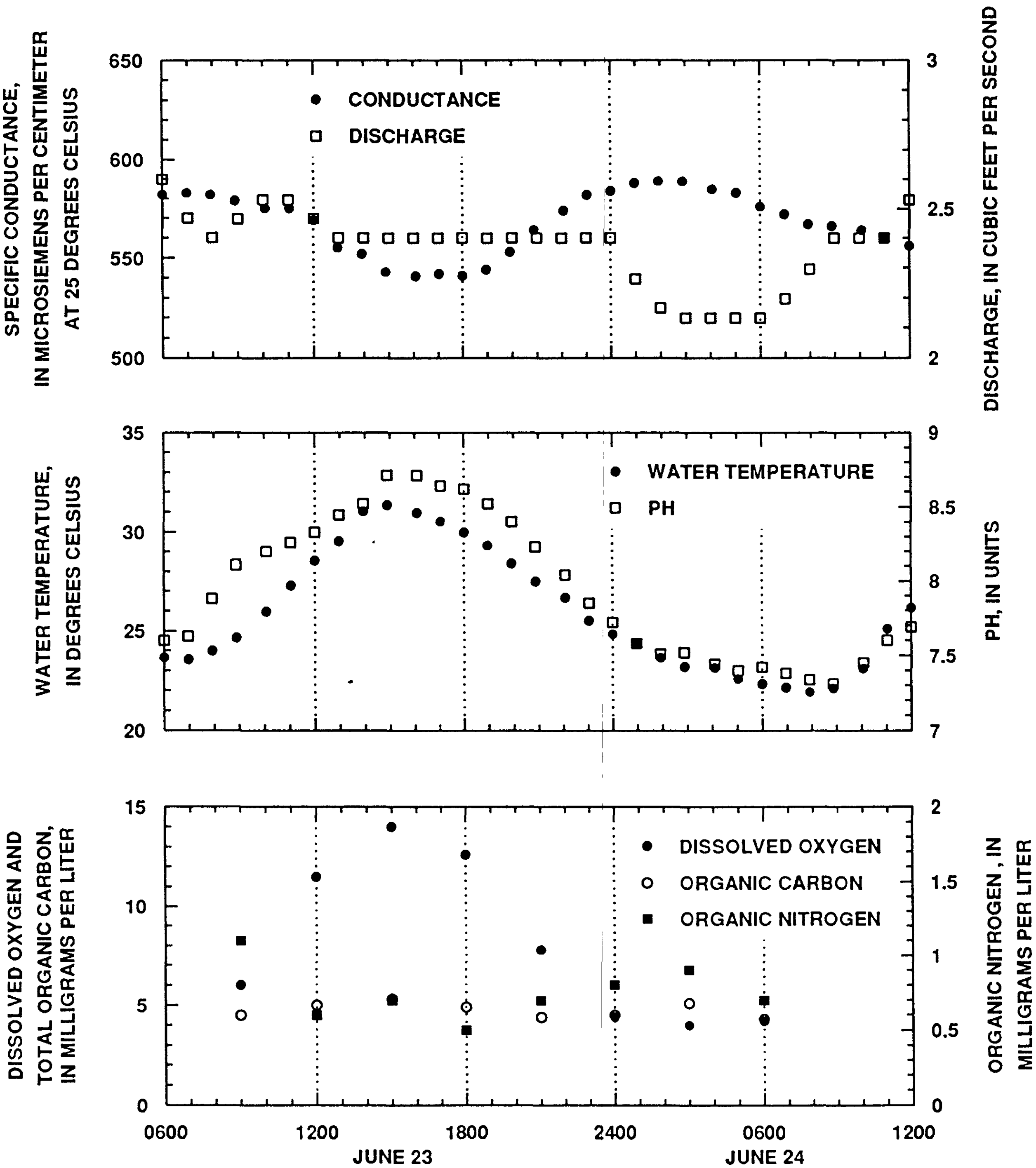

Figure 5.--Diurnal variation of selected physical and chemical constituents at site RC2, Roberts Creek above Saint Olaf, Iowa, June 23-24, 1988.

Ground Water

Big Spring

Continuous water quality data, as daily mean and median values, collected at Big Spring are shown in tables 17 and 18 and in figure 6. After installation of the monitoring equipment, it was determined that water quality varied from the top to the bottom of the spring pool. To obtain more representative values of water discharging from the spring, the water-quality-monitoring probes were lowered to within one foot of the bottom of the spring pool on May 4. The following discussion of water temperature, specific conductance, and pH deal only with values observed after May 4. Daily mean specific conductance values ranged from 690 µS/cm on June 7 and 9 to 735 µS/cm on September 21 and 24. The maximum daily median pH was 7.10 units on May 5 and the minimum daily median pH was on 6.65 units on July 8. Daily mean temperatures varied from 9.7 to 10.6 °C from May 5 to September 30.

