GEOCHEMISTRY OF ARTIFICIAL-RECHARGE TESTS IN THE OAKES AQUIFER NEAR OAKES, SOUTHEASTERN NORTH DAKOTA

By G. F. Huff and J. D. Wald

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SELECTED FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC UNITS

For those readers who may prefer to use metric (International System) units rather than inch-pound units, the conversion factors for the terms used in this report are given below.

Multiply inch-pound unit	By	To obtain metric unit
Acre	0.4047	hectare
Foot	0.3048	meter
Inch	25.40	millimeter
Inch per hour	2.540	centimeter per hour
Mile	1.609	kilometer
Million gallons	3.785	million liters
Square foot	0.09294	square meter

To convert degrees Celsius (°C) to degrees Fahrenheit (°F), use the following formula:

$$°F = 9/5(°C)+32$$

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ABSTRACT

As part of an artificial-recharge feasibility study, water from the James River was introduced into the Oakes aquifer of southeastern North Dakota by infiltration through a recharge basin. Chemical composition of water in the recharge basin and ground water from two separate flow paths beneath the basin was determined from samples taken during two artificial-recharge tests.

Changes between recharge-basin water and ground water from the termination of the flow paths during the spring 1987 test included increases in alkalinity, calcium, sodium, and silica and decreases in pH and dissolved oxygen. Interpretation of processes modifying the chemical composition of recharge water was complicated by mixing of recharge water with pre-existing ground water within the Oakes aquifer.

In the summer 1987 test, the recharge basin was lined with a decomposing organic mat. The purpose of the organic mat was to sustain large infiltration rates for a longer period of time and to evaluate the effect of a decomposing organic mat on water quality during sustained recharge-basin operation. Larger infiltration rates with the organic mat in place allowed recharge water to reach the termination of the flow paths prior to apparent mixing with pre-existing ground water for a period of as much as approximately 405 hours of recharge-basin operation.

Changes between recharge-basin water and ground water from the termination of the flow paths during the summer 1987 organic-mat test included increases in alkalinity, calcium, and silica and decreases in pH, dissolved oxygen, and total organic carbon. Detected changes between recharge-basin water and ground water from the termination of the flow paths were interpreted using a mass-balance geochemical model. Chemical changes of at least 2 milligrams per liter were modeled in terms of reactions, including those due to respiration of micro-organisms, dissolution of carbon dioxide, possible production of organic acids, dissolution of amorphous silica, cation exchange, and dissolution of carbonate minerals. Generation of organic acids within the decomposing organic mat may cause dissolution of dolomite in the subsurface.

INTRODUCTION

The Pick-Sloan Missouri River Basin Plan enacted by Congress in the Flood Control Act of 1944 was redesigned by the U.S. Bureau of Reclamation in 1957 to consider irrigating 1,007,120 acres of land in central and southeastern North Dakota. Missouri River water would be diverted from

Lake Sakakawea near Garrison Dam. The 1957 plan included 108,000 acres of proposed irrigation in the Oakes area of southeastern North Dakota. Construction of a 250,000-acre Garrison Diversion Unit was authorized by Congress in 1965 as the initial stage of the plan. The 1965 authorization designated 45,980 acres to be irrigated in the Oakes area. The Missouri River water would be delivered via canals and the James River. Because channel capacity of the James River upstream of Oakes was inadequate to meet peak irrigation demands, the U.S. Bureau of Reclamation proposed construction of Lake Taayer Reservoir about 6 miles east of Oakes.

The Garrison Diversion Unit, as authorized in 1965, raised significant issues of environmental and economic concern in both the United States and Canada. As a result, in accordance with Public Law 98-360, section 207, enacted by Congress on July 16, 1984, a 12-member commission was appointed by the Secretary of the Interior to "examine, review, evaluate, and make recommendations with regard to the contemporary water development needs of the State of North Dakota." The Garrison Diversion Unit Commission (1984) recommended the following changes for the proposed irrigation that was authorized in 1965 for the Oakes area:

1. Reduce the size from 45,980 acres to 23,660 acres,
2. deauthorize construction of Lake Taayer Reservoir, and
3. initiate a feasibility study to assess artificial recharge to the Oakes aquifer as an alternative to a surface reservoir.

On the basis of recommendations of the Garrison Diversion Unit Commission, Congress passed the Garrison Diversion Unit Reformulation Act of 1986. The act directed the Secretary of the Interior to submit a comprehensive report to Congress by no later than the end of fiscal year 1988; completion date, however, was extended to the end of fiscal year 1989. Results of a study to determine the feasibility of artificial recharge to the Oakes aquifer are to be included in the comprehensive report. In the proposed artificial-recharge plan, the Oakes aquifer would function as a storage reservoir and wells completed in the Oakes aquifer would be pumped during peak irrigation-demand periods.

In July 1985, the U.S. Geological Survey and the North Dakota State Water Commission entered into a cooperative agreement with the U.S. Bureau of Reclamation to investigate the feasibility of artificial recharge to the Oakes aquifer. The feasibility study was divided into three phases. Phases I and II were conducted by the North Dakota State Water Commission and the U.S. Geological Survey. Phase III was conducted by the North Dakota State Water Commission.

Phase I addresses the geometric, hydraulic, and hydrochemical properties of the Oakes aquifer. Phase II addresses the selection, construction, maintenance, and performance evaluation of recharge-test facilities in the Oakes aquifer. Phase III addresses preliminary cost analysis of a full-project-scale and pilot-scale well field and artificial-recharge facilities in the Oakes aquifer. Results of phases I and III of the feasibility study will be given in reports being prepared by the North Dakota State Water Commission.

Results of part of phase II, the selection, construction, and maintenance of the test facilities and recharge basins in the Oakes aquifer, are described in a report by Schuh and Shaver (1988). Their report also gives detailed information on the infiltration rates, physical processes that affected infiltration, and operational and maintenance techniques used to enhance infiltration rates during the artificial-recharge tests.

During phase II, recharge basins were operated over three periods: (1) September and October 1986, (2) May and June 1987, and (3) August, September, and October 1987. Two infiltration tests, the spring test, which was conducted May 4 to June 5, 1987, and the summer organic-mat test, which was conducted August 3 to September 2, 1987, were selected for geochemical analysis. The tests during these two operational periods were selected because ground-water chemical analyses were available for a longer period of recharge-basin operation than for the earlier operational period.

Purpose

The purpose of this report is to describe the sediment-ground water interaction that occurred along two separate ground-water flow paths during the spring 1987 test and the summer 1987 organic-mat test. The data obtained from the summer 1987 organic-mat test are interpreted using mass-balance geochemical and thermodynamic models. All chemical data collected during recharge-basin operation are included as supplemental data at the end of this report.

GENERAL DESCRIPTION OF TEST SITE, TEST FACILITIES, AND THE OAKES AQUIFER

Test Site

The test site selected for the feasibility study is in the SE¼SE¼ sec. 29, T. 131 N., R. 59 W. in eastern Dickey County, southeastern North Dakota (fig. 1). The test site is in the West Oakes Irrigation area and is about 1 mile east of the James River. Ground-water levels near the test site typically are 15-20 feet below land surface (Schuh and Shaver, 1988, p. 17).

Test Facilities

The 50-foot by 50-foot recharge basin originally was excavated to a depth of 4 feet. Additional excavation of about 1 foot was completed prior to the spring 1987 test. Sidewalls of the basin were lined with heavy polyethylene to prevent sloughing and erosion and to restrict infiltration to the 2,500 square-foot basin floor (Schuh and Shaver, 1988, p. 70).

Two multiport samplers were constructed using 2-inch polyvinyl-chloride casing. Sampling ports were drilled in the casings at 2-foot intervals. The sampling ports were covered with fiberglass wool to prevent entry of aquifer material into the 0.25-inch Tygon[1] tubing used to connect the

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

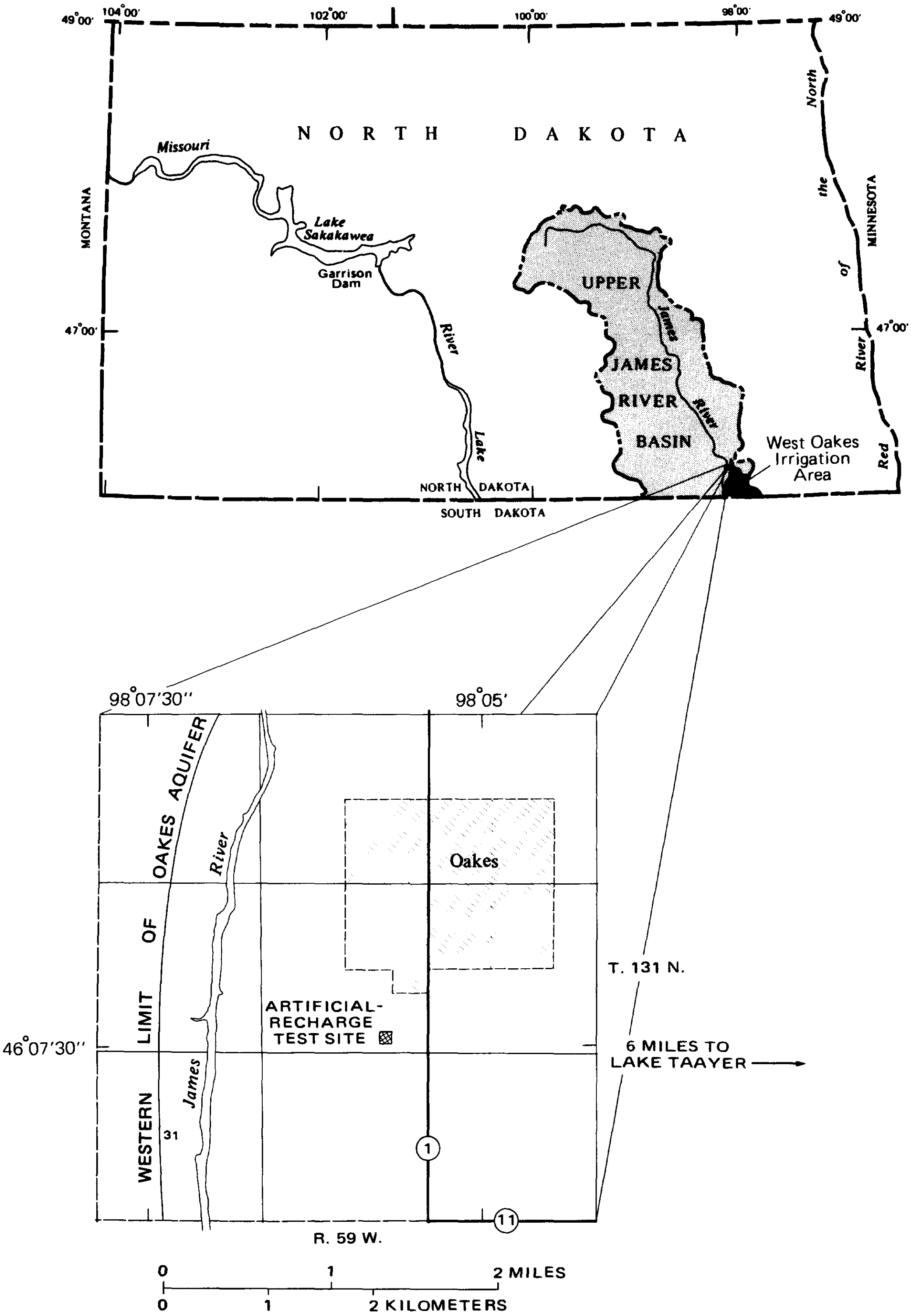

Figure 1.—Location of artificial-recharge test site.

sampling ports to the surface. The samplers were installed in the recharge basin (fig. 2) so that the sampling ports were located at 1-foot intervals starting at about 0.5 foot below the basin floor. The uppermost port was 5.5 feet below natural land surface. The design and operation of this type of sampler is discussed in detail by Pickens and others (1981).

North Dakota State Water Commission well OL-2A (fig. 2) also was sampled during both tests. The well is screened from 15.8 to 18 feet below land surface in very fine to coarse, slightly gravelly sand (Schuh and Shaver, 1988, p. 231-233).

Lithology, Mineralogy, and Petrography of the Oakes Aquifer

The Oakes aquifer beneath the recharge-test basin consists of sand and silt deposits of Holocene age and deltaic sand and gravel deposits of Pleistocene age. Lithologic logs indicate that the sediments below the topsoil layers range from very fine silty sand to very coarse gravelly sand. Clay layers for the most part are absent and the sediment sequence is well stratified (Schuh and Shaver, 1988, p. 17). The geology of the Oakes aquifer sediments is discussed in detail by Bluemle (1979).

The mineralogy of the Oakes aquifer beneath the recharge basin as determined by X-ray diffraction analysis is given in table 1. The major minerals identified include quartz, tridymite, calcite, dolomite, feldspar, and clay minerals. Clay minerals primarily are smectite plus minor amounts of chlorite and mica or illite.

Thin sections of the Oakes aquifer sediments were prepared from the coarser than 60 micrometer fraction of companion samples used for X-ray analysis. The size separation was made by dry sieving. Minerals identified in thin section include quartz, K-feldspar, plagioclase feldspar, dolomite, calcite, chert, and rare hornblende and muscovite. Quartz occurred as anhedral angular to rounded grains. The K-feldspar was largely unaltered, whereas much of the plagioclase feldspar was partly to largely replaced by calcite along cleavage planes. Na-feldspar was determined by optical methods to be in the albite through oligoclase compositional range. No evidence of zoning or alteration controlled by zoning was observed in any feldspar. Dolomite occurred exclusively as fine-grained sedimentary rock fragments. Calcite was present in three distinct occurrences: (1) Replacement of plagioclase feldspar, (2) fine-grained sedimentary rock fragments, and (3) calcite overgrowths.

Two distinct types of noncarbonate rock fragments commonly were observed in thin section. These included fine-grained chert-rich rock fragments that likely are of sedimentary origin and extremely fine-grained largely isotropic rock fragments that likely are of volcanic origin. The presence of tridymite, as detected by X-ray diffraction, strongly indicates a volcanic origin for some sediments in the Oakes aquifer. The abundant isotropic material and the banded texture observed in the volcanic rock fragments are characteristic of a welded tuff. Abundant isotropic material in these volcanic rock fragments is consistent with abundant volcanic glass commonly found in welded pyroclastic rocks. Rock fragments of all types are scattered throughout the examined sediments.

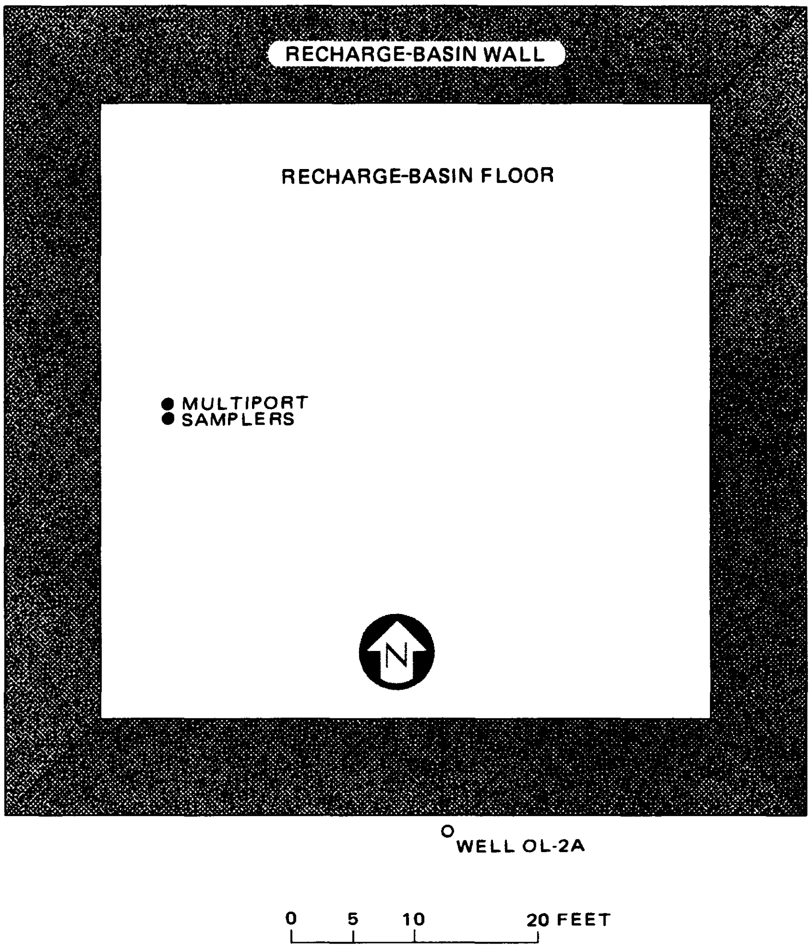

Figure 2.—Schematic diagram showing recharge basin and location of multiport samplers and well OL-2A.

Table 1.--Bulk mineralogy of composite sediment samples from the Oakes aquifer beneath the recharge basin as determined by X-ray diffraction

[Source, Mineralogy, Inc., Tulsa, Oklahoma; minerals are ranked by number, (1--largest weight percent of total sample, 2--next largest, etc.); subequal amounts are ranked using identical numbers; "ND" signifies none detected. The detection limit using X-ray diffraction is approximately 5 weight percent]

Depth below land surface (feet)	Quartz	Tridymite	Calcite	Dolomite	Feldspar	Clay + mica	Serpentine	Amphibole	Pyrite
4-5	1	5	3	2	4	5	ND	ND	ND
6-7	1	2	5	ND	4	3	ND	ND	ND
7-8	1	2	5	ND	4	3	ND	ND	ND
10-11	1	4	3	3	2	3	ND	3	4
14-15	1	4	4	2	3	3	ND	5	ND
17-18	1	3	4	4	2	4	ND	ND	ND
18-19	1	2	2	3	2	3	4	ND	ND
21-22	1	2	5	4	3	5	ND	ND	ND

RECHARGE-TEST PROCEDURES

Inflow from the James River to the recharge basin was controlled to maintain a water level of 2 feet above the basin floor during the spring 1987 test and the summer 1987 organic-mat test (Schuh and Shaver, 1988, p. 84). A peristaltic pump was used to collect water samples at regular intervals from the basin, multiport samplers, and well OL-2A. Samples could be taken from a port of the multiport samplers only if the aquifer at the port's level was saturated. The shallowest port opening onto saturated sediments during the entire summer 1987 organic-mat test was located 16.5 feet below natural land surface. The depth of this shallowest port marks the approximate location of the top of the saturated zone during both the spring 1987 test and the summer 1987 organic-mat test. The route traveled by recharge water to the 16.5-foot port is hereafter designated flow path 1. The route traveled by recharge water to well OL-2A is designated flow path 2.

Specific conductance, pH, temperature, and dissolved oxygen were measured at the test site. All other analyses were made by the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colo. Water samples were collected using the techniques described by Brown and others (1970).

Following the spring 1987 test, the floor of the recharge basin was lined with a 4-inch thick organic mat (composed primarily of sunflower-seed hulls) to filter a part of the suspended sediment introduced with recharge water and thereby slow the formation of a low-permeability layer on the basin floor.

The sunflower-seed hulls were treated with urea and mixed with topsoil in March 1987. The mixture was remixed and wetted repeatedly at 2- to 3-week intervals prior to emplacement as an organic mat in August 1987 (Schuh and Shaver, 1988, p. 153-154). This treatment established a high level of microbial activity within the mixture, as indicated by a sustained internal temperature of 150 °C (W. M. Schuh, North Dakota State Water Commission, oral commun., 1989). The summer 1987 organic-mat test was conducted with the organic mat in place.

GEOCHEMISTRY

Results from the Spring 1987 Test

Concentrations of selected chemical constituents in water from the recharge basin, the termination of flow path 1, and the termination of flow path 2 as a function of time during the spring 1987 test are plotted in figure 3. Changes between recharge-basin water and ground water from the termination of the flow paths include increases in alkalinity, calcium, sodium, and silica and decreases in pH and dissolved oxygen.

Chloride concentrations in water from the recharge basin were greater than or equal to chloride concentrations in ground water from the termination of both flow paths during approximately the first 90 hours of the spring 1987 test. However, the concentration of chloride in ground-water samples taken from the termination of both flow paths after approximately 200 hours exceeded that in the recharge-basin water. X-ray diffraction analysis of bulk and clay-size aquifer sediments show no evidence of chloride salts. During the fall 1986 recharge test, chloride concentrations in the recharge-basin water exceeded 50 mg/L (see supplemental data). Thus, any interstitial ground water remaining in the unsaturated zone beneath the basin could have had substantially larger chloride concentrations than the recharge-basin water of the spring 1987 test. Mixing of infiltrating water with interstitial ground water of larger chloride concentration during the spring 1987 test would account for the observed changes in chloride concentrations between approximately 200 and 600 hours. At some time after approximately 600 hours, chloride concentrations in water from the recharge basin exceeded those in ground water from the termination of flow path 1. Sufficient flushing of the unsaturated zone with infiltrating water could account for the observed changes in concentration of chloride after approximately 600 hours. Geochemical changes in infiltrating water through mixing with interstitial ground water in the unsaturated zone have been observed under similar circumstances by Wood and Signor (1975).

Geochemical changes between recharge-basin water and ground water from the termination of the flow paths may reflect the effects of mixing with pre-existing ground water in the Oakes aquifer as suggested above, chemical reaction of recharge water with the sediment it passes through, or both. Mixing of infiltrating water with interstitial water in the unsaturated zone, as illustrated by the observed changes in concentration of chloride,

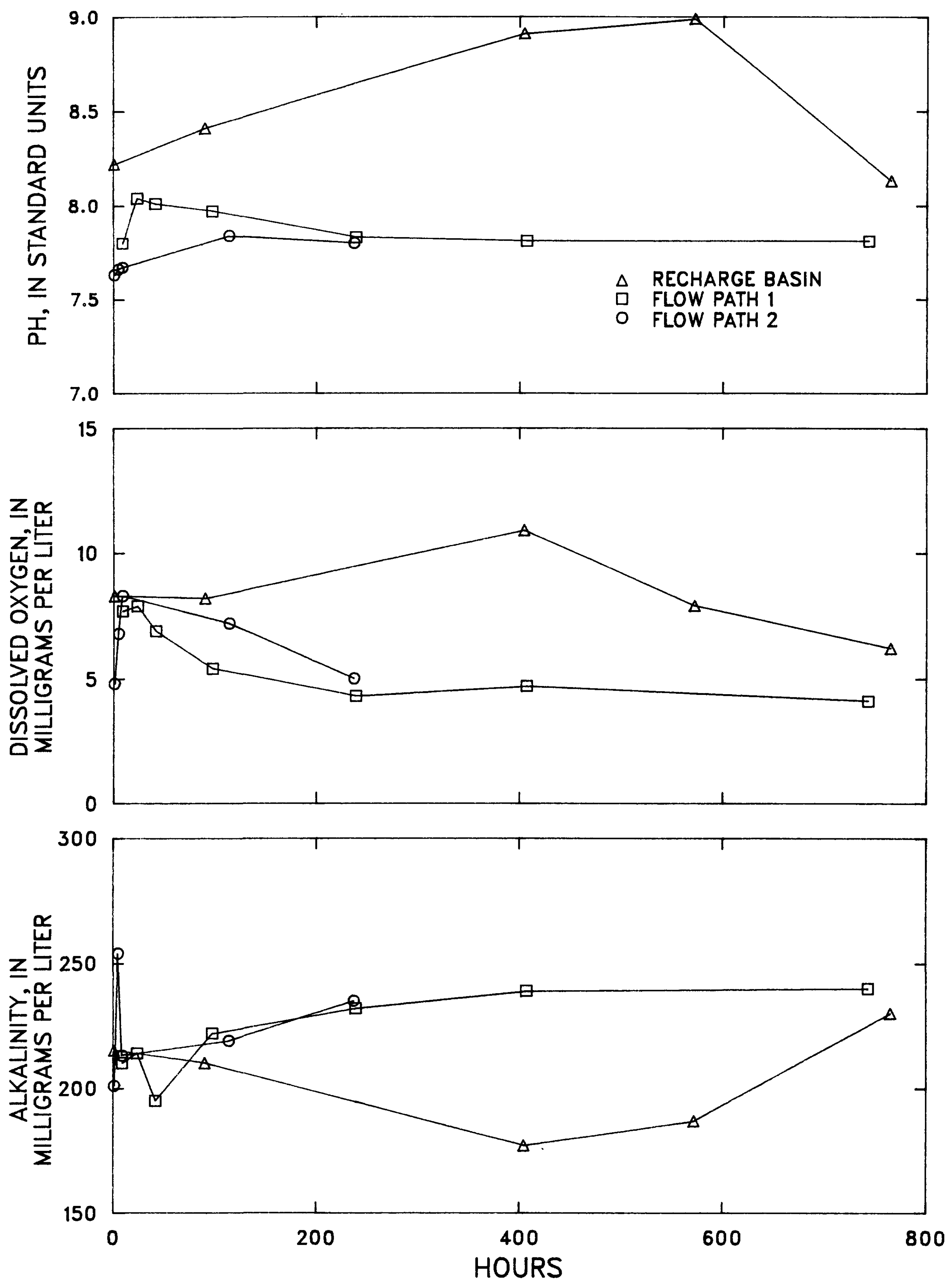

Figure 3.--Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the spring 1987 test.

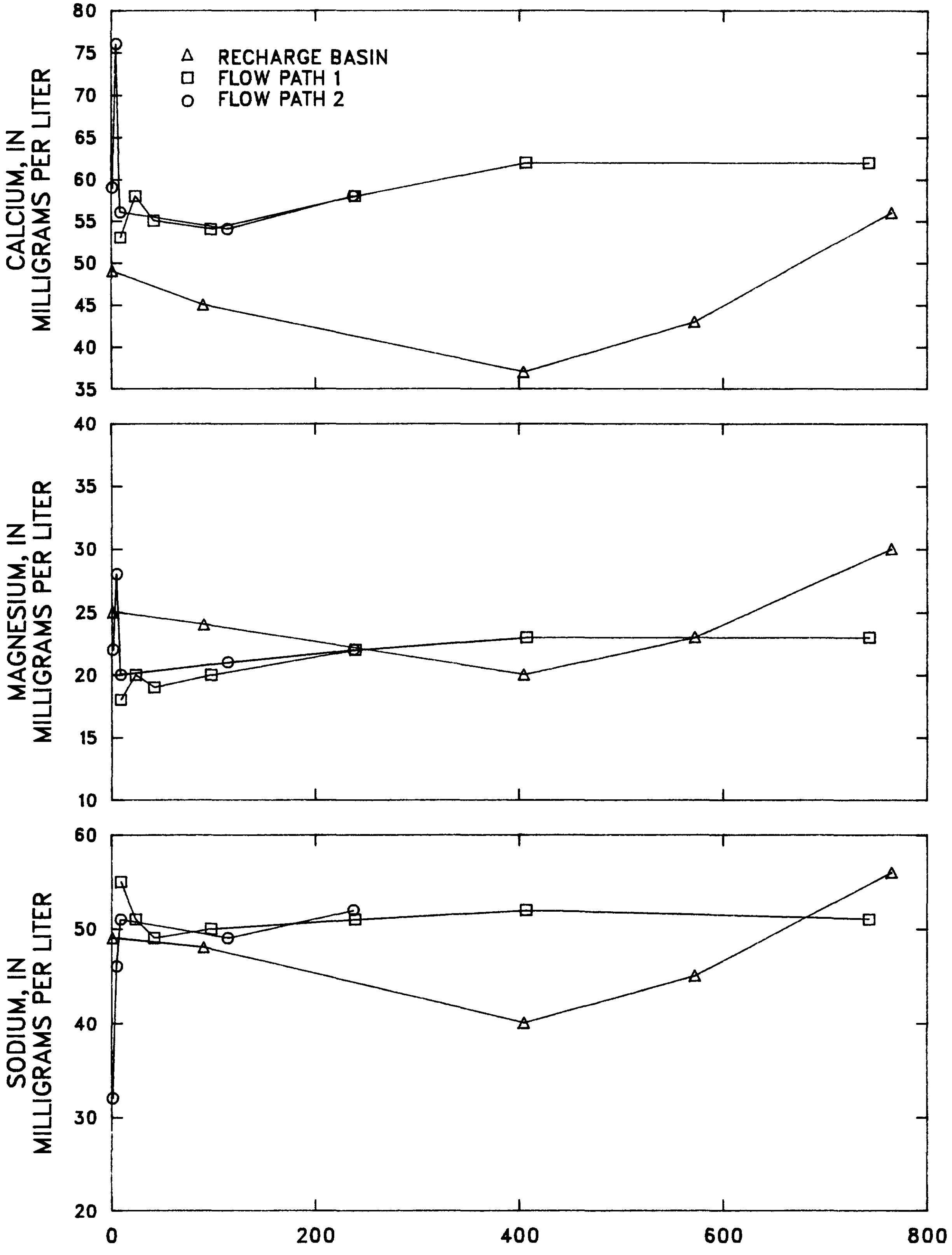

Figure 3.–Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the spring 1987 test--Continued.

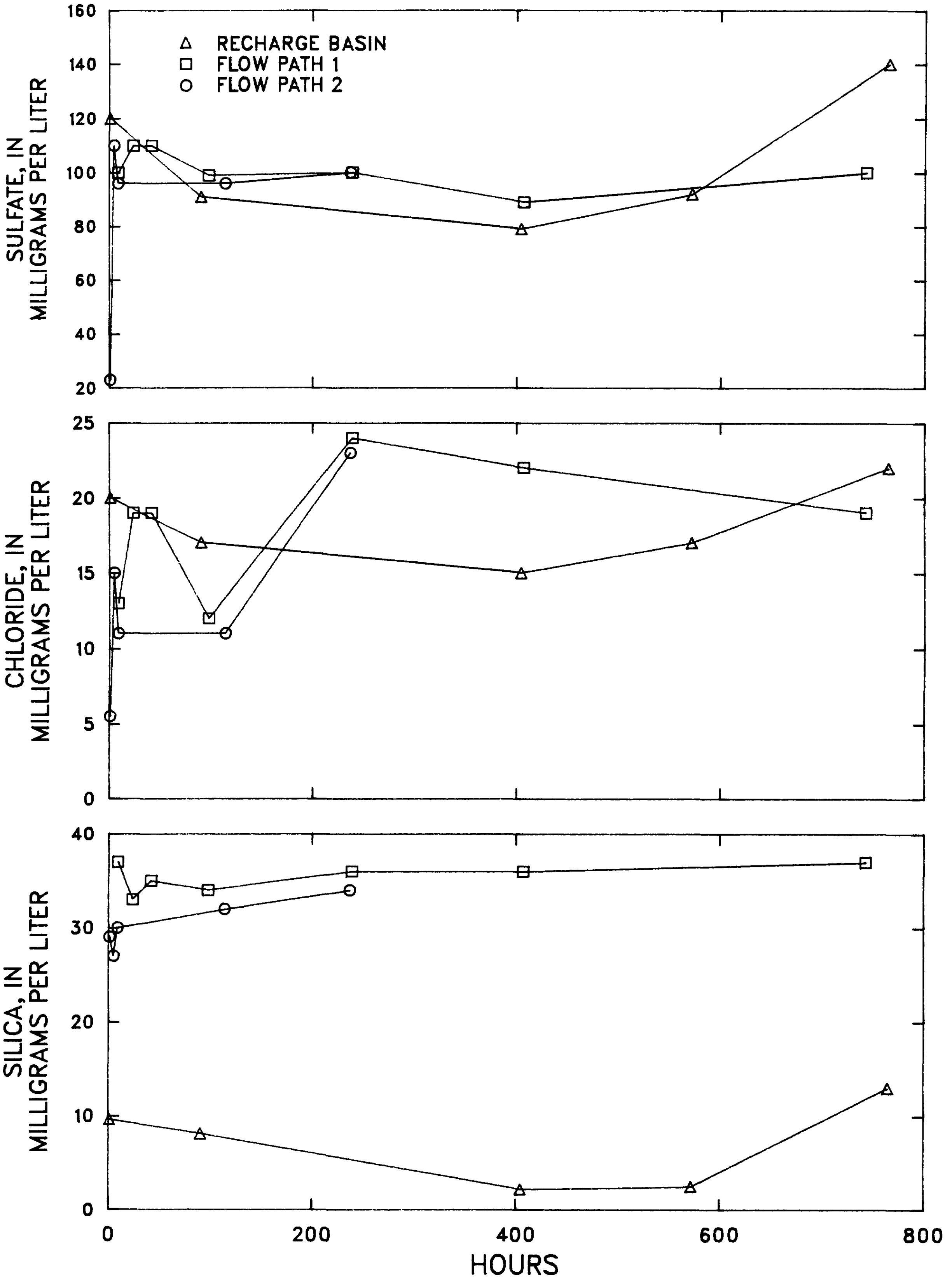

Figure 3.—Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the spring 1987 test--Continued.

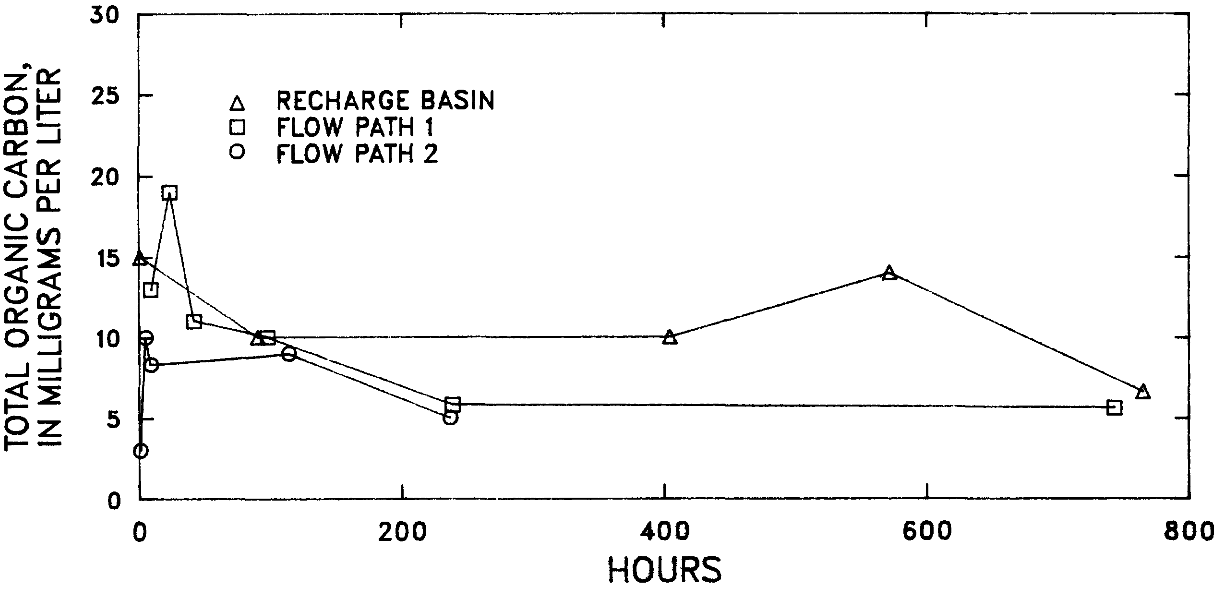

Figure 3.—Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the spring 1987 test--Continued.

may play a major role in observed changes in chemical constituents between water in the recharge basin and ground water from the termination of the flow paths. The data from the spring 1987 test were not used in a mass-balance geochemical model because of mixing of recharge water with pre-existing ground water.

Of the dissolved metals analyzed for during the spring 1987 test, maximum contaminant levels for potable water have been established by the Environmental Protection Agency (1986) for barium, cadmium, copper, iron, lead, and zinc. Concentrations of these metals did not exceed maximum contaminant levels for the period of ground-water sampling during the spring 1987 test.

Results from the Summer 1987 Organic-Mat Test

Concentrations of selected chemical constituents in water from the recharge basin, the termination of flow path 1, and the termination of flow path 2 as a function of time during the summer 1987 organic-mat test are shown in figure 4 and listed in table 2. Samples from the recharge basin and termination of the flow paths corresponding to a specified time in tables 2 and 3 were collected within ± 3 hours of the specified time. Changes between the recharge-basin water and ground water from the termination of both flow paths included increases in alkalinity, calcium, and silica and decreases in pH, dissolved oxygen, and total organic carbon. An increase in magnesium occurred at the termination of flow path 1 at approximately 405 hours.

A surge of nitrogen input to ground water accompanied the start of recharge-basin operation (fig. 4). The nitrogen surge lasted less than 16 hours and is thought to be the result of leaching of urea from the organic mat. Nitrogen concentrations did not exceed maximum contaminant levels established by the Environmental Protection Agency (1986) in any ground-water samples taken during the summer 1987 organic-mat test.

Interpretation of Results from the Summer 1987 Organic-Mat Test

Infiltration rates were larger with the organic mat in place. These larger infiltration rates allowed infiltrating water to completely flush the unsaturated zone during the first approximately 90 hours of basin operation. In addition, the larger infiltration rates allowed recharge water to reach the termination of the flow paths prior to apparent mixing with pre-existing ground water. The slow rates of chemical change in ground water as it flowed through the aquifer sediments starting at about 90 hours approximated steady-state conditions.