The predominant cations in solution were calcium and magnesium (table 9). Calcium concentrations ranged from 64 to 96 mg/L and magnesium concentrations ranged from 25 to 39 mg/L. Sodium and potassium concentrations were less than 15 mg/L. The predominant anion was bicarbonate. Bicarbonate concentrations ranged from 264 to 390 mg/L. Sulfate concentrations ranged from 23 to 37 mg/L and chloride concentrations ranged from 14 to 24 mg/L. Silica concentrations were 17 mg/L or less. Dissolved nitrate plus nitrite was the predominant nitrogen species in solution (table 10). Nitrate plus nitrite concentrations ranged from 7.5 to 11 mg/L as nitrogen. Two of eight samples had nitrate concentrations equal to or greater than the 10 mg/L maximum contaminant level (U.S. Environmental Protection Agency, 1986). Ammonia concentrations exceeded the detection limits in two samples. Organic nitrogen concentrations were less than the detection limits in three samples. The maximum organic nitrogen concentration in the remaining samples was 0.6 mg/L as nitrogen.

Atrazine was the only pesticide detected in Big Spring (table 11). Total recoverable atrazine concentrations ranged from less than the detection limit to 0.26 µg/L in a sample collected on May 4. Concentrations of cyanazine, metolachlor, alachlor, metribuzin, butylate, and trifluralin were less than the detection limit in all samples.

Table 17.--Daily mean specific conductance and water temperature at Big Springs
Water year October 1987 to September 1988
[Data before May 4 from a corresponding spring pool gage height of approximately 8.5 feet, and after May 4 from approximately 10 feet; ---, data not available to calculate mean values]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Daily mean specific conductance, in microsiemens per centimeter at 25 degrees Celsius												
1	---	---	---	---	---	---	717	726	---	711	703	727
2	---	---	---	---	---	---	717	726	705	708	704	728
3	---	---	---	---	---	---	717	724	705	708	703	729
4	---	---	---	---	---	---	716	723	703	709	703	728
5	---	---	---	---	---	---	707	722	704	711	701	726
6	---	---	---	---	---	---	706	723	699	713	704	726
7	---	---	---	---	---	---	712	723	690	715	704	726
8	---	---	---	---	---	---	716	724	691	714	705	726
9	---	---	---	---	---	---	718	724	690	716	705	---
10	---	---	---	---	---	---	720	725	696	717	708	---
11	---	---	---	---	---	---	721	726	699	719	709	---
12	---	---	---	---	---	---	---	---	700	719	---	---
13	---	---	---	---	---	---	723	---	700	717	---	722
14	---	---	---	---	---	---	724	715	701	712	---	722
15	---	---	---	---	---	---	724	716	702	709	---	727
16	---	---	---	---	---	---	725	718	701	707	---	731
17	---	---	---	---	---	---	726	722	700	704	---	732
18	---	---	---	---	---	---	726	722	700	703	---	734
19	---	---	---	---	---	---	---	721	701	702	708	732
20	---	---	---	---	---	---	726	722	701	703	708	728
21	---	---	---	---	---	---	727	723	700	705	708	735
22	---	---	---	---	---	---	727	724	703	706	708	729
23	---	---	---	---	---	---	728	720	700	704	709	730
24	---	---	---	---	---	---	728	720	699	703	710	735
25	---	---	---	---	---	---	727	722	698	704	717	726
26	---	---	---	---	---	718	727	722	698	705	722	717
27	---	---	---	---	---	712	727	722	701	707	721	715
28	---	---	---	---	---	712	727	722	711	710	722	717
29	---	---	---	---	---	713	727	724	730	708	724	721
30	---	---	---	---		717	726	724	717	707	726	718
31	---		---	---		717		---		705	725	
Daily mean water temperature, in degrees Celsius												
1	---	---	---	---	---	---	9.3	9.6	---	10.6	10.4	10.4
2	---	---	---	---	---	---	9.3	9.6	10.3	10.6	10.4	10.4
3	---	---	---	---	---	---	9.3	9.7	10.3	10.6	10.4	10.4
4	---	---	---	---	---	---	9.3	9.7	10.3	10.6	10.4	10.4
5	---	---	---	---	---	---	9.5	9.7	10.4	10.6	10.4	10.4
6	---	---	---	---	---	---	9.4	9.8	10.4	10.6	10.4	10.4
7	---	---	---	---	---	---	9.4	9.8	10.4	10.6	10.4	10.4
8	---	---	---	---	---	---	9.5	9.8	10.4	10.6	10.4	10.4
9	---	---	---	---	---	---	9.5	9.9	10.4	10.6	10.4	10.4
10	---	---	---	---	---	---	9.5	9.9	10.4	10.6	10.4	10.3
11	---	---	---	---	---	---	9.5	9.9	10.4	10.6	10.4	10.4
12	---	---	---	---	---	---	---	---	10.4	10.5	---	10.4
13	---	---	---	---	---	---	9.6	---	10.4	10.5	---	10.4
14	---	---	---	---	---	---	9.6	9.9	10.4	10.5	---	10.4
15	---	---	---	---	---	---	9.6	10.0	10.5	10.5	---	10.4
16	---	---	---	---	---	---	9.6	10.0	10.5	10.5	---	10.3
17	---	---	---	---	---	---	9.6	10.1	10.5	10.5	---	10.3
18	---	---	---	---	---	---	9.6	10.1	10.5	10.5	---	10.3
19	---	---	---	---	---	---	---	10.1	10.6	10.5	10.5	10.3
20	---	---	---	---	---	---	9.6	10.1	10.6	10.5	10.4	10.3
21	---	---	---	---	---	---	9.6	10.1	10.6	10.5	10.4	10.3
22	---	---	---	---	---	---	9.6	10.1	10.6	10.5	10.4	10.3
23	---	---	---	---	---	---	9.6	10.2	10.5	10.5	10.5	10.3
24	---	---	---	---	---	---	9.6	10.2	10.6	10.5	10.5	10.3
25	---	---	---	---	---	---	9.6	10.2	10.6	10.5	10.5	10.3
26	---	---	---	---	---	9.1	9.5	10.2	10.6	10.6	10.5	10.3
27	---	---	---	---	---	9.2	9.5	10.3	10.6	10.5	10.5	10.3
28	---	---	---	---	---	9.2	9.6	10.3	10.6	10.5	10.5	10.3
29	---	---	---	---	---	9.2	9.6	10.3	10.6	10.4	10.5	10.3
30	---	---	---	---		9.2	9.6	10.3	10.6	10.4	10.4	10.3
31	---		---	---		9.3		---		10.4	10.4	