No change in chloride concentration and no more than ± 2 milligram-per-liter change in sulfate concentration occurred between the recharge basin and the termination of flow path 1 from 90 through 405 hours of recharge-basin operation (table 2 and fig. 4). The same observations hold for flow path 2 from 90 through 211 hours. The -2 milligram-per-liter change in chloride concentration and the -10 milligram-per-liter change in sulfate concentration between the recharge basin and the termination of flow path 2 observed at 405 hours is interpreted to be the result of mixing between

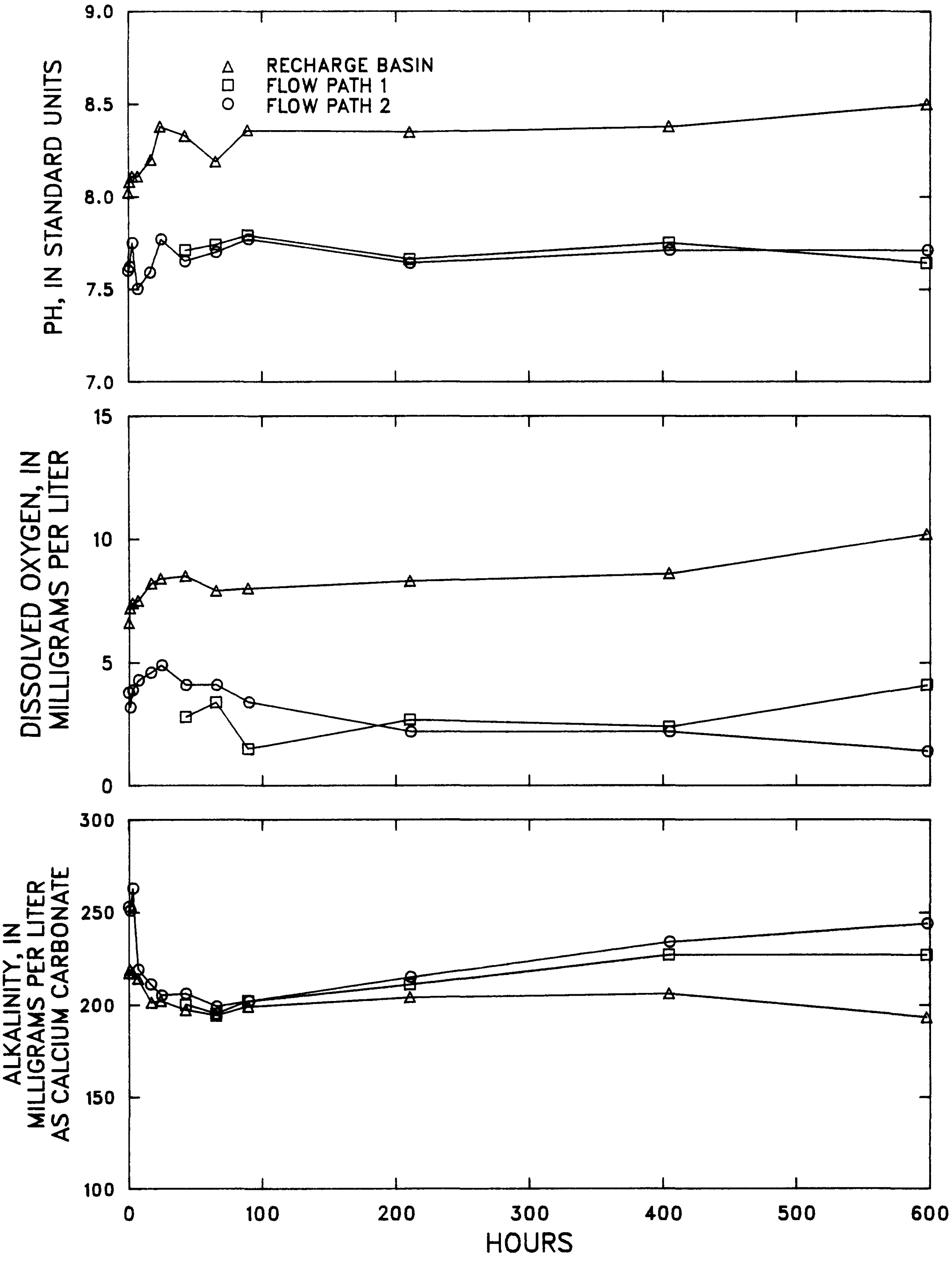

Figure 4.—Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the summer 1987 organic-mat test.

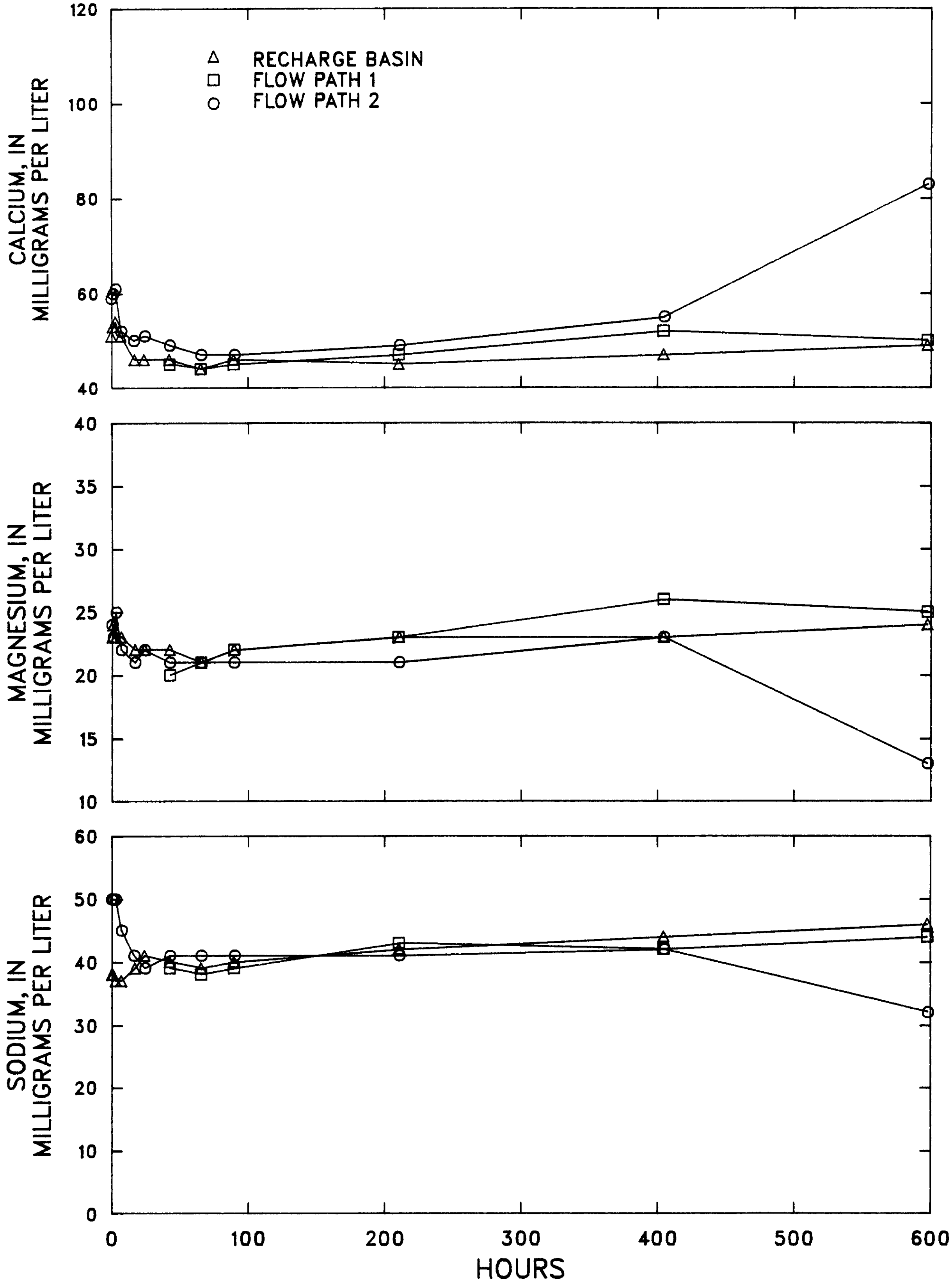

Figure 4.—Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the summer 1987 organic-mat test--Continued.

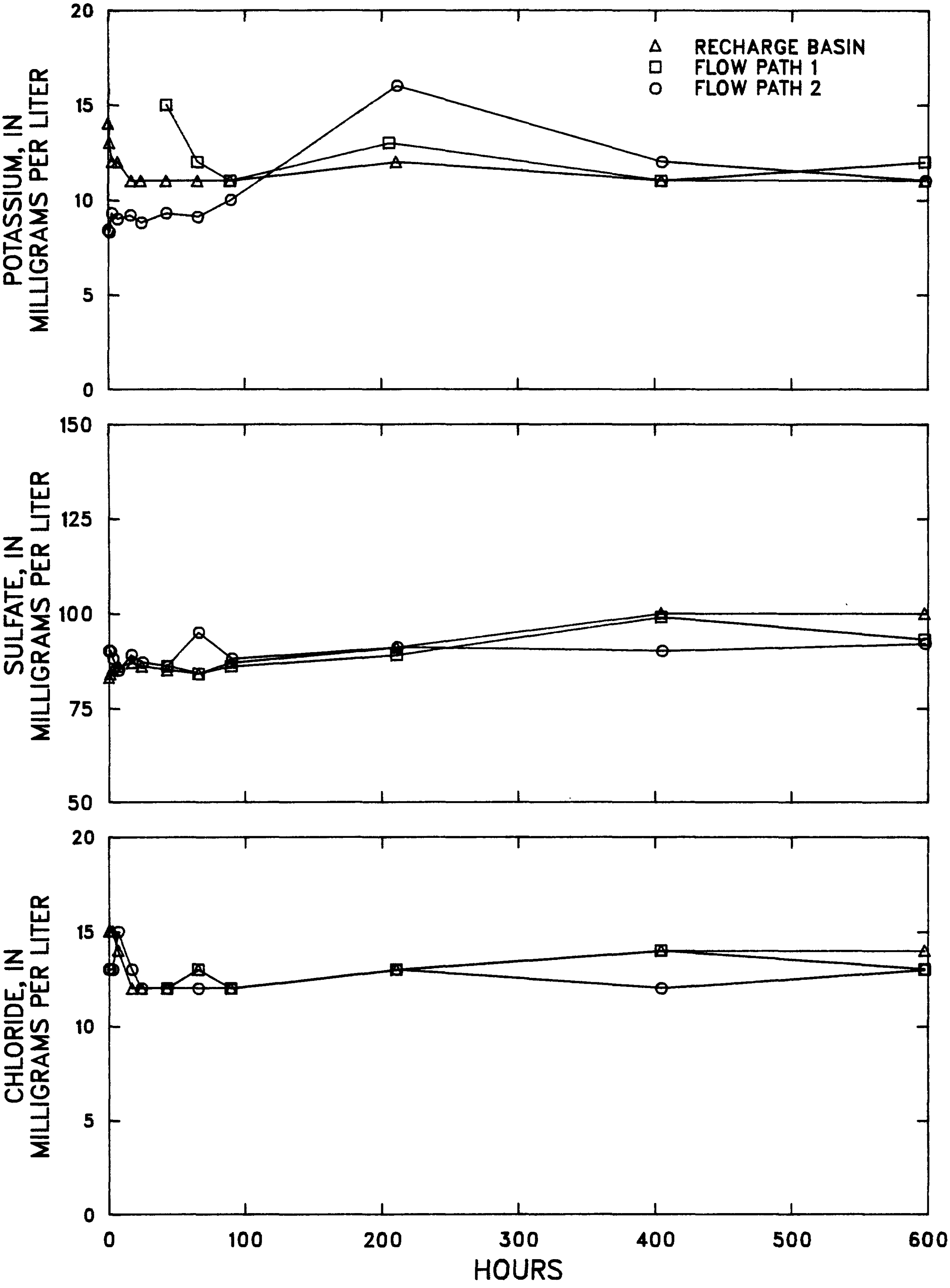

Figure 4.—Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the summer 1987 organic-mat test--Continued.

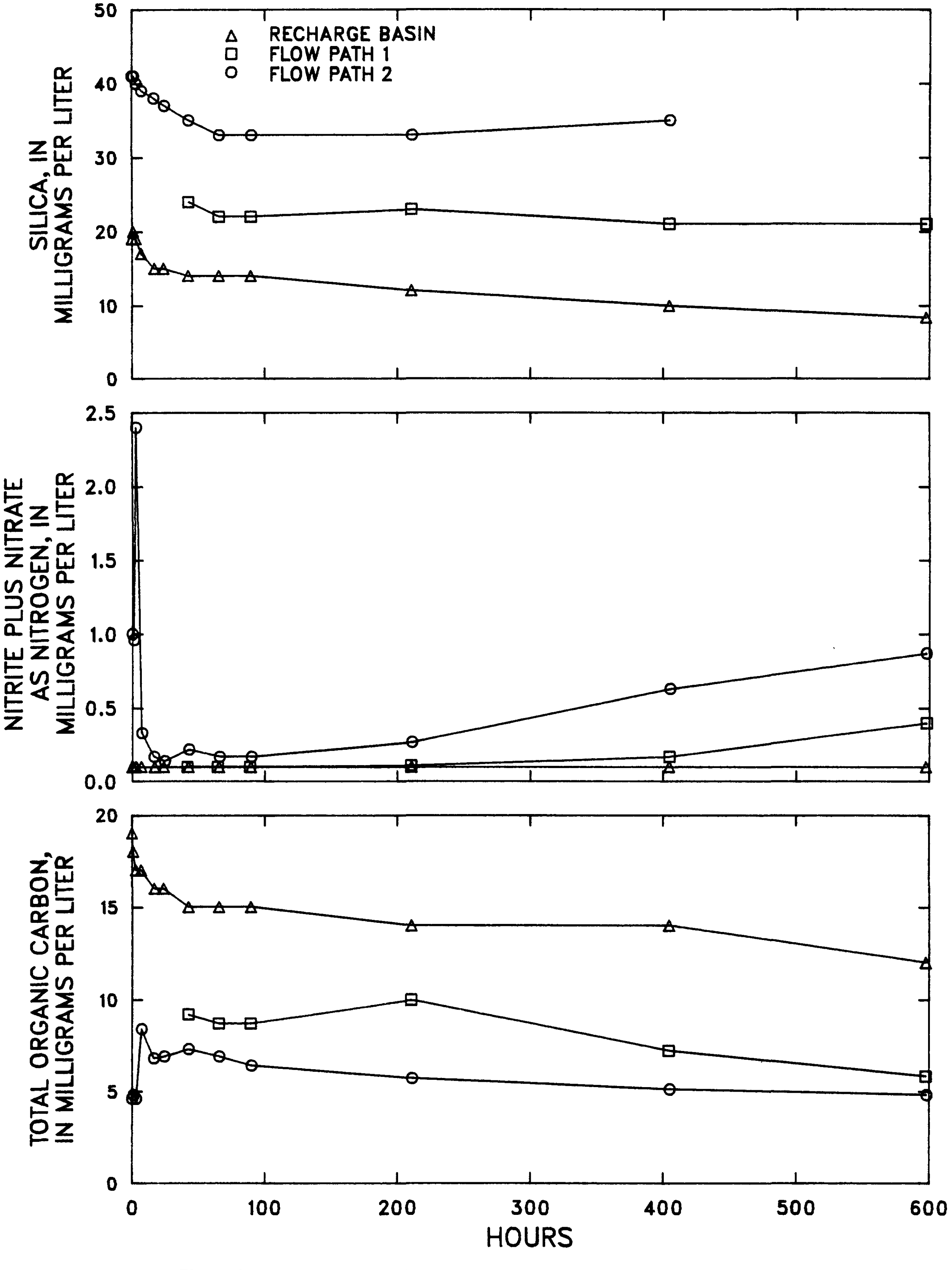

Figure 4.–Concentrations of selected chemical constituents in recharge-basin water and ground water from the termination of flow paths 1 and 2 during the summer 1987 organic-mat test--Continued.

Table 2.--Concentrations of selected constituents for the summer 1987 organic-mat test at approximate times

[All data are in milligrams per liter except pH which is in standard units, -- indicates value reported was in error and was not used]

Constituent	Recharge basin	Termination of flow path 1	Termination of flow path 2
	90 hours		
pH	8.36	7.79	7.77
Dissolved oxygen (DO)	8.0	1.5	3.4
Alkalinity as calcium carbonate ($CaCO_3$)	199	202	202
Calcium (Ca)	46	45	47
Magnesium (Mg)	22	22	21
Sodium (Na)	40	39	41
Potassium (K)	11	11	10
Sulfate (SO_4)	87	86	88
Chloride (Cl)	12	12	12
Silica (SiO_2)	14	22	33
Total organic carbon (TOC)	15	8.7	6.4
	211 hours		
pH	8.35	7.66	7.64
Dissolved oxygen (DO)	8.3	2.7	2.2
Alkalinity as calcium carbonate ($CaCO_3$)	204	211	215
Calcium (Ca)	45	47	49
Magnesium (Mg)	23	23	21
Sodium (Na)	42	43	41
Potassium (K)	12	13	16
Sulfate (SO_4)	91	89	91
Chloride (Cl)	13	13	13
Silica (SiO_2)	12	23	33
Total organic carbon (TOC)	14	10	5.7

Table 2.--Concentrations of selected constituents for the summer 1987 organic-mat test at approximate times--Continued

Constituent	Recharge basin	Termination of flow path 1	Termination of flow path 2
	405 hours		
pH	8.38	7.75	7.71
Dissolved oxygen (DO)	8.6	2.4	2.2
Alkalinity as calcium carbonate ($CaCO_3$)	206	227	234
Calcium (Ca)	47	52	55
Magnesium (Mg)	23	26	23
Sodium (Na)	44	42	42
Potassium (K)	11	11	12
Sulfate (SO_4)	100	99	90
Chloride (Cl)	14	14	12
Silica (SiO_2)	9.9	21	35
Total organic carbon (TOC)	14	7.2	5.1
	600 hours		
pH	8.50	7.64	7.71
Dissolved oxygen (DO)	10.2	4.1	1.4
Alkalinity as calcium carbonate ($CaCO_3$)	193	227	244
Calcium (Ca)	49	50	83
Magnesium (Mg)	24	25	13
Sodium (Na)	46	44	32
Potassium (K)	11	12	11
Sulfate (SO_4)	100	93	92
Chloride (Cl)	14	13	13
Silica (SiO_2)	8.3	21	--
Total organic carbon (TOC)	12	5.8	4.8

Table 3.--Summary of significant changes in the chemical composition between basin water and ground water from the termination of flow paths 1 and 2 at selected approximate times during the summer 1987 organic-mat test

Chemical constituent	Change (millimole per liter)	Hours
	Flow path 1	
Dissolved oxygen (DO as O_2)	-0.21	90
Alkalinity (as HCO_3)	+.06	90
Silica (SiO_2)	+.13	90
Total organic carbon (TOC as C)	-.53	90
Dissolved oxygen (DO as O_2)	-.18	211
Alkalinity (as HCO_3)	+.13	211
Calcium (Ca)	+.05	211
Sulfate (SO_4)	-.02	211
Silica (SiO_2)	+.18	211
Total organic carbon (TOC as C)	-.33	211
Dissolved oxygen (DO as O_2)	-.20	405
Alkalinity (as HCO_3)	+.43	405
Calcium (Ca)	+.12	405
Magnesium (Mg)	+.12	405
Sodium (Na)	-.09	405
Silica (SiO_2)	+.18	405
Total organic carbon (TOC as C)	-.57	405
	Flow path 2	
Dissolved oxygen (DO as O_2)	-0.15	90
Alkalinity (as HCO_3)	+.06	90
Silica (SiO_2)	+.32	90
Total organic carbon (TOC as C)	-.72	90
Dissolved oxygen (DO ad O_2)	-.19	211
Alkalinity (as HCO_3)	+.21	211
Calcium (Ca)	+.10	211
Magnesium (Mg)	-.08	211
Potassium (K)	+.10	211
Silica (SiO_2)	+.35	211
Total organic carbon (TOC as C)	-.69	211

recharge water and pre-existing ground water within the Oakes aquifer. Similar decreases in chloride and sulfate concentrations for flow path 1 were observed at 600 hours and also are attributed to mixing.