Table 18.--Daily median pH at Big Spring
Water year October 1987 to September 1988
[Data before May 4 from a corresponding spring pool gage height of approximately 8.5 feet, and after May 4 from approximately 10 feet; ---, data not available to calculate median values]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
					Daily median ph, in units							
1	---	---	---	---	---	---	7.41	7.61	---	6.92	6.75	6.75
2	---	---	---	---	---	---	7.42	7.60	6.76	6.92	6.74	6.75
3	---	---	---	---	---	---	7.42	7.58	6.77	6.91	6.74	6.76
4	---	---	---	---	---	---	7.42	7.14	6.82	6.90	6.75	6.76
5	---	---	---	---	---	---	---	7.10	6.87	6.88	6.75	6.77
6	---	---	---	---	---	---	---	7.09	6.91	6.88	6.75	6.77
7	---	---	---	---	---	---	---	7.08	6.83	6.86	6.74	6.77
8	---	---	---	---	---	---	---	7.07	6.87	6.65	6.75	6.76
9	---	---	---	---	---	---	---	7.07	6.92	6.67	6.75	6.77
10	---	---	---	---	---	---	---	7.05	6.99	6.75	6.75	6.76
11	---	---	---	---	---	---	---	7.04	7.02	6.82	6.75	6.76
12	---	---	---	---	---	---	---	---	7.01	6.94	---	6.77
13	---	---	---	---	---	---	---	---	7.00	6.92	---	6.78
14	---	---	---	---	---	---	---	6.99	6.99	6.85	---	6.76
15	---	---	---	---	---	---	7.47	6.98	6.97	6.80	---	6.77
16	---	---	---	---	---	---	7.48	7.00	6.97	6.80	---	6.76
17	---	---	---	---	---	---	7.47	6.99	6.97	6.80	---	6.74
18	---	---	---	---	---	---	7.50	6.99	6.96	6.81	---	6.74
19	---	---	---	---	---	---	---	6.98	6.96	6.81	6.81	6.75
20	---	---	---	---	---	---	7.52	6.95	6.95	6.79	6.81	6.77
21	---	---	---	---	---	---	7.55	6.96	6.95	6.78	6.81	6.75
22	---	---	---	---	---	---	7.56	6.97	6.94	6.77	6.81	6.76
23	---	---	---	---	---	---	7.57	6.96	6.95	6.77	6.82	6.87
24	---	---	---	---	---	---	7.59	6.94	6.95	6.77	6.81	6.86
25	---	---	---	---	---	---	7.59	6.93	6.94	6.77	6.82	6.85
26	---	---	---	---	---	7.38	7.60	6.94	6.94	6.76	6.81	6.84
27	---	---	---	---	---	7.39	7.61	6.95	6.92	6.75	6.79	6.85
28	---	---	---	---	---	7.38	7.60	6.96	6.91	6.75	6.79	6.86
29	---	---	---	---	---	7.39	7.61	6.96	6.92	6.74	6.77	6.82
30	---	---	---	---		7.40	7.61	6.96	6.91	6.75	6.77	6.83
31	---		---	---		7.41		---		6.74	6.75	