The overall decrease in infiltration rate through the recharge basin with time (fig. 5) correlated with the cumulative suspended sediment delivered to the recharge basin along with influent water (Schuh and Shaver, 1988, p. 202-203). As the infiltration rate declined with time, evidence of mixing, based on changes in chloride and sulfate concentrations between the recharge basin and the termination of the flow paths, was observed for flow path 2 at approximately 405 hours and for flow path 1 at approximately 600 hours.

Description of Mass-Balance Model

Where there was no evidence for mixing of infiltrating water with pre-existing ground water, a mass-balance geochemical model was used to describe selected changes in chemical composition between the recharge-basin water and ground water from the termination of each of the flow paths at selected times. The choice of solid phases used in writing chemical reactions was based on the mineralogy of the Oakes aquifer beneath the test basin (table 1), petrographic data, and stoichiometric relationships in observed chemical changes between recharge-basin water and ground water from the termination of each of the flow paths.

The magnitudes of changes other than those due to mixing along the flow paths were on the order of tenths of a millimole per liter. Because data were reported in milligrams per liter to two significant figures (with the exception of pH and alkalinity which were reported to three significant figures), any rounding of data was potentially of a significant magnitude relative to measured changes. To compensate for the effect of rounding and analytical scatter, only changes of a least ± 2 milligrams per liter along a flow path were considered significant. The detection limit and the relative standard deviation for selected chemical constituents are listed in table 4. In the range of concentration shown in table 2, analytical uncertainty exceeds the ± 2 milligram-per-liter significance level for calcium, sulfate, and alkalinity. The analytical uncertainty level for calcium is approximately ± 6 milligrams per liter; the uncertainty level for sulfate is approximately ± 3 milligrams per liter; and the uncertainty level for alkalinity is approximately ± 30 milligrams per liter. Recent data indicate that the relative standard deviation of 12 percent for alkalinity may be as much as four times the actual standard deviation (D. E. Erdmann, U.S. Geological Survey, oral commun., 1989). Given the amount of analytical uncertainty for calcium, sulfate, and alkalinity, a part of the significant changes shown in table 3 for these constituents may be attributable to analytical uncertainty.

The geochemical model used to describe significant changes in chemical composition of water between the recharge basin and the termination of the flow paths is outlined as follows:

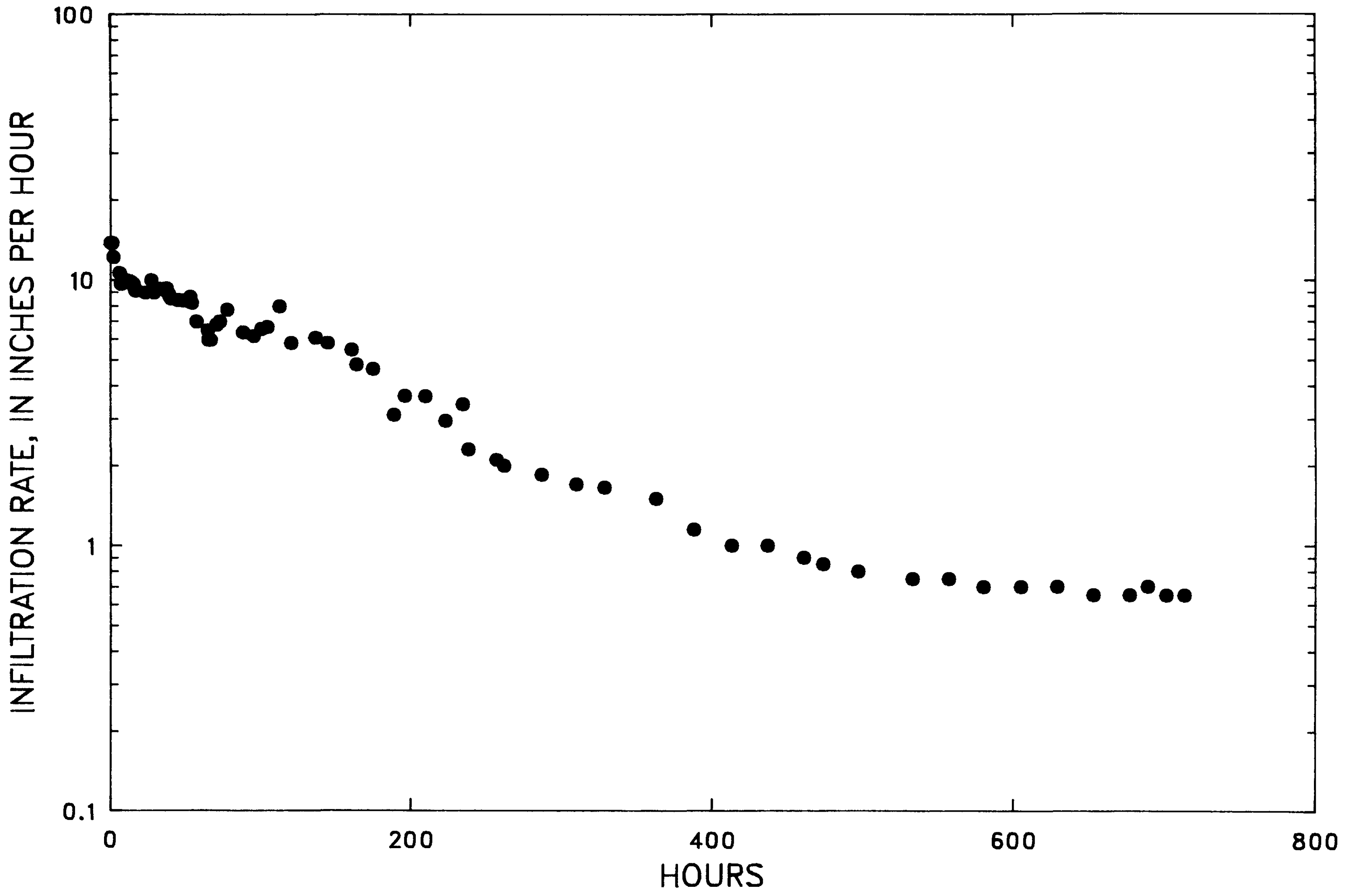

Figure 5.—Infiltration rate through the floor of the recharge basin during the summer 1987 organic-mat test. (Modified from Schuh and Shaver, 1988, p. 166.)

Table 4.--Analytical method, detection limit, and relative standard deviation of analytical determination of selected constituents

[NA indicates data not available]

Constituent	Analytical method	Detection limit (milligrams per liter)	Relative standard deviation (percent)	Reference
Dissolved oxygen (DO)	Dissolved oxygen electrode.	0.05	1.0	Brown and others, 1970, p. 129.
Alkalinity as calcium carbonate ($CaCO_3$)	Electrometric titration.	1.0	12	Fishman and Friedman, 1985, p. 96-97.
Calcium (Ca)	Atomic absorption.	1.0	8	Fishman and Friedman, 1985, p. 198-202.
Magnesium (Mg)	Atomic absorption.	2.5	7	Fishman and Friedman, 1985, p. 355-359.
Sodium (Na)	Atomic absorption.	0.1	5	Fishman and Friedman, 1985, p. 564-566.
Potassium (K)	Atomic absorption.	0.1	8	Fishman and Friedman, 1985, p. 526-529.
Sulfate (SO_4)	Turbidimetric barium sulfate.	0.2	3.2	Fishman and Friedman, 1985, p. 613-616.
Chloride (Cl)	Ferric thiocyanate titration.	0.1	0.5	Fishman and Friedman, 1985, p. 217-220.
Silica (SiO_2)	Colorimetric molybdate blue.	1.0	7	Fishman and Friedman, 1985, p. 555-559.
Total organic carbon (TOC)	Wet oxidation.	0.1	NA	Wershaw and others, 1987, p. 15.

Step (1) Dissolved oxygen and total organic carbon were depleted, CO_2 was added, and the pH was lowered in water passing through the organic mat and immediately underlying sediments by microbial respiration following the reaction

$$(CH_2O)_{106}(NH_3)_{16}(H_3PO_4) + 138O_2 = \tag{1a}$$

$$106CO_2 + 16NO_3^- + 122H_2O + HPO_4^{-2} + 18H^+.$$

Reaction 1a is a generalized oxygen respiration reaction that has been used to describe the respiration of micro-organisms in shallow ground-water systems (Jacobs and others, 1988). A part of the CO_2 produced could further lower pH by the reaction

$$CO_2 + H_2O = H^+ + HCO_3^-. \tag{1b}$$

Step (2) Silica was added to the water along the flow paths by dissolution of amorphous SiO_2 following the reaction

$$SiO_2 + 2H_2O = Si(OH)_4. \tag{2}$$

Addition of 0.32 millimole per liter of silica to water between the recharge basin and the termination of flow path 2 at 90 hours (table 3) was unaccompanied by significant increases in the concentration of any cation. This requires a source of silica in the Oakes aquifer that does not contribute cations into solution. The X-ray-determined mineralogy of and petrographic observations on Oakes aquifer sediments indicate four possible sources of silica: (1) Dissolution of quartz, (2) dissolution of tridymite, (3) dissolution or alteration of feldspars, and (4) dissolution of amorphous SiO_2 associated with volcanic rock fragments. Because ground water at the termination of flow path 2 is undersaturated with respect to amorphous SiO_2 and oversaturated with respect to quartz (table 5) and amorphous SiO_2 has a greater solubility than either quartz or tridymite, it is the more likely source.

The molar ratios of calcium, sodium, and potassium to silicon released into solution as a result of common end-member feldspar alteration reactions as well as congruent end-member feldspar dissolution are listed in table 6. Calculations made assuming the release of 0.32 millimole per liter of silica to solution indicate that only reaction of anorthite to form gibbsite plus calcite would fail to release a significant concentration of cations to solution. The conclusion drawn from the reactions listed in table 6 is valid for plagioclase feldspar in the albite through oligoclase and anorthite through mid-labradorite compositional ranges. Evidence of alteration of plagioclase feldspar to calcite was observed in thin section. A trace of Ca-feldspar was detected by X-ray diffraction analysis in a composite sediment sample from 7 to 8 feet below land surface at the recharge-test site. Thus, Ca-feldspar cannot be ruled out as a potential source of silica to recharge water.

Ground water from the termination of flow path 2 is more enriched in silica than ground water from the termination of flow path 1 (fig. 4). Because the two flow paths are of roughly equal length, the preferential

Table 5.--Saturation indices calculated using WATEQF for ground water from the termination of flow paths 1 and 2 at approximate times during the summer 1987 organic-mat test

[Saturation indices less than zero (-) indicate undersaturation; indices greater than zero indicate oversaturation]

Phase	Saturation index	
	Flow path 1	Flow path 2
	90 hours	
Quartz	0.621	0.805
Silica glass	-.382	-.200
Calcite	.285	.276
Dolomite	.573	.509
	211 hours	
Quartz	0.594	0.798
Silica glass	-.396	-.205
Calcite	.231	.196
Dolomite	.502	.337
	405 hours	
Quartz	0.539	0.808
Silica glass	-.447	-.191
Calcite	.398	.359
Dolomite	.858	.665
	600 hours	
Quartz	0.563	--
Silica glass	-.430	--
Calcite	.257	.565
Dolomite	.558	.664

Table 6.--Molar ratios of calcium, sodium, and potassium to silicon produced by selected common reactions of feldspar minerals assuming conservation of aluminum

Reaction	Ca:Si produced	Ca (milligrams per liter) released into solution along with 0.32 millimole per liter aqueous $Si(OH)_4$
Anorthite → Ca-smectite[1]	[2]1:-1.33	--
Anorthite → kaolinite	1:0	--
Anorthite → gibbsite + calcite	0:2	0
Anorthite → congruent dissolution	1:2	6.4

	Na:Si produced	Na (milligrams per liter) released into solution along with 0.32 millimole per liter aqueous $Si(OH)_4$
Albite → Na-smectite[3]	1:1.61	4.6
Albite → kaolinite	1:2	3.7
Albite → gibbsite + calcite	1:3	2.5
Albite → congruent dissolution	1:3	2.5

	K:Si produced	K (milligrams per liter) released into solution along with 0.32 millimole per liter aqueous $Si(OH)_4$
K-feldspar → muscovite[4]	1:3	4.2
K-feldspar → kaolinite	1:2	6.3
K-feldspar → congruent dissolution	1:3	4.2

[1] Chemical composition of Ca-smectite taken as $Ca_{0.17}Al_{2.33}Si_{3.67}O_{10}(OH)_2$.

[2] Reaction requires consumption of 1.33 moles of Si per release of 1 mole of Ca.

[3] Chemical composition of Na-smectite taken as $Na_{0.33}Al_{2.33}Si_{3.67}O_{10}(OH)_2$.

[4] Reaction approximates alteration of K-feldspar to illite.

enrichment in silica of ground water from the termination of flow path 2 indicates a source of silica that is inhomogeneously distributed through the aquifer sediments. The observed distribution of volcanic rock fragments throughout the sediment samples is consistent with such a source. Thus, amorphous SiO_2 associated with volcanic rock fragments is considered the most likely source of silica to recharge water.

Step (3) Sodium and potassium gained or lost was exchanged for calcium and magnesium by the cation-exchange reactions

$$\text{Ca,Mg-clay} + 2(\text{Na,K})^{+} = 2(\text{Na,K-clay}) + (\text{Ca,Mg})^{+2} \text{ or} \qquad (3a)$$

$$2(\text{Na,K-clay}) + (\text{Ca,Mg})^{+2} = \text{Ca,Mg-clay} + 2(\text{Na,K})^{+}. \qquad (3b)$$

At the termination of flow path 2 after approximately 600 hours, increases in calcium concentration in ground-water samples coincide with decreases in magnesium and sodium (fig. 4). Although no quantitative calculations can be made because of mixing effects, this pattern suggests that calcium may be added to ground water by exchange for magnesium or sodium. Because dolomite is theoretically the most stable carbonate mineral in the proposed mass-balance model, cation-exchange reactions have been used so as to minimize the amount of dolomite dissolution required to account for observed changes in water chemistry between the recharge basin and the termination of the flow paths.

Step (4) Ca(+Mg) was added to water along the flow paths by dissolution of calcite (+ dolomite) following the reactions

$$CaCO_3 + CO_2 + H_2O = Ca^{+2} + 2HCO_3^{-} \text{ and} \qquad (4a)$$

$$CaMg(CO_3)_2 + 2CO_2 + 2H_2O = Ca^{+2} + Mg^{+2} + 4HCO_3^{-}. \qquad (4b)$$

Okubo and Matsumoto (1979) documented the production and aqueous transport of monofunctional volatile fatty acids under aerobic conditions during simulated artificial recharge through an organic substrate. Their findings indicate another possible mechanism of carbonate dissolution described by the reactions

$$CaCO_3 + CH_3COOH = Ca^{+2} + CH_3COO^{-} + HCO_3^{-} \text{ and} \qquad (4c)$$

$$CaMg(CO_3)_2 + 2CH_3COOH = Ca^{+2} + Mg^{+2} + 2CH_3COO^{-} + 2HCO_3^{-}. \qquad (4d)$$

Reactions 4c and 4d are written in terms of acetic acid because this was the dominant species of volatile fatty acid produced in the experiment of Okubo and Matsumoto (1979).

Application of Mass-Balance Model

The model does not account for the excess alkalinity presented in table 3 or in calculations shown in tables 7-9. The cation-anion charge balance for each of the data sets modeled in tables 7-9 is shown in figure 6. In all the data sets, the total significant increase in alkalinity exceeds the total significant increase in cations. The apparent charge imbalance may be caused by analytical uncertainty or the screening out of some processes that

Table 7.--Reconstruction of chemical reactions between the recharge basin and the termination of flow path 1 at 211 hours for the summer 1987 organic-mat test

[All reaction coefficients are in millimole per liter (mmol/L)]

	Total organic carbon (as C)	Dissolved oxygen (as O_2)	Silica	Calcium	Alkalinity
Total significant change	-0.33	-0.18	0.18	0.05	0.13
(1) Consume 0.18 mmol/L dissolved oxygen (reaction 1a)	-.19	0	.18	.05	.13
(2) Dissolve 0.18 mmol/L silica (reaction 2)	-.19	0	0	.05	.13
(3) Dissolve 0.05 mmol/L calcite (reactions 4a, 4c)	-.19	0	0	0	.03

are contributing cations into solution by the ± 2 milligram-per-liter significance level.

Interpretation of Mass-Balance Model and WATEQF Results

The amount of dissolved oxygen consumed from ground water by microbial respiration between the recharge basin and the termination of the flow paths (tables 7-9) does not fully account for the observed decrease in total organic carbon. The discrepancy requires an additional sink for organic carbon. Three possibilities for the organic carbon sink are: (1) Consumption of organic carbon by microbial respiration using oxygen present in the unsaturated zone; (2) an open system allowing oxygen to migrate either from the atmosphere or surrounding sediments for use in microbial respiration; and (3) sorption of organic carbon onto sediments or organic matter.

The total volume of water that passed through the recharge basin during the summer 1987 organic-mat test is estimated to be approximately 19.3 million gallons, based on data presented by Schuh and Shaver (1988, p. 198). The average amount of total organic carbon lost between the recharge-basin

Table 8.--Reconstruction of chemical reactions between the recharge basin and the termination of flow path 1 at 405 hours for the summer 1987 organic-mat test

[All reaction coefficients are in millimole per liter (mmol/L)]

	Total organic carbon (as C)	Dissolved oxygen (as O_2)	Silica	Calcium	Magnesium	Sodium	Alkalinity
Total significant change	-0.57	-0.20	0.18	0.12	0.12	-0.09	0.43
(1) Consume 0.20 mmol/L dissolved oxygen (reaction 1a)	-.42	0	.18	.12	.12	-.09	.43
(2) Dissolve 0.18 mmol/L silica (reaction 2)	-.42	0	0	.12	.12	-.09	.43
(3) Exchange 0.05 mmol/L magnesium for 0.10 mmol/L sodium (reaction 3a)	-.42	0	0	.12	.07	.01	.43
(4) Dissolve 0.07 mmol/L dolomite (reactions 4b, 4d)	-.42	0	0	.05	0	.01	.15
(5) Dissolve 0.05 mmol/L calcite (reactions 4a, 4c)	-.42	0	0	0	0	.01	.05

water and ground water from the termination of the flow paths in excess of the amount that is accounted for by the mass-balance model is assumed to be about 0.45 millimole per liter. If this excess organic carbon was consumed by microbial respiration following reaction 1a, the total amount of oxygen required over the duration of the summer 1987 organic-mat test was approximately 4.28 x 10^7 millimoles of O_2. Based on the depth below land surface of the shallowest water-producing port of the multiport sampler, the thickness of the unsaturated zone below the recharge-basin floor during the summer 1987 organic-mat test is estimated to be 12.5 feet. Assuming a porosity of 40 percent, an oxygen content of 21 percent by volume (atmospheric

Table 9.--Reconstruction of chemical reactions between the recharge basin and the termination of flow path 2 at 211 hours for the summer 1987 organic-mat test

[All reaction coefficients are in millimole per liter (mmol/L)]

	Total organic carbon (as C)	Dissolved oxygen (as O_2)	Silica	Calcium	Magnesium	Potassium	Alkalinity
Total significant change	-0.69	-0.19	0.35	0.10	-0.08	0.10	0.21
(1) Consume 0.19 mmol/L dissolved oxygen (reaction 1a)	-.54	0	.35	.10	-.08	.10	.21
(2) Dissolve 0.35 mmol/L silica (reaction 2)	-.54	0	0	.10	-.08	.10	.21
(3) Exchange 0.05 mmol/L magnesium for 0.10 mmol/L potassium (reaction 4b)	-.54	0	0	.10	-.03	0	.21
(4) Dissolve 0.10 mmol/L calcite (reactions 4a, 4c)	-.54	0	0	0	-.03	0	.01

composition) of gases present, 1 atmosphere pressure, and a subsurface temperature of 20 °C, a column of dewatered sediment with the dimensions of the recharge-basin floor (50 feet by 50 feet) and 12.5 feet thick would contain a maximum of approximately 3.09 x 10^6 millimoles of O_2. These rough calculations indicate that the amount of oxygen required to consume all of the excess organic carbon by microbial respiration exceeds that potentially available in a column of unsaturated sediments equal in volume to those immediately below the recharge basin by at least one order of magnitude. If the volume of sediment-ground water interaction was larger than assumed above, it is unlikely that the volume was larger by an order of magnitude. In addition, the assumption of an oxygen content of 21 percent by volume in subsurface gases and a porosity of 40 percent are maximum values. Thus, the calculations demonstrating oxygen deficiency are qualitatively valid.

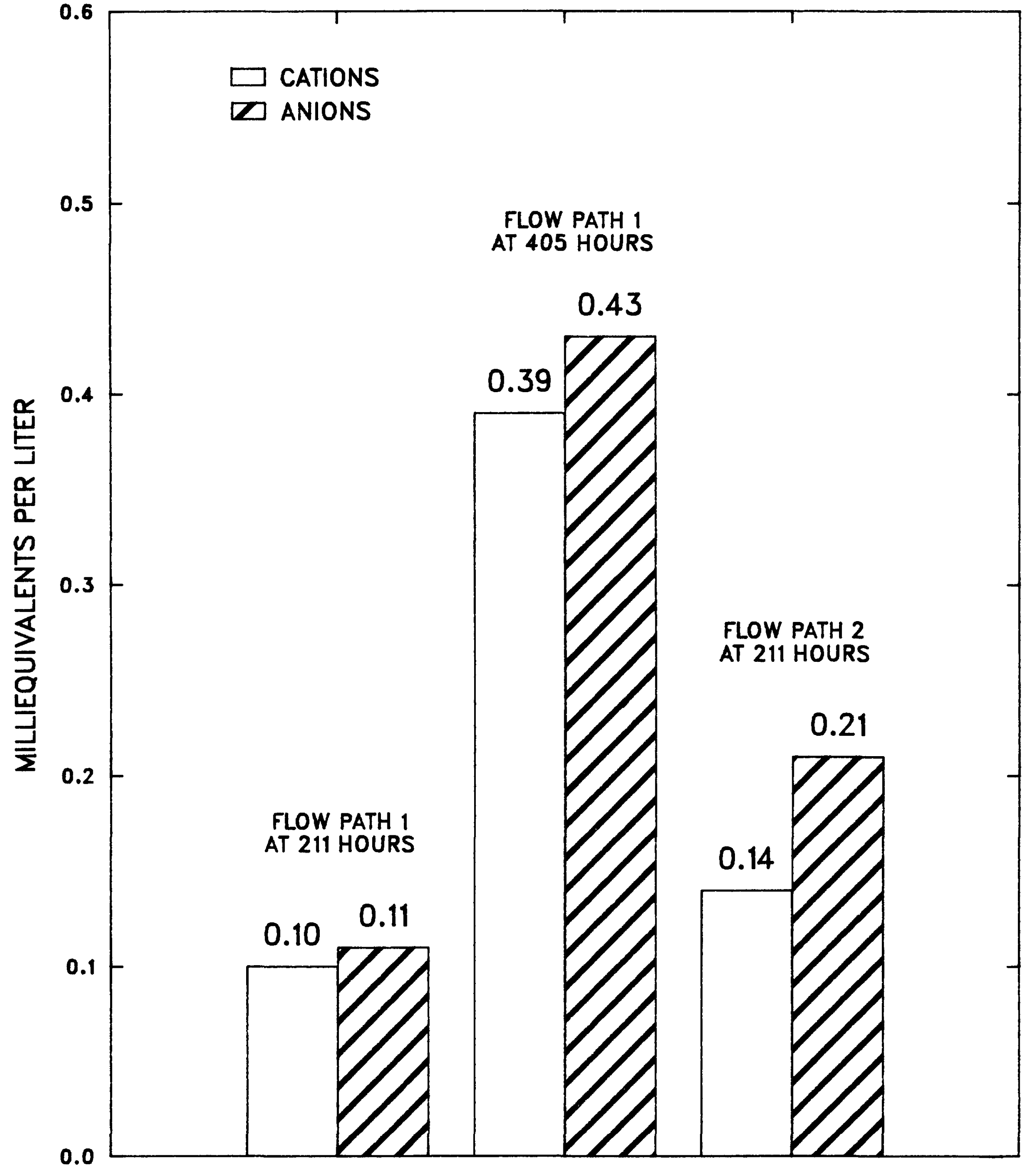

Figure 6.—Cation-anion balance of significant chemical changes between recharge-basin water and ground water from the termination of flow paths 1 and 2 at selected times during the summer 1987 organic-mat test.

The oxygen deficiency requires that the volume of sediment-water interaction be open to oxygen either from the atmosphere or surrounding sediments in order for microbial respiration to account for the complete amount of total organic carbon lost in excess of that accounted for using the mass-balance model. The amount of excess organic carbon lost by sorption onto sediments or organic matter is not known. In the absence of quantitative information on sorption effects it is not possible to conclusively determine if the volume of sediment-water interaction was open or closed to oxygen.

Dissolution of 0.18 to 0.35 millimole per liter of amorphous SiO_2 was required to account for silica added to water between the recharge basin and the termination of the flow paths (tables 7-9). The amount of silica added to water along a given flow path remained fairly constant with time throughout the summer 1987 organic-mat test (fig. 4). Dissolution of 0.05 to 0.10 millimole per liter of calcite and 0.07 millimole per liter of dolomite along with cation-exchange reactions involving magnesium, sodium, and potassium accounted for observed changes in calcium, magnesium, sodium, potassium, and alkalinity (tables 7-9).

Detected changes in the concentrations of nitrate and phosphate predicted by reaction 1a were less than the significance level used in the mass-balance model.

The mass-balance model calls for exchange of magnesium for potassium between recharge-basin water and the termination of flow path 2 at approximately 211 hours (table 9). An alternative explanation for the changes in ground-water composition shown in table 9 would involve exchange of magnesium for calcium and addition of potassium to water by K-feldspar dissolution or alteration. The observed addition of 0.10 millimole per liter of potassium to water by K-feldspar dissolution or alteration would require accompanying addition of at least 0.20 millimole per liter (12 milligrams per liter as SiO_2) of silica (table 6). No additional increase of this magnitude in the degree of silica added to water occurred at approximately 211 hours for flow path 2 (fig. 4). The lack of additional increases of silica does not support the onset of K-feldspar dissolution or alteration.

Apparent dissolution of calcite in the subsurface was observed only after approximately 200 hours (table 3). Tables 7-9 show that 0.05-0.10 millimole per liter of calcite was dissolved in modeled reactions. Three scenarios are proposed for the onset of calcite dissolution: (1) Mixing of recharge water (at or near calcite saturation) with pre-existing ground water (also at or near calcite saturation) to produce a ground water undersaturated with respect to calcite (Drever, 1982, p. 48-49), (2) addition of CO_2 and H^+ to the recharge water by microbial respiration such that undersaturation with respect to calcite was achieved, or (3) attack of calcite by organic acids produced within the microbially active organic mat. No evidence of mixing, based on changes in chloride and sulfate concentrations between the recharge basin and the termination of the flow paths, was observed until after the apparent onset of calcite dissolution. This observation does not support scenario 1.

Calculations using WATEQF (Plummer and others, 1976) indicated that ground water from the termination of both flow paths was oversaturated with respect to calcite and dolomite and undersaturated with respect to amorphous silica at selected times from 90 to 600 hours (table 5).

Calcite containing greater than roughly 6 mole-percent $MgCO_3$ is more soluble than pure calcite (Stumm and Morgan, 1981, p. 294). The magnesium content of calcites in the sediments beneath the recharge basin was estimated by the position of their (104) copper K-alpha X-ray diffraction peaks using the technique presented by St. Arnaud and Herbillon (1973). None of the calcites contained more than approximately 4 mole-percent $MgCO_3$. Thus, the magnesium content of calcites in the Oakes aquifer sediments cannot be used to explain any apparent oversaturation with respect to calcite.

Oversaturated solutions of $CaCO_3$ can be stabilized by the presence of naturally occurring water-soluble organic ligands (Inskeep and Bloom, 1986). The decomposing organic mat was a potentially rich source of such ligands as well as a source of H^+ and CO_2 to recharging water. If outgassing of CO_2 from the recharge water occurred at any time between subsurface carbonate dissolution and sample collection, the resulting oversaturated solutions could have been stabilized by organic ligands. Comparisons of pH measured on ground-water samples from the termination of both flow paths at selected times and pH required for equilibrium with calcite as calculated using WATEQF are given in table 10. Assuming that the increase in measured pH over calcite-equilibrium pH can be attributed to outgassing of CO_2, the percent of total CO_2 lost to outgassing can be calculated. A loss of approximately 3 percent of total CO_2 (table 10) from ground-water samples taken up to approximately 200 hours would account for the change in pH and, in turn, account for the apparent oversaturation with respect to calcite. Because ground-water samples were collected using a peristaltic pump, this amount of CO_2 loss is possible. The calculated difference in pH's for flow path 1 at 405 hours requires a greater percentage loss of CO_2. Interpretation of data presented in table 10 for flow path 1 at 600 hours and flow path 2 at 405 and 600 hours is complicated by apparent mixing effects.

Microbial metabolism of complex organic compounds is a source of volatile fatty acids, including acetic acid (Thurman, 1985, p. 116). Acetic acid has a proton donor capacity six times that of carbonic acid and calcium acetate has a solubility three orders of magnitude greater than that of calcium carbonate. Both the proton donor capacity and the solubility of the corresponding salt are important factors in determining the corrosiveness of an acid to a given mineral (Meshri, 1986). WATEQF does not consider the effects of organic acids in mineral stability calculations. Thus, if organic acids increased the solubility of carbonate minerals in Oakes aquifer sediments, calculations using WATEQF would indicate oversaturation.

Alkalinity was determined on water samples by titration to an end-point of pH 4.5. Titration to this end-point gives an acceptably accurate determination of carbonate alkalinity (Brown and others, 1970, p. 42). To accurately determine alkalinity attributable to organic acid anions, a titration end-point of approximately pH 3.5 is required (Willey and others,

Table 10.--Measured pH of ground-water samples, pH required for calcite equilibrium, and percent CO_2 loss to outgassing corresponding to the difference in the two for approximate times during the summer 1987 organic-mat test

Time	Measured pH	Calcite-equilibrium pH	Percent CO_2 lost
		Flow path 1	
90 hours	7.79	7.50	3.3
211 hours	7.66	7.43	3.1
405 hours	7.75	7.35	5.5
600 hours	7.64	7.38	3.9
		Flow path 2	
90 hours	7.77	7.49	3.3
211 hours	7.64	7.44	2.8
405 hours	7.71	7.35	5.3
600 hours	7.71	7.14	9.8

1975). Alkalinities were not determined in the field. Collected ground-water samples were shipped to the U.S. Geological Survey National Water-Quality Laboratory for analysis. Volatile fatty acids are consumed in oxidative bacterial degradation of dissolved organic carbon (Thurman, 1985, p. 124). In addition, Okubo and Matsumoto (1979) observed rapid breakdown of volatile fatty acids produced during their simulated artificial-recharge experiments. If complete bacterial degradation of organic acid anions took place prior to alkalinity determination, titration to end-point 4.5 would produce a correct result.

Significant increases in anions exceed significant increases in cations in all modeled data sets (fig. 6). All excess anions shown in figure 6 were in the form of alkalinity. The lack of an alkalinity deficit in modeled data sets strongly suggests the decomposition of any organic acid anions present in ground-water samples prior to alkalinity determination.

At approximately 405 hours for flow path 1, addition of calcium and magnesium to recharging water suggested the dissolution of magnesium-bearing calcite or dolomite (table 3). If all the sodium lost along flow path 1 is attributed to cation exchange for magnesium, there still was magnesium added to the recharging water that was unaccounted for. Even if dissolution of a calcite containing 4 mole-percent $MgCO_3$ proceeded incongruently, it is unlikely that roughly equimolar amounts of calcium and magnesium would be released into solution. This leaves dolomite dissolution as a reasonable mechanism for introduction of magnesium into recharging water along flow path 1 near 405 hours. A dolomite-rich interval was located immediately beneath the basin floor (table 1). Any organic acids produced within the organic mat would have to migrate only a short distance before interacting with dolomite.

Okubo and Matsumoto (1979) observed the onset of volatile fatty acid production after approximately 5 days (120 hours) and a rapid increase in volatile fatty acid production after approximately 20 days (480 hours) of their artificial-recharge experiment. The pattern of acetic acid production observed by Okubo and Matsumoto (1979) coincides with the pattern of significant calcite dissolution at some time prior to 200 hours followed by dolomite dissolution at some time prior to 405 hours observed in the summer 1987 organic-mat test. Dolomite dissolution into CO_2-charged water proceeds very slowly under near-surface conditions (Drever, 1982, p. 53; Stumm and Morgan, 1981, p. 274) and may, therefore, result in dolomite persisting as a metastable phase. Apparent dissolution of dolomite at some time before 405 hours, in itself, strongly suggests the action of corrosive agents such as organic acids.

Because no analyses for the presence of organic acids were made on ground-water samples, there is no direct evidence for their existence during basin operation. However, there is sufficient indirect evidence of their effect on dolomite stability to warrant their proposal as a theory to partly account for carbonate mineral dissolution.

SUMMARY

Changes between recharge-basin water and ground water from the termination of the flow paths during the spring 1987 recharge test in the Oakes aquifer included increases in alkalinity, calcium, sodium, and silica and decreases in pH and dissolved oxygen. Interpretation of processes modifying the chemical composition of recharge water was complicated by mixing of recharge water with pre-existing ground water within the Oakes aquifer.

Concentrations of barium, cadmium, copper, iron, lead, and zinc in ground water were monitored during the spring 1987 recharge test. Concentrations of these metals in any ground-water sample did not exceed maximum contaminant levels established for potable water by the Environmental Protection Agency (1986).

For the summer 1987 recharge test, the floor of the recharge basin was lined with a decomposing organic mat. Larger infiltration rates through the recharge basin with the organic mat in place allowed recharge water to reach the termination of the flow paths without apparent mixing with pre-existing ground water for a period of as much as approximately 405 hours of recharge-basin operation. Changes in the chemical composition between recharge-basin water and water from the termination of the flow paths during the summer 1987 organic-mat test included increases in alkalinity, calcium, and silica and decreases in pH, dissolved oxygen, and total organic carbon. A significant increase in magnesium was observed for flow path 1 at approximately 405 hours. The slow rate of chemical change between water in the recharge basin and ground water from the termination of both flow paths starting at about 90 hours approximated steady-state conditions. Chemical changes of at least 2 milligrams per liter were modeled in terms of reactions, including those due to respiration of micro-organisms, dissolution of carbon dioxide, possible production of organic acids, dissolution of amorphous silica, cation exchange, and dissolution of carbonate minerals.

The observed decrease in total organic carbon concentrations between water in the recharge basin and ground-water samples from the termination of the flow paths required that the subsurface be open to oxygen from the atmosphere or the surrounding sediments or that some unquantified process, such as sorption of organic carbon onto sediments or organic matter, remove organic carbon from ground water.

Calculations using WATEQF indicated oversaturation of ground water with respect to calcite and dolomite from approximately 90 hours through the duration of ground-water sampling. Chemical changes observed in recharge water as it moved through the Oakes aquifer sediments reflected dissolution of calcite at some time before 200 hours. Oversaturation of ground water with respect to carbonate minerals could be explained by loss of CO_2 from ground-water samples to outgassing, either before or during sampling. Calculations show that a loss of about 3 percent of the CO_2 required for equilibrium with calcite would produce the calculated oversaturation. The presence of organic ligands, likely available in abundance from the decomposing organic mat, would act to stabilize the calcite-oversaturated ground water.

Alternatively, onset of calcite dissolution at some time before 200 hours may indicate the attack of calcite by organic acids generated by the decomposing organic mat. The pattern of calcite dissolution starting at some time before 200 hours followed by dolomite dissolution starting at some time before 405 hours coincides with the onset of volatile fatty acid production near 120 hours and a rapid increase in volatile fatty acid production near 480 hours observed in laboratory simulation of artificial recharge through an organic substrate. Apparent dissolution of dolomite at some time before 405 hours in the summer 1987 organic-mat test, in itself, strongly suggests the action of corrosive agents such as organic acids.