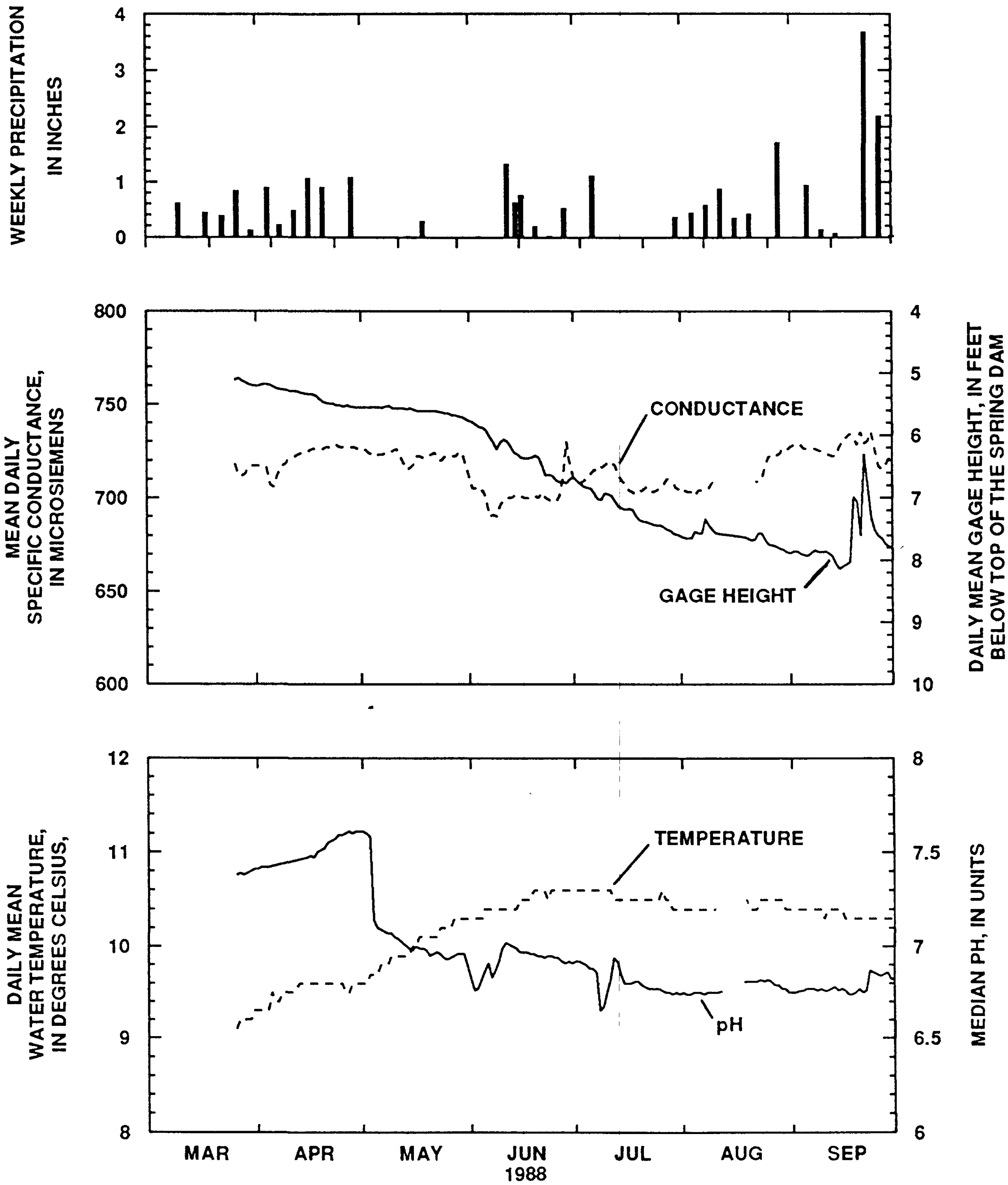

Figure 6.--Weekly precipitation, daily mean specific conductance, gage height, water temperature, and daily median pH at Big Spring, Clayton County, Iowa, March-September, 1988.

Seepage study

Stream discharge was measured at sites(fig. 1) in the study area after an extended period without rain (June 28-29) to determine areas where streamflow was being lost to the ground-water system through seepage and to determine areas where water was flowing into the streams from shallow aquifers. Measurements were also made to quantify the gain or loss to the stream. Water samples were collected concurrently to document nutrient inflow from ground water and outflow into the underlying aquifer. The results of the study are presented in table 19 and figures 7 and 8. Discussion and interpretation of the results is beyond the scope of this report and will be presented in future reports. The results of discharge measurements and chemical analyses of samples from sites on Roberts Creek and a stretch of Silver Creek are summarized here.

Discharge

Discharge increased in Roberts Creek from 0.10 ft^3/s at site RC13, the most upstream site, to 5.17 ft^3/s at RC18 approximately 17 miles downstream (fig. 7). Streamflow in this stretch partially originated from three tributaries, West Branch Roberts Creek, Deer Creek, and Silver Creek. West Branch Roberts Creek added 0.82 ft^3/s, Deer Creek added approximately 0.77 ft^3/s and Silver Creek added approximately 0.36 ft^3/s. Discharge decreased in a 9.5 mile stretch downstream of site RC18 from 5.17 ft^3/s to 2.11 ft^3/s at site RC2. Total discharge lost from Roberts Creek during the seepage study was 3.25 ft^3/s. This includes 0.33 ft^3/s lost from sites RC16 to RC18 and 3.06 ft^3/s lost from sites RC18 to RC2. During subsequent measurements (table 20), Roberts Creek lost from approximately 1.5 to 3.1 ft^3/s from site RC18 to RC2. The losses are from 31 to 99 percent of the discharge measured at site RC18.

Determination of seepage in Silver Creek is complicated by non-uniform point-source discharges in the headwaters of the stream. A municipality discharges upstream of site SC10 and an industrial user discharges waste water upstream of site SC13. Discharges for sites SC10 on East Fork Silver Creek to SC1 on Silver Creek are shown in figure 8. Discharges were 0.12 and 1.19 ft^3/s at sites SC10 and SC13, respectively. The combined flow of East Fork and the main stem of Silver Creek (SC6 plus SC5) was 2.12 ft^3/s. Downstream at site SC1 discharge had decreased to 0.81 ft^3/s. A measurement also was made at site SC14, on a tributary of Silver Creek, however, this water did not reach the main stem. The total loss of discharge in Silver Creek was approximately 1.46 ft^3/s. The discharge loss downstream of site SC1 on Silver Creek was not used in calculating loss from the stream because it is not known whether discharge is representative of the intermittent point source discharge or of natural flow.

Table 19.--Field measurements and chemical analyses of samples from streams in the Big Spring Basin during low-flow conditions

[Dissolved chemical constituents in milligrams per liter]

[--, missing data; ft^3/s, cubic feet per second: μS/cm, microsiemens per centimeter; C, degrees celsius; N, nitrogen; P, phosphorus; C, carbon; <, less than]

Station number	Date	Time	Streamflow (ft^3/s)	Specific conductance (μS/cm)	pH (units)	Temperature (C)	Chloride	Nitrite plus nitrate (as N)	Ammonia (as N)	Organic nitrogen (as N)	Orthophosphorus (as P)	Total organic carbon (as C)
HS5	6-29-88	1345	0.20	750	8.0	17.0	29	0.2	<0.1	0.7	0.3	2.4
HS6	6-29-88	1500	.29	700	8.1	17.0	19	5.7	< .1	3.3	.2	3.3
HS4	6-29-88	1600	.36	695	7.9	15.0	17	9.0	< .1	.6	< .1	1.8
HS2	6-29-88	1700	.27	690	--	16.5	18	8.0	.3	.6	.3	7.5
HS3	6-29-88	1730	.71	625	8.3	18.0	18	5.7	< .1	.4	.1	2.6
HS1	6-29-88	1700	.30	600	8.3	20.0	16	4.7	< .1	.8	.2	3.7
RC13	6-29-88	1530	.10	680	8.3	18.0	23	4.3	.3	1.0	.7	4.5
RC21	6-29-88	1430	.82	619	8.5	18.5	22	7.3	.1	.3	< .1	2.2
RC20	6-29-88	1345	2.54	621	8.4	19.0	18	4.9	.1	.3	.3	2.8
RC11	6-29-88	1145	2.79	640	8.7	18.5	18	4.7	< .1	.5	.2	2.8
RC10	6-29-88	0915	3.59	630	8.2	19.0	21	3.4	< .1	.3	.1	3.7
RC15	6-28-88	1215	3.44	615	8.1	22.5	20	1.5	< .1	1.0	.2	11
DC4	6-28-88	1845	.42	561	8.4	26.5	15	4.4	< .1	.5	< .1	2.4
DC2	6-28-88	1345	.77	680	8.3	22.0	16	5.4	< .1	1.6	.1	2.2
F45	6-28-88	1530	4.37	598	8.6	22.0	20	2.2	< .1	.6	.1	4.1
RC16	6-28-88	1715	4.86	574	8.7	28.5	21	1.2	< .1	.4	.1	4.1
RC17	6-28-88	1130	4.67	595	--	23.5	22	2.2	< .1	.4	.3	4.2
SC10	6-29-88	0815	.12	1,280	--	12.0	200	27	< .1	1.2	6.2	6.1
SC13	6-29-88	0900	1.19	1,000	--	30.0	64	< .1	3.1	5.2	3.8	2.4
SC3	6-29-88	1135	1.24	1,135	--	22.0	80	1.4	4.9	2.0	4.4	1.6
SC6	6-29-88	1515	1.43	1,090	--	19.0	90	.4	7.8	3.0	4.3	1.7
SCU1	6-29-88	1650	.12	630	--	26.5	18	4.6	.2	1.9	.1	5.1
SCU2	6-29-88	1730	--	710	--	18.5	20	15	< .1	.3	< .1	1.3
L23	6-29-88	1805	.52	680	--	27.5	24	7.6	.8	2.8	.2	6.2
SC5	6-28-88	1905	.69	665	--	25.5	23	8.2	< .1	.5	< .1	2.8
SC1	6-29-88	1900	.81	1,130	--	19.5	100	.5	9.5	.5	4.9	6.5
SC14	6-29-88	1030	.15	710	--	15.5	34	6.7	< .1	.2	.1	2.1
SC2	6-28-88	1445	.25	1,310	--	29.0	160	1.0	< .1	.5	.2	4.2
SC4	6-28-88	1240	.36	1,490	--	22.0	250	3.0	1.2	.8	2.2	5.5
RC18	6-28-88	1350	5.17	600	--	24.0	23	2.5	3.9	1.2	3.2	8.7
F47	6-28-88	1200	4.02	670	8.3	23.0	24	.7	< .1	.7	.3	5.6
RC19	6-28-88	1315	3.38	630	8.4	24.0	26	.8	< .1	.9	.3	7.1
RC19	6-29-88		4.24	--	--	--	--	--	--	--	--	--
RC24	6-29-88	0900	3.84	630	8.0	21.0	32	.5	< .1	1.1	.3	5.0
RC23	6-29-88	1100	3.49	590	8.4	21.0	24	.2	< .1	.5	.3	4.9
RC22	6-28-88	1430	2.63	580	8.9	27.0	24	< .1	< .1	.6	.3	6.6
RC2	6-28-88	1530	2.11	533	9.0	30.0	23	.2	.1	.7	.2	6.4
HC1	6-28-88	1700	.59	700	8.4	24.0	18	5.2	< .1	1.5	< .1	5.0
HC2	6-28-88	1800	.52	710	8.1	26.0	18	4.4	< .1	.4	< .1	2.3