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SUPPLEMENTAL DATA

[µS/cm, microsiemens per centimeter; deg. C, degree Celsius; mg/L, milligrams per liter; µg/L micrograms per liter; --, no data; <, less than]

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053801	131-059-29DDCC1, multiport sampler	09-18-86	1430	4.50	675	805	8.40	8.10	16.5	6.4	290
		09-18-86	2230	4.50	625	845	8.67	8.00	12.0	7.5	300
		09-19-86	0030	4.50	780	860	8.62	8.00	13.0	8.0	300
		09-19-86	0240	4.50	660	871	8.61	7.90	12.0	7.1	300
		09-19-86	0430	4.50	670	868	8.56	8.00	11.5	7.5	300
		09-19-86	0830	4.50	650	874	8.43	7.90	11.0	7.6	290
		09-19-86	1030	4.50	885	888	8.04	8.00	11.0	6.9	300
		09-19-86	1230	4.50	990	906	8.34	7.90	12.5	8.6	300
		09-20-86	1000	4.50	1,000	929	8.46	7.90	12.5	8.2	310
		09-21-86	1111	4.50	1,050	981	8.40	8.00	14.0	7.2	320
		09-22-86	1015	4.50	1,040	937	8.43	8.50	14.0	6.9	310
		09-23-86	0850	4.50	950	825	8.62	8.00	14.0	8.1	280
		10-01-86	1645	4.50	658	612	8.66	7.90	15.5	9.2	220
460731098053802	131-059-29DDCC2, multiport sampler	09-18-86	1430	5.50	568	693	7.90	8.00	14.5	5.5	380
		09-18-86	1530	5.50	669	765	7.85	7.90	14.5	6.4	380
		09-18-86	1855	5.50	--	803	--	7.80	--	--	380
		09-18-86	2050	5.50	761	819	7.84	7.80	13.5	7.6	340
		09-18-86	2240	5.50	620	823	8.01	7.90	13.0	7.3	320
		09-19-86	0440	5.50	660	851	8.07	8.00	11.5	7.5	300
		09-19-86	0835	5.50	630	844	8.05	8.00	10.5	7.2	290
		09-19-86	1040	5.50	850	865	7.70	8.20	11.0	6.7	300
		09-19-86	1240	5.50	900	878	7.82	8.00	12.0	6.8	300
		09-20-86	1000	5.50	1,000	930	8.29	7.90	12.5	6.8	300
		05-04-87	1617	5.50	620	655	7.87	7.70	18.0	6.9	210
		05-04-87	1725	5.50	620	653	7.83	7.90	21.0	7.7	210
		05-04-87	2015	5.50	630	648	7.80	8.30	18.5	8.2	210
		05-05-87	0015	5.50	610	653	7.74	8.20	17.5	8.5	210
		05-05-87	1405	5.50	573	639	8.14	7.80	23.5	7.3	220
460731098053803	131-059-29DDCC3, multiport sampler	09-18-86	1430	6.50	730	789	8.12	8.00	15.0	5.7	300
		09-19-86	0450	6.50	670	871	8.47	8.00	11.5	6.7	290
		09-19-86	0845	6.50	640	878	8.32	7.80	10.5	6.4	290
		09-19-86	1050	6.50	900	890	8.08	7.80	12.0	7.0	300
		09-19-86	1250	6.50	935	908	8.21	8.00	12.5	6.9	300

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053801	09-18-86	245	--	490	72	26	72	2	9.4	130	37	0.30	0.27
	09-18-86	262	--	510	71	31	78	2	12	140	42	0.30	0.052
	09-19-86	262	--	547	69	31	79	2	12	140	44	0.30	0.028
	09-19-86	262	--	540	67	32	84	2	12	140	46	0.30	0.030
	09-19-86	260	--	565	67	32	84	2	12	140	47	0.30	0.025
	09-19-86	255	--	570	66	31	85	2	10	160	54	0.30	0.030
	09-19-86	255	--	555	68	32	87	2	11	150	54	0.30	0.034
	09-19-86	256	--	567	67	33	94	2	11	150	57	0.30	0.028
	09-20-86	262	--	600	67	34	95	2	11	150	60	0.30	0.060
	09-21-86	271	--	633	71	35	100	2	13	160	66	0.30	0.033
	09-22-86	263	--	625	69	33	95	2	12	160	54	0.30	0.028
	09-23-86	252	--	493	66	29	78	2	11	140	36	0.30	0.022
	10-01-86	189	64	480	48	24	50	2	14	110	25	0.10	0.055
460731098053802	09-18-86	177	--	492	93	36	11	0.3	2.4	120	34	0.30	0.073
	09-18-86	213	--	500	92	37	26	0.6	2.5	140	37	0.30	0.043
	09-18-86	238	--	500	91	37	40	0.9	3.4	140	41	0.30	0.036
	09-18-86	241	--	553	82	33	56	1	4.2	140	44	0.40	0.038
	09-18-86	240	--	540	77	30	68	2	5.3	140	44	0.30	0.065
	09-19-86	251	--	575	73	28	79	2	7.1	140	46	0.30	0.029
	09-19-86	246	--	615	73	27	79	2	7.5	140	48	0.30	0.046
	09-19-86	245	--	607	68	31	88	2	12	150	54	0.30	0.057
	09-19-86	248	--	567	74	29	84	2	8.2	150	55	0.30	0.036
	09-20-86	261	--	640	70	31	94	2	11	150	60	0.30	0.033
	05-04-87	183	--	--	46	22	52	2	--	85	18	--	--
	05-04-87	203	--	--	46	22	55	2	--	100	18	--	--
	05-04-87	206	--	--	46	22	53	2	--	110	18	--	--
	05-05-87	207	--	--	47	23	51	2	--	110	18	--	--
	05-05-87	213	--	--	48	24	49	1	--	110	19	--	--
460731098053803	09-18-86	242	--	555	79	25	62	2	6.8	140	39	0.30	0.033
	09-19-86	259	--	613	66	30	77	2	13	150	49	0.30	0.029
	09-19-86	258	--	565	67	31	86	2	12	150	53	0.30	0.047
	09-19-86	254	--	600	67	32	87	2	13	160	56	0.30	0.044
	09-19-86	256	--	627	67	32	90	2	11	160	60	0.30	0.046

Station identification number	Date	Silica, dis- solved (mg/L as SiO_2)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, NO_2+NO_3 dis- solved (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, Am- monia + organic dis- solved (mg/L as N)	Phos- phorous, dis- solved (mg/L as P)	Phos- phorous, ortho dis- solved (mg/L as P)	Barium, dis- solved (µg/L as Ba)	Beryl- lium, dis- solved (µg/L as Be)	Cadmium, dis- solved (µg/L as Cd)	Cobalt, dis- solved (µg/L as Co)	Copper, dis- solved (µg/L as Cu)
460731098053801	09-18-86	18	<0.010	<0.100	0.040	0.70	0.070	0.050	--	--	--	--	--
	09-18-86	15	<0.010	<0.100	0.050	0.80	0.090	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.040	0.80	0.080	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	0.60	0.080	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	0.60	0.080	0.060	--	--	--	--	--
	09-19-86	17	<0.010	<0.100	0.020	0.80	0.150	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	0.60	0.090	0.070	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	0.50	0.090	0.080	--	--	--	--	--
	09-20-86	16	<0.010	<0.100	0.030	0.70	0.120	0.100	--	--	--	--	--
	09-21-86	17	<0.010	<0.100	0.040	0.90	0.100	0.080	--	--	--	--	--
	09-22-86	16	<0.010	<0.100	0.040	0.60	0.090	0.070	--	--	--	--	--
	09-23-86	16	<0.010	<0.100	0.030	0.60	0.060	0.050	--	--	--	--	--
	10-01-86	17	<0.010	<0.100	0.020	0.80	0.070	0.030	--	--	--	--	--
460731098053802	09-18-86	35	<0.010	2.80	0.020	0.80	0.030	0.020	--	--	--	--	--
	09-18-86	34	<0.010	0.280	0.030	0.70	0.030	0.020	--	--	--	--	--
	09-18-86	35	<0.010	<0.100	0.040	0.70	0.030	0.020	--	--	--	--	--
	09-18-86	34	<0.010	<0.100	0.030	0.70	0.030	0.020	--	--	--	--	--
	09-18-86	33	<0.010	<0.100	0.030	0.70	0.040	0.020	--	--	--	--	--
	09-19-86	29	<0.010	<0.100	0.040	0.70	0.040	0.030	--	--	--	--	--
	09-19-86	28	<0.010	<0.100	0.040	0.80	0.050	0.020	--	--	--	--	--
	09-19-86	17	<0.010	<0.100	0.030	0.80	0.090	0.060	--	--	--	--	--
	09-19-86	27	<0.010	<0.100	0.040	0.80	0.040	0.030	--	--	--	--	--
	09-20-86	25	<0.010	<0.100	0.020	0.90	0.080	0.040	--	--	--	--	--
	05-04-87	29	--	--	--	--	--	--	53	<0.5	<1	<3	<10
	05-04-87	31	--	--	--	--	--	--	55	<0.5	<1	<3	<10
	05-04-87	31	--	--	--	--	--	--	58	<0.5	<1	<3	<10
	05-05-87	29	--	--	--	--	--	--	58	<0.5	<1	<3	<10
	05-05-87	25	--	--	--	--	--	--	58	<0.5	<1	<3	<10
460731098053803	09-18-86	24	<0.010	0.100	0.040	0.70	0.050	0.040	--	--	--	--	--
	09-19-86	19	<0.010	<0.100	0.040	0.80	0.070	0.050	--	--	--	--	--
	09-19-86	17	<0.010	<0.100	0.030	0.80	0.070	0.050	--	--	--	--	--
	09-19-86	17	--	<0.100	0.030	0.80	0.080	0.060	--	--	--	--	--
	09-19-86	17	<0.010	<0.100	0.030	0.50	0.070	0.060	--	--	--	--	--

Station identification number	Date	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053801	09-18-86	12	--	--	5	--	--	--	--	39
	09-18-86	11	--	--	97	--	--	--	--	10
	09-19-86	15	--	--	67	--	--	--	--	10
	09-19-86	10	--	--	72	--	--	--	--	11
	09-19-86	11	--	--	78	--	--	--	--	11
	09-19-86	33	--	--	86	--	--	--	--	10
	09-19-86	21	--	--	110	--	--	--	--	9.9
	09-19-86	24	--	--	160	--	--	--	--	10
	09-20-86	9	--	--	170	--	--	--	--	11
	09-21-86	11	--	--	240	--	--	--	--	15
	09-22-86	25	--	--	160	--	--	--	--	11
	09-23-86	7	--	--	70	--	--	--	--	10
	10-01-86	14	--	--	24	--	--	--	--	11
460731098053802	09-18-86	7	--	--	<1	--	--	--	--	9.4
	09-18-86	4	--	--	7	--	--	--	--	10
	09-18-86	<3	--	--	21	--	--	--	--	8.8
	09-18-86	45	--	--	33	--	--	--	--	9.7
	09-18-86	5	--	--	3	--	--	--	--	8.8
	09-19-86	10	--	--	34	--	--	--	--	11
	09-19-86	22	--	--	8	--	--	--	--	9.4
	09-19-86	34	--	--	13	--	--	--	--	11
	09-19-86	14	--	--	32	--	--	--	--	7.8
	09-20-86	5	--	--	5	--	--	--	--	14
	05-04-87	6	10	35	6	<10	190	<6	<3	14
	05-04-87	7	<10	39	20	<10	190	<6	<3	13
	05-04-87	<3	<10	39	6	<10	190	<6	6	8.7
	05-05-87	<3	<10	37	16	<10	200	<6	6	15
	05-05-87	7	<10	36	7	<10	210	<6	<3	14
460731098053803	09-18-86	8	--	--	<1	--	--	--	--	8.0
	09-19-86	15	--	--	6	--	--	--	--	11
	09-19-86	25	--	--	14	--	--	--	--	12
	09-19-86	38	--	--	18	--	--	--	--	12
	09-19-86	5	--	--	6	--	--	--	--	11

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Spe-cific con-duct-ance (µS/cm)	Spe-cific con-duct-ance lab (µS/cm)	pH (stand-ard units)	pH lab (stand-ard units)	Temper-ature water (deg. C)	Oxygen, dis-solved (mg/L)	Hard-ness total (mg/L as $CaCO_3$)
460731098053803	131-059-29DDCC3, multiport sampler	09-20-86	1022	6.50	997	940	8.40	7.60	13.0	6.2	300
		09-21-86	1125	6.50	1,060	1,000	8.34	7.60	14.5	7.1	320
		09-22-86	1030	6.50	1,040	951	8.31	7.70	14.5	4.7	310
		09-23-86	0910	6.50	950	840	8.56	8.60	14.5	6.6	280
		05-04-87	1630	6.50	640	678	7.80	8.00	20.0	6.3	220
		05-04-87	1735	6.50	630	661	7.88	7.90	21.5	7.3	220
		05-04-87	2030	6.50	630	655	7.81	7.80	18.0	7.2	210
		05-05-87	0025	6.50	610	661	7.73	7.80	16.5	7.4	220
		05-05-87	1420	6.50	556	660	8.19	7.80	21.5	5.6	220
		08-03-87	1603	6.50	631	613	7.63	7.50	28.5	5.4	210
		08-03-87	1707	6.50	665	641	7.79	7.60	28.0	5.3	190
		08-03-87	1915	6.50	637	628	7.82	7.70	25.0	5.1	200
		08-03-87	2315	6.50	624	606	7.78	7.80	23.5	4.5	210
		08-04-87	0847	6.50	595	583	7.87	7.90	20.5	5.0	200
		08-04-87	1510	6.50	594	583	7.62	7.80	27.5	4.6	210
		08-05-87	1020	6.50	585	574	7.71	7.70	24.5	2.6	200
		08-06-87	0920	6.50	556	571	7.77	7.80	23.0	1.7	200
460731098053804	131-059-29DDCC4, multiport sampler	09-18-86	1500	7.50	713	805	8.26	8.10	15.5	6.8	280
		09-18-86	1915	7.50	744	861	8.46	8.00	14.5	6.9	290
		09-18-86	2110	7.50	635	858	8.44	8.00	13.0	7.2	290
		09-19-86	0500	7.50	650	864	8.48	8.00	11.5	6.8	290
		09-19-86	0855	7.50	640	880	8.26	7.70	10.5	6.8	290
		09-19-86	1105	7.50	895	892	8.08	8.00	12.0	6.8	300
		09-19-86	1305	7.50	945	917	8.15	7.90	12.5	6.9	290
		09-20-86	1030	7.50	1,000	940	8.40	7.60	12.5	7.4	300
		09-21-86	1130	7.50	1,060	995	8.32	7.70	14.0	6.4	330
		09-22-86	1045	7.50	1,060	949	8.32	7.70	15.0	4.7	310
		09-23-86	0930	7.50	965	824	8.47	7.90	15.0	5.4	280
		05-04-87	1640	7.50	640	663	8.00	7.80	21.0	8.0	220
		05-04-87	1745	7.50	630	660	8.10	8.10	21.0	8.7	220
		05-04-87	2035	7.50	630	662	8.18	8.00	17.5	8.9	220
		05-05-87	0030	7.50	610	676	8.14	7.80	16.5	8.9	230
		05-05-87	1435	7.50	545	512	8.31	7.80	23.0	7.8	220
		08-03-87	2320	7.50	620	600	7.76	7.70	22.5	4.9	220

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053803	09-20-86	259	--	650	67	33	92	2	11	170	63	0.30	0.044
	09-21-86	270	--	680	71	35	100	2	12	210	71	0.30	0.043
	09-22-86	261	--	620	68	34	93	2	12	200	57	0.30	0.026
	09-23-86	251	--	533	63	30	77	2	14	150	36	0.30	0.014
	05-04-87	203	--	--	49	24	52	2	--	110	19	--	--
	05-04-87	205	--	--	49	23	51	2	--	110	15	--	--
	05-04-87	209	--	--	48	23	48	1	--	110	13	--	--
	05-05-87	214	--	--	50	24	49	1	--	120	13	--	--
	05-05-87	216	--	--	50	24	49	1	--	110	19	--	--
	08-03-87	211	--	--	48	22	37	1	25	91	15	0.20	--
	08-03-87	222	--	--	45	20	40	1	37	87	15	0.20	--
	08-03-87	219	--	--	46	21	37	1	35	86	15	0.20	--
	08-03-87	212	--	--	48	22	36	1	21	87	14	0.20	--
	08-04-87	202	--	--	45	22	40	1	13	87	12	0.20	--
	08-04-87	203	--	--	46	22	38	1	14	88	13	0.20	--
	08-05-87	199	--	--	44	21	39	1	13	86	12	0.20	--
	08-06-87	197	--	--	45	21	38	1	12	84	13	0.20	--
460731098053804	09-18-86	245	--	507	72	25	76	2	9.9	140	38	0.30	0.027
	09-18-86	254	--	580	68	30	81	2	13	150	45	0.20	0.020
	09-18-86	257	--	680	67	30	80	2	11	160	47	0.30	0.037
	09-19-86	258	--	693	66	31	80	2	14	160	50	0.30	0.018
	09-19-86	253	--	673	65	30	82	2	12	160	55	0.30	0.046
	09-19-86	254	--	685	72	28	80	2	7.8	160	56	0.30	0.051
	09-19-86	257	--	685	64	31	91	2	12	170	63	0.30	0.025
	09-20-86	260	--	710	66	33	95	2	12	170	64	0.30	0.022
	09-21-86	271	--	725	73	36	100	2	12	190	71	0.30	0.040
	09-22-86	262	--	720	68	33	92	2	15	180	58	0.30	0.028
	09-23-86	250	--	647	62	30	77	2	13	160	38	0.20	0.011
	05-04-87	209	--	--	49	24	49	1	--	110	19	--	--
	05-04-87	210	--	--	48	24	48	1	--	110	17	--	--
	05-04-87	212	--	--	48	25	48	1	--	93	18	--	--
	05-05-87	220	--	--	50	26	48	1	--	110	13	--	--
	05-05-87	215	--	--	48	24	49	1	--	110	17	--	--
	08-03-87	210	--	--	50	23	37	1	16	85	14	0.20	--

Station identification number	Date	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, Am-monia + organic dis-solved (mg/L as N)	Phos-phorous, dis-solved (mg/L as P)	Phos-phorous, ortho dis-solved (mg/L as P)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cadmium, dis-solved (µg/L as Cd)	Cobalt, dis-solved (µg/L as Co)	Copper, dis-solved (µg/L as Cu)
460731098053803	09-20-86	16	<0.010	<0.100	0.050	1.1	0.110	0.080	--	--	--	--	--
	09-21-86	17	<0.010	<0.100	0.020	0.80	0.110	0.070	--	--	--	--	--
	09-22-86	16	<0.010	<0.100	0.020	0.70	0.080	0.060	--	--	--	--	--
	09-23-86	15	<0.010	<0.100	0.020	0.60	0.070	0.050	--	--	--	--	--
	05-04-87	29	--	--	--	--	--	--	52	<0.5	<1	<3	<10
	05-04-87	27	--	--	--	--	--	--	52	<0.5	<1	<3	<10
	05-04-87	25	--	--	--	--	--	--	51	<0.5	<1	<3	<10
	05-05-87	22	--	--	--	--	--	--	51	<0.5	<1	<3	<10
	05-05-87	18	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	08-03-87	27	--	0.320	0.100	--	0.360	0.260	--	--	--	--	--
	08-03-87	27	--	0.150	0.190	--	0.340	0.280	--	--	--	--	--
	08-03-87	25	--	<0.100	0.180	--	0.280	0.240	--	--	--	--	--
	08-03-87	23	--	<0.100	0.080	--	0.220	0.200	--	--	--	--	--
	08-04-87	18	--	<0.100	0.010	--	0.170	0.130	--	--	--	--	--
	08-04-87	19	--	<0.100	0.020	--	0.160	0.140	--	--	--	--	--
	08-05-87	14	--	<0.100	<0.010	--	0.180	0.140	--	--	--	--	--
	08-06-87	14	--	<0.100	<0.010	--	0.130	0.110	--	--	--	--	--
460731098053804	09-18-86	19	<0.010	<0.100	0.060	1.9	0.100	0.040	--	--	--	--	--
	09-18-86	18	<0.010	<0.100	0.040	2.4	0.050	0.050	--	--	--	--	--
	09-18-86	18	<0.010	<0.100	<0.010	0.80	0.070	0.050	--	--	--	--	--
	09-19-86	17	<0.010	<0.100	0.010	0.70	0.070	0.050	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.020	1.0	0.080	0.060	--	--	--	--	--
	09-19-86	28	<0.010	<0.100	0.020	0.90	0.070	0.020	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.010	0.30	0.080	0.070	--	--	--	--	--
	09-20-86	16	<0.010	<0.100	0.010	1.0	0.100	0.090	--	--	--	--	--
	09-21-86	18	<0.010	<0.100	0.020	1.1	0.090	0.080	--	--	--	--	--
	09-22-86	17	<0.010	<0.100	0.010	1.1	0.080	0.060	--	--	--	--	--
	09-23-86	16	<0.010	<0.100	0.010	0.90	0.080	0.050	--	--	--	--	--
	05-04-87	16	--	--	--	--	--	--	50	<0.5	<1	<3	<10
	05-04-87	15	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-04-87	13	--	--	--	--	--	--	46	<0.5	<1	<3	<10
	05-05-87	12	--	--	--	--	--	--	47	<0.5	<1	<3	<10
	05-05-87	12	--	--	--	--	--	--	47	<0.5	<1	<3	<10
	08-03-87	19	--	<0.100	0.060	--	0.170	0.150	--	--	--	--	--