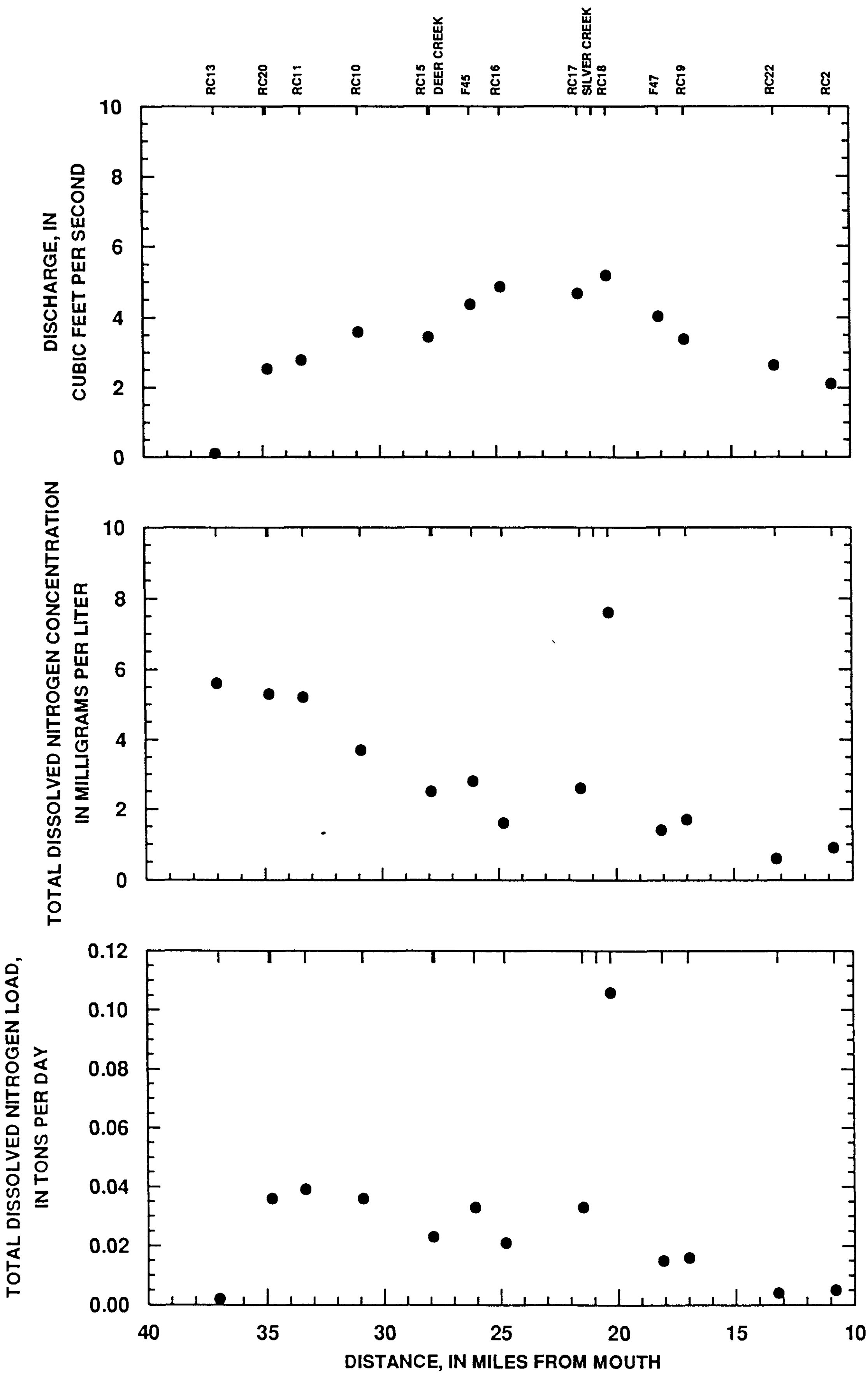

Figure 7.--Discharge, total dissolved nitrogen concentration, and total dissolved nitrogen load in Roberts Creek, June 28-29, 1988.