Station identification number	Date	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053803	09-20-86	10	--	--	5	--	--	--	--	17
	09-21-86	7	--	--	<1	--	--	--	--	22
	09-22-86	10	--	--	11	--	--	--	--	21
	09-23-86	21	--	--	5	--	--	--	--	22
	05-04-87	6	<10	40	6	<10	210	<6	3	13
	05-04-87	6	<10	35	6	<10	210	<6	<3	12
	05-04-87	<3	<10	38	<1	<10	210	<6	<3	18
	05-05-87	6	<10	37	2	<10	220	<6	<3	15
	05-05-87	6	<10	36	3	<10	210	<6	<3	12
	08-03-87	32	--	--	20	--	--	--	--	35
	08-03-87	15	--	--	48	--	--	--	--	20
	08-03-87	8	--	--	18	--	--	--	--	13
	08-03-87	7	--	--	21	--	--	--	--	12
	08-04-87	9	--	--	<1	--	--	--	--	12
	08-04-87	4	--	--	2	--	--	--	--	12
	08-05-87	6	--	--	2	--	--	--	--	12
	08-06-87	4	--	--	2	--	--	--	--	13
460731098053804	09-18-86	11	--	--	1	--	--	--	--	--
	09-18-86	6	--	--	3	--	--	--	--	--
	09-18-86	11	--	--	3	--	--	--	--	13
	09-19-86	19	--	--	4	--	--	--	--	10
	09-19-86	53	--	--	14	--	--	--	--	11
	09-19-86	51	--	--	15	--	--	--	--	13
	09-19-86	14	--	--	6	--	--	--	--	11
	09-20-86	9	--	--	4	--	--	--	--	17
	09-21-86	5	--	--	18	--	--	--	--	15
	09-22-86	13	--	--	10	--	--	--	--	18
	09-23-86	28	--	--	16	--	--	--	--	13
	05-04-87	7	<10	36	6	<10	210	<6	<3	12
	05-04-87	8	<10	35	6	<10	210	<6	<3	14
	05-04-87	<3	<10	34	2	<10	210	<6	<3	--
	05-05-87	6	<10	38	2	<10	220	<6	<3	11
	05-05-87	6	<10	35	2	<10	210	<6	<3	11
	08-03-87	8	--	--	4	--	--	--	--	13

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Spe-cific con-duct-ance (µS/cm)	Spe-cific con-duct-ance lab (µS/cm)	pH (stand-ard units)	pH lab (stand-ard units)	Temper-ature water (deg. C)	Oxygen, dis-solved (mg/L)	Hard-ness total (mg/L as $CaCO_3$)
460731098053805	131-059-29DDCC5, multiport sampler	09-18-86	1612	8.50	677	763	7.79	7.90	14.5	7.1	410
		09-18-86	1920	8.50	684	811	7.83	7.80	14.0	7.3	350
		09-18-86	2120	8.50	640	828	7.88	7.90	11.5	7.6	320
		09-18-86	2310	8.50	660	820	7.88	7.90	13.5	7.4	300
		09-19-86	0510	8.50	630	851	7.95	7.90	12.0	7.5	300
		09-19-86	0905	8.50	625	848	7.82	7.80	11.5	6.1	290
		09-19-86	1115	8.50	915	863	7.59	7.90	11.5	7.3	300
		05-04-87	1650	8.50	640	667	7.84	8.00	19.0	6.7	220
		05-04-87	1755	8.50	620	664	7.84	8.00	20.5	7.2	210
		05-05-87	0040	8.50	600	627	7.87	8.20	16.5	7.6	210
		05-05-87	1445	8.50	525	653	8.06	7.80	21.5	5.9	220
460731098053806	131-059-29DDCC6, multiport sampler	09-18-86	1630	9.50	651	754	7.86	7.90	15.0	6.3	430
		09-18-86	1930	9.50	646	788	7.53	7.80	14.0	7.0	430
		09-18-86	2130	9.50	620	801	7.77	8.10	12.0	7.1	410
		09-18-86	2320	9.50	650	812	7.79	7.80	13.0	7.4	350
		09-19-86	0330	9.50	650	821	7.82	8.20	13.0	6.9	300
		09-19-86	0515	9.50	610	836	7.80	7.90	11.5	7.2	300
		09-19-86	1130	9.50	865	852	7.39	7.90	12.0	6.2	300
		09-19-86	1325	9.50	905	864	7.60	8.00	13.0	--	290
		09-20-86	1105	9.50	985	922	8.05	7.90	13.0	7.4	290
		05-04-87	1800	9.50	590	656	7.84	8.10	18.5	9.0	220
		05-04-87	1905	9.50	620	658	7.86	7.90	18.5	9.0	220
		05-05-87	0050	9.50	600	657	7.93	8.00	17.0	9.1	210
		05-05-87	1500	9.50	503	658	8.14	8.00	20.5	7.8	220
		08-04-87	0915	9.50	590	583	7.78	7.90	21.0	5.9	200
		08-04-87	1530	9.50	605	591	7.71	7.80	26.0	4.6	170
		08-05-87	1005	9.50	579	576	7.79	7.80	24.0	5.8	200
460731098053807	131-059-29DDCC7, multiport sampler	09-18-86	1825	10.50	668	766	7.76	7.90	14.0	7.3	440
		09-19-86	0125	10.50	670	814	7.80	7.80	13.0	7.2	310
		09-19-86	0525	10.50	620	838	7.77	7.80	11.5	--	300
		09-19-86	0935	10.50	860	832	7.57	7.80	11.0	7.0	290
		09-19-86	1335	10.50	910	864	7.59	7.80	13.0	7.7	300
		09-20-86	1130	10.50	985	914	8.06	8.10	13.5	7.0	300
460731098053808	131-059-29DDCC8, multiport sampler	09-18-86	1840	11.50	676	764	7.78	7.90	14.0	6.3	430
		09-18-86	1955	11.50	645	770	7.71	8.10	13.0	6.9	440
		09-19-86	0535	11.50	615	830	7.71	8.10	11.5	6.2	310
		09-19-86	0945	11.50	660	828	7.67	7.90	11.5	6.4	290
		09-19-86	1145	11.50	870	851	7.87	7.90	12.0	6.2	300

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053805	09-18-86	196	--	600	99	39	15	0.3	1.8	150	39	0.30	0.038
	09-18-86	228	--	560	86	34	44	1	2.7	160	45	0.30	0.029
	09-18-86	235	--	687	78	31	67	2	3.4	160	47	0.30	0.047
	09-18-86	244	--	595	72	28	70	2	3.5	150	45	0.30	0.034
	09-19-86	246	--	613	71	29	75	2	4.0	160	50	0.30	0.032
	09-19-86	242	--	620	69	28	81	2	4.1	160	52	0.30	0.034
	09-19-86	244	--	690	72	30	86	2	4.3	160	56	0.30	0.037
	05-04-87	197	--	--	49	24	53	2	--	110	18	--	--
	05-04-87	200	--	--	47	23	53	2	--	110	19	--	--
	05-05-87	212	--	--	48	23	52	2	--	120	13	--	--
	05-05-87	215	--	--	49	24	48	1	--	89	18	--	--
460731098053806	09-18-86	222	--	485	94	47	9.2	0.2	1.5	140	39	0.30	0.055
	09-18-86	228	--	500	93	47	13	0.3	1.5	160	44	0.40	0.044
	09-18-86	200	--	633	88	46	24	0.5	1.8	160	47	0.40	0.052
	09-18-86	218	--	625	76	39	46	1	2.3	160	46	0.40	0.043
	09-19-86	197	--	635	66	34	70	2	2.7	160	48	0.30	0.043
	09-19-86	240	--	647	66	34	78	2	2.7	160	50	0.30	0.034
	09-19-86	240	--	605	65	33	78	2	2.7	160	56	0.30	0.041
	09-19-86	214	--	667	64	32	82	2	2.8	160	59	0.30	0.038
	09-20-86	254	--	753	67	30	93	2	4.0	170	64	0.30	0.030
	05-04-87	211	--	--	56	19	51	2	--	100	12	--	--
	05-04-87	212	--	--	55	19	53	2	--	120	13	--	--
	05-05-87	212	--	--	53	19	56	2	--	110	13	--	--
	05-05-87	213	--	--	54	21	50	2	--	89	19	--	--
	08-04-87	200	--	--	44	21	40	1	9.4	88	12	0.20	--
	08-04-87	198	--	--	40	18	39	1	37	87	12	0.20	--
	08-05-87	197	--	--	44	21	40	1	15	86	12	0.20	--
460731098053807	09-18-86	190	--	508	110	41	6.9	0.1	1.9	150	41	0.30	0.045
	09-19-86	230	--	540	75	30	67	2	3.4	150	48	0.30	0.045
	09-19-86	242	--	547	72	29	77	2	3.7	150	48	0.30	0.036
	09-19-86	238	--	560	69	29	78	2	3.5	150	50	0.30	0.049
	09-19-86	220	--	520	71	31	80	2	2.9	160	56	0.30	0.045
	09-20-86	252	--	600	69	31	94	2	3.1	170	63	0.30	0.034
460731098053808	09-18-86	215	--	500	100	44	9.5	0.2	2.1	150	41	0.30	0.042
	09-18-86	180	--	567	100	45	11	0.2	2.3	150	44	0.30	0.071
	09-19-86	243	--	553	68	33	74	2	3.6	160	48	0.30	0.030
	09-19-86	237	--	600	64	32	76	2	3.3	150	51	0.30	--
	09-19-86	239	--	665	66	33	80	2	3.4	160	54	0.30	0.043

Station identification number	Date	Silica, dis- solved (mg/L as SiO_2)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, NO_2+NO_3 dis- solved (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, Am- monia + organic dis- solved (mg/L as N)	Phos- phorous, dis- solved (mg/L as P)	Phos- phorous, ortho dis- solved (mg/L as P)	Barium, dis- solved (µg/L as Ba)	Beryl- lium, dis- solved (µg/L as Be)	Cadmium, dis- solved (µg/L as Cd)	Cobalt, dis- solved (µg/L as Co)	Copper, dis- solved (µg/L as Cu)
460731098053805	09-18-86	36	<0.010	0.170	0.030	0.80	0.020	0.010	--	--	--	--	--
	09-18-86	35	<0.010	<0.100	0.020	0.90	0.040	0.020	--	--	--	--	--
	09-18-86	35	<0.010	<0.100	0.020	0.80	0.030	0.010	--	--	--	--	--
	09-18-86	33	<0.010	<0.100	0.020	0.90	0.030	0.020	--	--	--	--	--
	09-19-86	30	<0.010	<0.100	<0.010	1.2	0.030	0.020	--	--	--	--	--
	09-19-86	29	<0.010	<0.100	<0.010	0.60	0.040	0.020	--	--	--	--	--
	09-19-86	29	<0.010	<0.100	0.020	0.70	0.030	0.020	--	--	--	--	--
	05-04-87	32	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-04-87	32	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-05-87	31	--	--	--	--	--	--	48	<0.5	<1	<3	<10
	05-05-87	29	--	--	--	--	--	--	49	<0.5	<1	<3	<10
460731098053806	09-18-86	36	<0.010	0.350	0.050	0.70	0.100	0.020	--	--	--	--	--
	09-18-86	37	<0.010	<0.100	0.030	0.70	0.030	0.020	--	--	--	--	--
	09-18-86	37	<0.010	<0.100	0.020	0.70	0.030	0.020	--	--	--	--	--
	09-18-86	36	<0.010	<0.100	0.020	0.20	0.030	0.020	--	--	--	--	--
	09-19-86	35	<0.010	<0.100	0.010	0.70	0.030	0.010	--	--	--	--	--
	09-19-86	35	<0.010	<0.100	0.020	0.90	0.020	0.010	--	--	--	--	--
	09-19-86	33	<0.010	<0.100	0.020	0.70	0.720	0.010	--	--	--	--	--
	09-19-86	30	<0.010	<0.100	0.020	0.60	0.030	0.020	--	--	--	--	--
	09-20-86	30	<0.010	<0.100	0.010	1.2	0.030	0.020	--	--	--	--	--
	05-04-87	35	--	--	--	--	--	--	62	<0.5	<1	<3	<10
	05-04-87	36	--	--	--	--	--	--	65	2	<1	<3	<10
	05-05-87	35	--	--	--	--	--	--	60	<0.5	<1	<3	<10
	05-05-87	32	--	--	--	--	--	--	65	<0.5	<1	<3	<10
	08-04-87	27	--	<0.100	<0.010	--	0.060	0.040	--	--	--	--	--
	08-04-87	32	--	<0.100	0.010	--	0.080	0.060	--	--	--	--	--
	08-05-87	27	--	<0.100	0.020	--	0.090	0.070	--	--	--	--	--
460731098053807	09-18-86	36	<0.010	0.140	0.060	0.60	0.020	0.020	--	--	--	--	--
	09-19-86	34	<0.010	<0.100	0.030	0.80	0.030	0.020	--	--	--	--	--
	09-19-86	33	<0.010	<0.100	0.030	0.70	0.030	0.020	--	--	--	--	--
	09-19-86	32	<0.010	<0.100	0.030	0.60	0.030	0.020	--	--	--	--	--
	09-19-86	32	<0.010	<0.100	0.030	0.60	0.040	0.020	--	--	--	--	--
	09-20-86	29	<0.010	<0.100	0.040	0.50	0.030	0.020	--	--	--	--	--
460731098053808	09-18-86	37	<0.010	0.100	0.040	0.50	0.030	0.020	--	--	--	--	--
	09-18-86	37	<0.010	<0.100	0.060	0.80	0.040	0.020	--	--	--	--	--
	09-19-86	35	<0.010	<0.100	0.030	0.90	0.030	0.020	--	--	--	--	--
	09-19-86	33	<0.010	<0.100	0.030	0.90	0.030	0.020	--	--	--	--	--
	09-19-86	33	<0.010	<0.100	0.040	0.80	0.030	0.020	--	--	--	--	--

Station identification number	Date	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053805	09-18-86	7	--	--	4	--	--	--	--	11
	09-18-86	4	--	--	4	--	--	--	--	8.9
	09-18-86	27	--	--	2	--	--	--	--	11
	09-18-86	8	--	--	2	--	--	--	--	8.1
	09-19-86	7	--	--	7	--	--	--	--	8.3
	09-19-86	22	--	--	12	--	--	--	--	8.4
	09-19-86	19	--	--	11	--	--	--	--	7.7
	05-04-87	4	<10	38	6	<10	200	<6	<3	12
	05-04-87	5	<10	38	5	<10	200	<6	<3	13
	05-05-87	<3	<10	38	2	<10	200	<6	<3	14
	05-05-87	<3	<10	37	1	<10	210	<6	<3	12
460731098053806	09-18-86	<3	--	--	3	--	--	--	--	--
	09-18-86	6	--	--	4	--	--	--	--	6.0
	09-18-86	25	--	--	6	--	--	--	--	6.0
	09-18-86	9	--	--	2	--	--	--	--	7.7
	09-19-86	11	--	--	3	--	--	--	--	8.3
	09-19-86	12	--	--	5	--	--	--	--	8.4
	09-19-86	21	--	--	11	--	--	--	--	8.6
	09-19-86	11	--	--	8	--	--	--	--	8.0
	09-20-86	6	--	--	2	--	--	--	--	9.0
	05-04-87	<3	<10	41	2	<10	140	<6	<3	17
	05-04-87	5	<10	42	<1	<10	140	<6	<3	18
	05-05-87	5	<10	42	<1	<10	140	<6	<3	16
	05-05-87	<3	<10	33	<1	<10	150	<6	<3	--
	08-04-87	8	--	--	<1	--	--	--	--	12
	08-04-87	8	--	--	<1	--	--	--	--	10
	08-05-87	8	--	--	<1	--	--	--	--	10
460731098053807	09-18-86	<3	--	--	2	--	--	--	--	6.4
	09-19-86	9	--	--	<1	--	--	--	--	6.5
	09-19-86	9	--	--	3	--	--	--	--	7.0
	09-19-86	18	--	--	9	--	--	--	--	7.1
	09-19-86	10	--	--	6	--	--	--	--	7.3
	09-20-86	6	--	--	4	--	--	--	--	7.0
460731098053808	09-18-86	5	--	--	21	--	--	--	--	5.7
	09-18-86	12	--	--	6	--	--	--	--	7.1
	09-19-86	15	--	--	3	--	--	--	--	6.6
	09-19-86	24	--	--	12	--	--	--	--	6.5
	09-19-86	39	--	--	16	--	--	--	--	6.3

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053808	131-059-29DDCC8, multiport sampler	09-19-86	1340	11.50	910	860	7.54	7.90	13.0	8.2	300
		09-20-86	1140	11.50	985	912	7.98	7.80	13.5	7.4	300
		09-21-86	1200	11.50	1,020	965	8.07	8.00	15.0	6.1	310
		05-04-87	1915	11.50	630	652	7.87	7.90	18.0	8.7	220
		05-05-87	0055	11.50	590	652	7.88	8.00	17.5	8.9	210
		05-05-87	1513	11.50	663	656	7.90	8.00	21.0	7.9	220
460731098053809	131-059-29DDCC9, multiport sampler	05-04-87	2110	12.50	650	669	7.87	7.90	17.5	7.5	220
		05-05-87	0100	12.50	580	653	7.84	7.90	17.5	7.9	210
		05-05-87	1545	12.50	669	655	8.15	8.00	21.0	7.1	220
460731098053810	131-059-29DDCC10, multiport sampler	09-21-86	1215	13.50	1,010	958	8.05	7.90	14.5	6.0	320
		09-22-86	1115	13.50	1,120	968	8.10	7.90	19.0	4.7	320
		05-04-87	2310	13.50	660	662	7.83	8.00	18.0	7.8	210
		05-05-87	0105	13.50	570	655	7.86	7.90	17.5	8.4	210
		05-06-87	0945	13.50	626	639	8.00	7.90	20.5	7.4	210
460731098053811	133-059-29DDCC11, multiport sampler	05-04-87	2320	14.50	660	676	7.80	8.10	17.5	8.4	210
		05-05-87	0115	14.50	560	660	7.83	7.90	17.5	7.9	210
		05-05-87	1610	14.50	670	659	8.06	8.00	21.5	7.5	220
		05-07-87	0912	14.50	620	652	7.98	8.00	18.5	6.5	220
		08-05-87	0945	14.50	594	575	7.71	7.80	25.0	3.8	200
		08-06-87	0850	14.50	557	565	7.75	7.80	24.0	3.4	200
		08-07-87	0918	14.50	587	578	7.84	7.80	20.5	7.4	210
460731098053812	131-059-29DDCC12, multiport sampler	10-01-86	1745	15.50	699	665	7.99	7.90	16.5	4.8	210
		05-04-87	2333	15.50	660	676	7.80	7.90	14.5	9.2	220
		05-05-87	0125	15.50	570	659	7.80	8.20	17.0	7.9	210
		05-08-87	0900	15.50	630	658	7.96	7.90	20.0	5.9	230
		05-14-87	1118	15.50	682	695	7.85	7.90	22.5	4.7	240
		05-21-87	1117	15.50	726	729	7.76	8.10	15.0	5.1	260
		05-28-87	1042	15.50	723	746	7.78	7.80	21.5	4.4	270
		06-04-87	1145	15.50	707	716	7.77	7.90	23.0	4.7	260
460731098053813	131-059-29DDCC13, multiport sampler (flow path 1)	10-08-86	1515	16.50	600	667	8.16	8.00	11.0	5.4	240
		10-14-86	1400	16.50	730	710	7.92	8.10	14.0	4.8	270
		05-05-87	0133	16.50	550	656	7.80	7.90	17.5	7.7	210
		05-05-87	1640	16.50	670	663	8.04	7.90	21.5	7.9	230
		05-06-87	1045	16.50	613	641	8.01	7.90	21.5	6.9	220