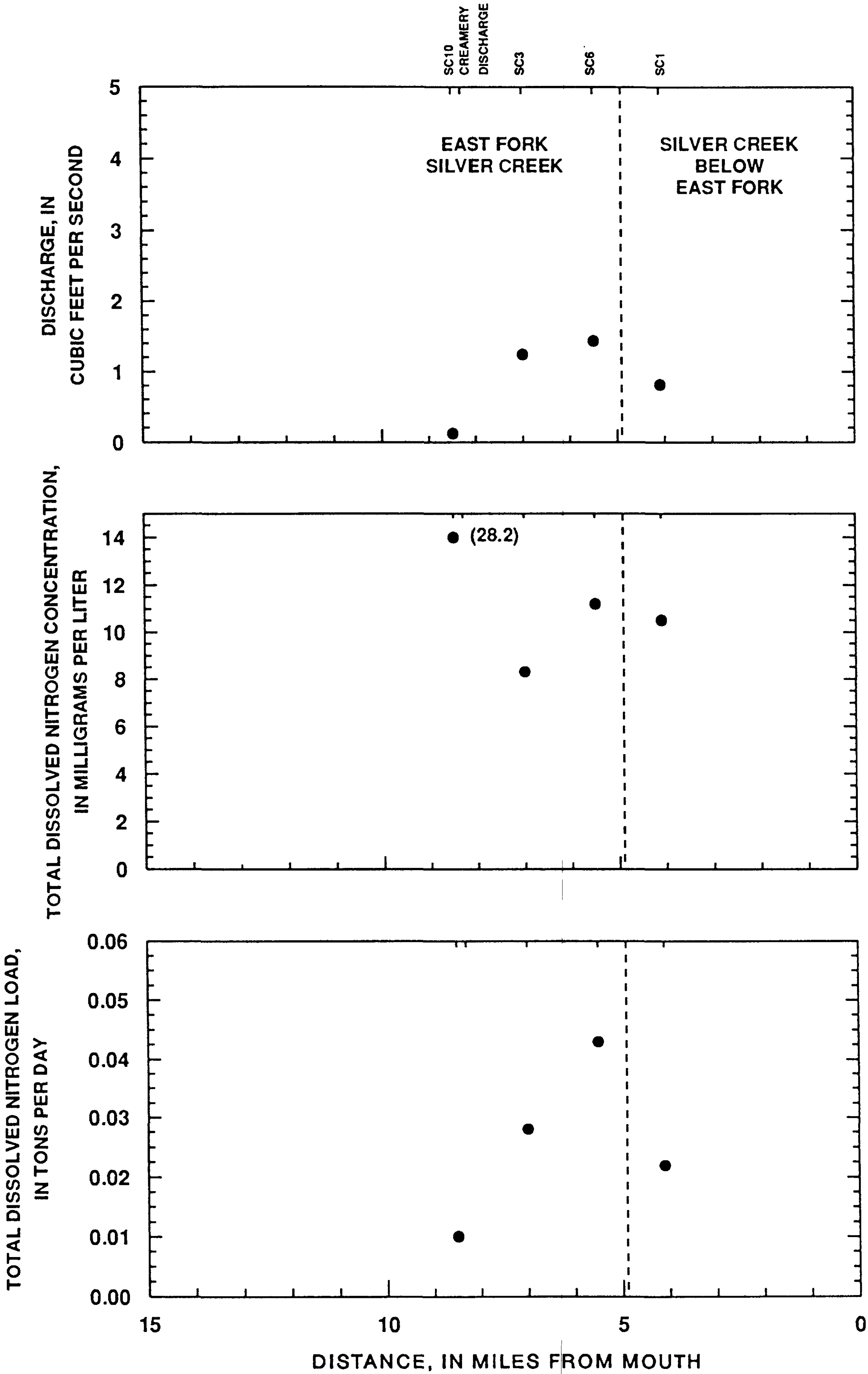

Figure 8.--Discharge, total dissolved nitrogen concentration, and total dissolved nitrogen load in East Fork Silver Creek and Silver Creek, June 28-29, 1988.

Table 20.--Seepage in a selected reach of Roberts Creek
[Discharge in cubic feet per second]

Date	Discharge RC18	Discharge RC2	Net loss	Percent loss
6/28/88	5.17	2.11	3.06	59
7/19/88	4.39	1.32	3.07	70
8/09/88	6.28	4.31	1.97	31
9/09/88	1.50	.017	1.48	99

Additional stream discharge was lost from Hatchery and Howard Creek. Approximately 0.50 ft^3/s and 0.07 ft^3/s was lost from Hatchery and Howard Creek, respectively. The total measured discharge lost in the Big Spring basin during the two day seepage study was 5.57 ft^3/s and the total measured discharge leaving the basin in streams was 2.93 ft^3/s.

Water Quality

Total nitrogen concentrations in samples collected during the seepage study generally decreased downstream of the headwater sites in Roberts Creek in samples collected during the seepage study (fig. 7). At sites RC13, RC20, and RC11 total dissolved nitrogen concentrations exceeded 5.0 mg/L. Between sites RC10 and RC17 concentrations ranged from 1.6 to 3.7 mg/L. The greatest total dissolved nitrogen concentration (7.6 mg/L) was in a sample from site RC18, located downstream of the mouth of Silver Creek. Concentrations then decreased downstream to site RC2. The total dissolved nitrogen concentration of water in Roberts Creek leaving the study area was 1.0 mg/L. Upstream of site RC18, the dominant nitrogen species was nitrate plus nitrite. Ammonia was the predominant nitrogen species at RC18 and organic nitrogen was the predominant species downstream of RC18.

Total nitrogen loads displayed a similar pattern to total dissolved nitrogen concentrations in Roberts Creek, greatest in the headwaters sites then decreasing downstream to site RC17 (fig.8). The load increased from RC17 to RC18 and then decreased downstream in the final 9.5 miles of Roberts Creek in the study area. During the two-day seepage study, 0.13 t/d (tons per day) of total dissolved nitrogen were lost from Roberts Creek and approximately 0.01 t/d left the study area in Roberts Creek.

Total dissolved nitrogen concentrations, almost entirely as nitrate plus nitrite, were 28 mg/L at site SC10 and decreased to 8.3 mg/l at site SC3 (fig. 8). Downstream total nitrogen concentrations ranged from approximately 8.0 to 11.0 mg/L and the predominant nitrogen species was ammonia. Combined total dissolved nitrogen loads as nitrogen at the two upstream sites was 0.04 t/d. The load decreased at the next downstream site, SC3, to 0.03 t/d and then increased downstream to 0.04 t/d at site SC6. The load at SC1 was 0.02 t/d which is a loss of approximately 0.04 t/d from the combined load of East Fork and the main stem of Silver Creek. The total measured nitrogen loss in Silver Creek was approximately 0.05 t/d.

Nitrogen also was lost from Hatchery and Howard Creeks. The total measured nitrogen load decreased 0.01 t/d in Hatchery Creek and decreased approximately 0.004 t/d in Howard Creek. The total dissolved nitrogen load lost in the study area was 0.19 t/d and the dissolved nitrogen load leaving the Big Spring basin in streams was approximately 0.02 t/d.

SUMMARY

An investigation to collect hydrologic data in the Big Spring ground-water basin in northeastern Iowa was initiated in water year 1988. The investigation was conducted in cooperation with the Iowa Department of Natural Resources, Geological Survey Bureau. The study area is located in Clayton County in northeastern Iowa in an area of karst topography and corresponds with a ground-water basin draining through Big Spring.

Information on precipitation, streams, and ground water was collected in water year 1988. Precipitation was measured at three sites and precipitation quality was determined from samples collected at Big Spring. Stream discharge was monitored at three sites and monthly water-quality samples collected at two sites on streams in the Big Spring Basin. Discharge was measured and water-quality samples collected at 38 sites on streams in the basin to determine loss of water and nutrients during a period of low streamflow. Discharge from Big Spring was monitored continuously and water-quality samples were collected monthly.

Total rainfall at Big Spring was 24.08 in. The greatest rainfall was in the month of September when 4.89 and 4.82 in. fell at sites BOOGD and RC2, respectively. Chemical analyses of precipitation indicates that calcium and sulfate are the predominant ions in solution. The median calcium concentration was 0.81 mg/L and the median sulfate concentration was 2.0 mg/L. Median concentrations of nitrate and ammonia as nitrogen were 0.40 and 0.37 mg/L, respectively.

The daily mean discharge of Unnamed Creek at site BOOGD was 0.0 to 7.0 ft^3/s. Unnamed Creek was dry during parts of December and January and from the last week in June through the end of the water year. Calcium, magnesium, and bicarbonate are the predominant ions in the monthly samples. Nitrate plus nitrite concentrations ranged from 7.6 to 14 mg/L as nitrogen. Two pesticides, atrazine and alachlor, were detected in the four monthly samples. Atrazine was present in all samples and the concentration ranged from 0.16 to 0.34 $\mu g/L$. The concentration of alachlor was greater than the detection level in one sample (0.11 $\mu g/L$).

The daily mean discharge at site RC2, Roberts Creek above Saint Olaf, ranged from 190 to 0.02 ft^3/s. The median discharge for the 1988 water year was 7.7 ft^3/s. Continuous monitoring indicates that pH and water temperature vary diurnally and are greatest during the mid-afternoon and smallest from 0600 to 0900 hours. Specific conductance varies inversely with pH and water temperature. Calcium, magnesium, and bicarbonate are the predominant ions in the monthly samples from site RC2. Nitrate plus nitrite concentrations ranged from 0.5 to 15 mg/L as nitrogen. Four pesticides, atrazine, cyanazine, alachlor, and metolachlor, were detected in nine samples. Total recoverable atrazine concentrations ranged from less than 0.10 to 0.72 $\mu g/L$. Total recoverable cyanazine concentrations ranged from less than 0.10 to 0.72 $\mu g/L$. Metolachlor (0.11 $\mu g/L$) and alachlor (0.55 $\mu g/L$) concentrations exceeded the detection limit in one sample.

Continuous monitoring indicates that water temperature, pH, and specific conductance were relatively constant in Big Spring for the period May 4 to September 30. The daily mean water temperature ranged from 9.7 to 10.6 C, the daily mean specific conductance ranged from 690 to 735 μS/cm, and the daily median pH ranged from 6.65 to 7.10 units. The predominant ions in solution are calcium, magnesium, and bicarbonate. Dissolved nitrate plus nitrite concentrations ranged from 7.5 to 11 mg/L. Atrazine was the only pesticide present in concentrations greater than the detection limit of 0.10 μg/L. Concentrations ranged from less than 0.10 μg/L to 0.26 μg/L.

A seepage study was conducted during a period of low streamflow from June 28 to June 29 to determine gaining and losing reaches of streams and to determine changes in nutrient concentrations and loads in streams. The total measured discharge lost in the Big Spring basin during the seepage study was 5.57 ft^3/s and the total measured discharge leaving the basin through streamflow was 2.93 ft^3/s. The total dissolved nitrogen load lost was 0.19 t/d and the total dissolved nitrogen load leaving the basin in streams was 0.02 t/d.

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