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053808	09-19-86	241	--	605	65	33	81	2	3.1	160	58	0.30	0.048
	09-20-86	253	--	615	67	33	95	2	3.0	170	63	0.30	0.032
	09-21-86	265	--	800	75	31	99	3	7.3	160	65	0.30	0.053
	05-04-87	211	--	--	54	21	51	2	--	110	12	--	--
	05-05-87	207	--	--	52	20	54	2	--	110	18	--	--
	05-05-87	214	--	--	55	21	50	2	--	140	18	--	--
460731098053809	05-04-87	212	--	--	54	21	55	2	--	120	13	--	--
	05-05-87	211	--	--	52	20	54	2	--	110	12	--	--
	05-05-87	213	--	--	51	23	49	1	--	120	18	--	--
460731098053810	09-21-86	262	--	640	72	34	99	2	5.0	180	69	0.30	0.087
	09-22-86	261	--	640	74	32	100	3	6.9	210	64	0.30	0.044
	05-04-87	214	--	--	51	21	56	2	--	120	13	--	--
	05-05-87	208	--	--	51	20	55	2	--	110	19	--	--
	05-06-87	214	--	--	53	20	49	2	--	110	11	--	--
460731098053811	05-04-87	212	--	--	51	21	56	2	--	110	13	--	--
	05-05-87	208	--	--	51	21	56	2	--	110	18	--	--
	05-05-87	213	--	--	52	22	51	2	--	110	19	--	--
	05-07-87	216	--	--	53	22	49	1	--	100	18	--	--
	08-05-87	201	--	--	48	20	40	1	9.8	85	12	0.20	--
	08-06-87	194	--	--	46	21	40	1	10	84	13	0.20	--
	08-07-87	202	--	--	47	22	41	1	11	85	12	0.20	--
460731098053812	10-01-86	213	--	460	50	20	64	2	7.1	110	29	0.30	0.023
	05-04-87	218	--	--	52	22	54	2	--	130	14	--	--
	05-05-87	210	--	--	50	21	55	2	--	100	19	--	--
	05-08-87	225	--	--	56	21	50	1	--	100	12	--	--
	05-14-87	238	--	--	59	22	52	2	--	86	23	--	--
	05-21-87	237	--	--	64	24	53	1	--	87	23	--	--
	05-28-87	256	--	--	67	24	52	1	--	88	21	--	--
	06-04-87	257	--	--	66	24	52	1	--	98	33	--	--
460731098053813	10-08-86	210	--	500	61	22	53	2	5.4	120	25	0.20	0.014
	10-14-86	223	--	507	68	25	55	1	5.6	130	26	0.20	0.017
	05-05-87	210	--	--	53	18	55	2	--	100	13	--	--
	05-05-87	214	--	--	58	20	51	2	--	110	19	--	--
	05-06-87	195	--	--	55	19	49	2	--	110	19	--	--

Station identification number	Date	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, Am-monia + organic dis-solved (mg/L as N)	Phos-phorous, dis-solved (mg/L as P)	Phos-phorous, ortho dis-solved (mg/L as P)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cadmium, dis-solved (µg/L as Cd)	Cobalt, dis-solved (µg/L as Co)	Copper, dis-solved (µg/L as Cu)
460731098053808	09-19-86	32	<0.010	<0.100	0.040	1.0	0.030	0.020	--	--	--	--	--
	09-20-86	31	<0.010	<0.100	0.040	1.2	0.040	0.020	--	--	--	--	--
	09-21-86	31	<0.010	<0.100	0.020	0.70	0.040	0.030	--	--	--	--	--
	05-04-87	37	--	--	--	--	--	--	55	<0.5	<1	<3	<10
	05-05-87	36	--	--	--	--	--	--	54	<0.5	<1	<3	<10
	05-05-87	34	--	--	--	--	--	--	57	<0.5	<1	<3	<10
460731098053809	05-04-87	36	--	--	--	--	--	--	100	<0.5	<1	<3	<10
	05-05-87	35	--	--	--	--	--	--	93	<0.5	<1	<3	<10
	05-05-87	32	--	--	--	--	--	--	99	<0.5	<1	<3	<10
460731098053810	09-21-86	30	<0.010	<0.100	0.030	0.90	0.070	0.020	--	--	--	--	--
	09-22-86	30	<0.010	<0.100	0.030	0.70	0.050	0.030	--	--	--	--	--
	05-04-87	37	--	--	--	--	--	--	84	<0.5	<1	<3	<10
	05-05-87	37	--	--	--	--	--	--	83	<0.5	<1	<3	<10
	05-06-87	35	--	--	--	--	--	--	85	<0.5	<1	<3	<10
460731098053811	05-04-87	36	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-05-87	37	--	--	--	--	--	--	50	<0.5	<1	<3	<10
	05-05-87	32	--	--	--	--	--	--	57	<0.5	<1	<3	<10
	05-07-87	33	--	--	--	--	--	--	60	<0.5	<1	<3	<10
	08-05-87	24	--	0.130	0.020	--	0.030	0.020	--	--	--	--	--
	08-06-87	21	--	<0.100	0.010	--	0.040	0.020	--	--	--	--	--
	08-07-87	20	--	<0.100	0.010	--	0.060	0.040	--	--	--	--	--
460731098053812	10-01-86	34	<0.010	<0.100	0.020	0.50	0.040	0.030	--	--	--	--	--
	05-04-87	34	--	--	--	--	--	--	55	<0.5	<1	<3	<10
	05-05-87	37	--	--	--	--	--	--	58	<0.5	<1	<3	<10
	05-08-87	36	--	--	--	--	--	--	71	<0.5	<1	<3	<10
	05-14-87	37	--	--	--	--	--	--	80	1	<1	<3	<10
	05-21-87	38	--	--	--	--	--	--	91	<0.5	<1	<3	<10
	05-28-87	38	--	--	--	--	--	--	94	<0.5	<1	<3	<10
	06-04-87	37	--	--	--	--	--	--	90	<0.5	<1	<3	<10
460731098053813	10-08-86	32	<0.010	0.270	0.020	0.90	0.050	0.030	--	--	--	--	--
	10-14-86	31	<0.010	0.330	0.020	0.60	0.040	0.030	--	--	--	--	--
	05-05-87	37	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-05-87	33	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-06-87	35	--	--	--	--	--	--	50	<0.5	<1	<3	<10

Station identification number	Date	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053808	09-19-86	8	--	--	6	--	--	--	--	6.6
	09-20-86	4	--	--	3	--	--	--	--	7.5
	09-21-86	15	--	--	6	--	--	--	--	9.4
	05-04-87	3	<10	42	<1	<10	130	<6	<3	9.2
	05-05-87	<3	<10	39	<1	<10	130	<6	<3	23
	05-05-87	6	<10	37	2	<10	140	<6	<3	12
460731098053809	05-04-87	<3	<10	40	1	<10	140	8	<3	16
	05-05-87	<3	<10	38	1	<10	140	6	<3	16
	05-05-87	<3	<10	37	1	<10	140	7	<3	--
460731098053810	09-21-86	8	--	--	2	--	--	--	--	7.9
	09-22-86	3	--	--	4	--	--	--	--	8.8
	05-04-87	<3	<10	40	<1	<10	130	<6	<3	16
	05-05-87	<3	<10	41	<1	<10	120	<6	3	9.9
	05-06-87	<3	<10	38	2	<10	130	<6	<3	11
460731098053811	05-04-87	<3	<10	38	3	<10	130	<6	<3	16
	05-05-87	<3	<10	39	<1	<10	120	<6	4	20
	05-05-87	<3	<10	37	1	<10	130	<6	<3	10
	05-07-87	<3	<10	37	2	<10	130	<6	5	9.3
	08-05-87	<3	--	--	3	--	--	--	--	9.2
	08-06-87	5	--	--	<1	--	--	--	--	11
	08-07-87	5	--	--	<1	--	--	--	--	9.6
460731098053812	10-01-86	13	--	--	5	--	--	--	--	6.3
	05-04-87	<3	<10	39	1	<10	130	<6	<3	6.8
	05-05-87	<3	<10	37	2	<10	130	<6	<3	9.5
	05-08-87	<3	<10	37	1	<10	140	<6	<3	10
	05-14-87	<3	<10	41	1	<10	150	<6	<3	--
	05-21-87	<3	<10	46	2	<10	160	<6	5	6.2
	05-28-87	6	<10	47	<1	<10	160	<6	<3	5.8
	06-04-87	<3	<10	45	2	<10	160	<6	<3	7.6
460731098053813	10-08-86	6	--	--	7	--	--	--	--	6.4
	10-14-86	7	--	--	5	--	--	--	--	6.4
	05-05-87	<3	<10	41	<1	<10	140	<6	<3	13
	05-05-87	<3	<10	37	<1	<10	150	<6	<3	19
	05-06-87	<3	<10	37	1	<10	150	<6	<3	11

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053813	131-059-29DDCC13, multiport sampler (flow path 1)	05-08-87	0843	16.50	629	654	7.97	8.00	19.5	5.4	220
		05-14-87	1105	16.50	671	686	7.83	7.90	23.0	4.3	240
		05-21-87	1103	16.50	716	714	7.81	8.00	14.5	4.7	250
		06-04-87	1133	16.50	663	692	7.81	7.90	23.5	4.1	250
		08-05-87	0922	16.50	598	575	7.71	7.80	24.5	2.8	190
		08-06-87	0835	16.50	565	564	7.74	7.80	24.0	3.4	200
		08-07-87	0900	16.50	591	574	7.79	7.80	21.5	1.5	200
		08-12-87	1025	16.50	606	599	7.66	7.60	24.5	2.7	210
		08-20-87	1220	16.50	628	644	7.75	7.70	25.5	2.4	240
		08-28-87	1330	16.50	621	632	7.64	7.90	24.0	4.0	230
460731098053814	131-059-29DDCC14, multiport sampler	05-05-87	0145	17.50	540	653	7.80	7.90	15.0	8.4	210
		05-05-87	1655	17.50	685	660	8.03	7.90	20.0	7.6	230
		05-06-87	1100	17.50	611	636	7.97	7.90	21.5	6.7	220
		05-14-87	1047	17.50	663	688	7.80	8.00	24.0	4.4	240
		05-28-87	1015	17.50	683	714	7.76	7.80	21.5	4.7	260
460731098053815	131-059-29DDCC15, multiport sampler	10-01-86	1700	18.50	694	663	7.91	7.90	17.5	4.8	220
		05-05-87	0155	18.50	530	652	7.75	7.80	17.5	7.7	200
		05-05-87	1705	18.50	685	658	8.04	8.00	19.5	8.0	220
		05-08-87	0815	18.50	634	651	7.85	7.90	18.0	5.6	220
		05-14-87	1030	18.50	668	678	7.76	7.90	23.0	4.2	230
		08-04-87	1548	18.50	584	574	7.68	7.80	26.0	4.1	210
		08-05-87	0900	18.50	598	579	7.56	7.80	24.5	3.7	190
		08-06-87	0815	18.50	564	566	7.68	7.80	23.5	2.4	190
		08-07-87	0840	18.50	588	573	7.74	7.80	22.0	1.9	190
		08-12-87	1007	18.50	618	598	7.63	7.70	23.0	2.4	210
		08-20-87	1155	18.50	631	638	7.59	7.80	26.0	2.8	230
		08-28-87	1300	18.50	638	629	7.66	7.90	27.0	4.1	230
460731098053816	131-059-29DDCC16, well OL-2A (flow path 2)	09-18-86	1330	18.00	460	592	7.53	7.70	11.5	6.5	300
		09-18-86	2030	18.00	670	740	7.60	7.90	12.5	7.4	430
		09-19-86	0830	18.00	620	817	7.65	7.70	12.5	7.6	310
		09-19-86	1030	18.00	845	824	7.36	7.70	12.0	7.4	310
		10-08-86	1610	18.00	605	660	7.87	8.00	14.0	5.4	240
		10-14-86	1300	18.00	782	720	7.89	7.90	14.5	6.8	270
		05-04-87	1605	18.00	570	627	7.63	8.10	13.0	4.8	240
		05-04-87	2005	18.00	690	795	7.66	7.80	11.5	6.8	310
		05-04-87	2400	18.00	640	655	7.67	7.90	11.0	8.3	220
		05-09-87	0853	18.00	623	648	7.84	7.90	18.5	7.2	220

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053813	05-08-87	222	--	--	54	20	50	2	--	99	12	--	--
	05-14-87	232	--	--	58	22	51	1	--	100	24	--	--
	05-21-87	239	--	--	62	23	52	1	--	89	22	--	--
	06-04-87	240	--	--	62	23	51	1	--	100	19	--	--
	08-05-87	200	--	--	45	20	39	1	15	86	12	0.20	--
	08-06-87	195	--	--	44	21	38	1	12	84	13	0.20	--
	08-07-87	202	--	--	45	22	39	1	11	86	12	0.20	--
	08-12-87	211	--	--	47	23	43	1	13	89	13	0.20	--
	08-20-87	227	--	--	52	26	42	1	11	99	14	0.10	--
	08-28-87	227	--	--	50	25	44	1	12	93	13	0.20	--
460731098053814	05-05-87	212	--	--	48	23	54	2	--	120	12	--	--
	05-05-87	212	--	--	49	25	54	2	--	110	19	--	--
	05-06-87	211	--	--	48	24	51	2	--	110	17	--	--
	05-14-87	238	--	--	55	26	52	1	--	95	27	--	--
	05-28-87	244	--	--	57	28	53	1	--	86	20	--	--
460731098053815	10-01-86	213	--	480	48	24	63	2	4.7	110	27	0.30	0.058
	05-05-87	208	--	--	50	19	58	2	--	110	12	--	--
	05-05-87	212	--	--	55	20	52	2	--	120	19	--	--
	05-08-87	219	--	--	57	19	49	1	--	100	12	--	--
	05-14-87	227	--	--	59	19	50	1	--	110	17	--	--
	08-04-87	199	--	--	50	20	38	1	8.2	87	12	0.20	--
	08-05-87	200	--	--	45	19	38	1	18	85	12	0.20	--
	08-06-87	195	--	--	45	20	39	1	13	83	13	0.20	--
	08-07-87	199	--	--	45	20	39	1	12	86	12	0.20	--
	08-12-87	211	--	--	47	23	41	1	12	90	13	0.20	--
	08-20-87	222	--	--	52	25	43	1	10	100	14	0.10	--
	08-28-87	228	--	--	49	25	44	1	13	91	13	0.20	--
460731098053816	09-18-86	169	--	396	75	28	4.8	0.1	2.2	19	7.8	0.20	0.17
	09-18-86	178	--	533	110	38	5.1	0.1	2.7	130	37	0.20	0.061
	09-19-86	235	--	530	79	28	60	2	7.3	140	43	0.20	0.044
	09-19-86	236	--	527	78	28	67	2	7.8	140	45	0.30	0.060
	10-08-86	205	--	467	64	20	54	2	6.6	120	25	0.20	0.066
	10-14-86	221	--	527	72	22	58	2	6.6	140	29	0.20	0.030
	05-04-87	201	--	--	59	22	32	0.9	--	23	5.5	--	--
	05-04-87	254	--	--	76	28	46	1	--	110	15	--	--
	05-04-87	213	--	--	56	20	51	2	--	96	11	--	--
	05-09-87	219	--	--	54	21	49	1	--	96	11	--	--

Station identification number	Date	Silica, dis- solved (mg/L as SiO_2)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, NO_2+NO_3 dis- solved (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, Am- monia + organic dis- solved (mg/L as N)	Phos- phorous, dis- solved (mg/L as P)	Phos- phorous, ortho dis- solved (mg/L as P)	Barium, dis- solved (µg/L as Ba)	Beryl- lium, dis- solved (µg/L as Be)	Cadmium, dis- solved (µg/L as Cd)	Cobalt, dis- solved (µg/L as Co)	Copper, dis- solved (µg/L as Cu)
460731098053813	05-08-87	34	--	--	--	--	--	--	46	<0.5	<1	<3	<10
	05-14-87	36	--	--	--	--	--	--	51	<0.5	<1	<3	<10
	05-21-87	36	--	--	--	--	--	--	57	<0.5	<1	<3	<10
	06-04-87	37	--	--	--	--	--	--	57	<0.5	<1	<3	<10
	08-05-87	24	--	<0.100	0.020	--	0.040	0.020	--	--	--	--	--
	08-06-87	22	--	<0.100	0.030	--	0.030	0.020	--	--	--	--	--
	08-07-87	22	--	<0.100	0.020	--	0.040	0.020	--	--	--	--	--
	08-12-87	23	--	0.110	0.010	--	0.040	0.030	--	--	--	--	--
	08-20-87	21	--	0.170	0.020	--	0.050	0.030	--	--	--	--	--
	08-28-87	21	--	0.400	<0.010	--	0.050	0.040	--	--	--	--	--
460731098053814	05-05-87	36	--	--	--	--	--	--	29	<0.5	<1	<3	<10
	05-05-87	35	--	--	--	--	--	--	29	<0.5	<1	<3	<10
	05-06-87	37	--	--	--	--	--	--	29	<0.5	<1	<3	<10
	05-14-87	38	--	--	--	--	--	--	29	<0.5	<1	<3	<10
	05-28-87	39	--	--	--	--	--	--	33	<0.5	<1	<3	<10
460731098053815	10-01-86	34	0.010	<0.100	0.020	0.50	0.050	0.040	--	--	--	--	--
	05-05-87	36	--	--	--	--	--	--	30	<0.5	<1	<3	<10
	05-05-87	33	--	--	--	--	--	--	33	<0.5	<1	<3	<10
	05-08-87	35	--	--	--	--	--	--	35	<0.5	<1	<3	<10
	05-14-87	36	--	--	--	--	--	--	38	<0.5	<1	<3	<10
	08-04-87	30	--	<0.100	0.010	--	0.040	0.020	--	--	--	--	--
460731098053815	08-05-87	29	--	<0.100	0.010	--	0.050	0.020	--	--	--	--	--
	08-06-87	27	--	0.100	0.020	--	0.040	0.020	--	--	--	--	--
	08-07-87	26	--	<0.100	0.020	--	0.040	0.020	--	--	--	--	--
	08-12-87	24	--	<0.100	0.010	--	0.040	0.020	--	--	--	--	--
	08-20-87	25	--	<0.100	0.020	--	0.040	0.020	--	--	--	--	--
	08-28-87	24	--	0.160	<0.010	--	0.030	0.020	--	--	--	--	--
460731098053816	09-18-86	32	<0.010	30.0	0.020	1.5	0.030	0.030	--	--	--	--	--
	09-18-86	35	<0.010	0.230	0.030	0.60	0.040	0.030	--	--	--	--	--
	09-19-86	33	<0.010	0.110	0.020	0.80	--	0.040	--	--	--	--	--
	09-19-86	32	<0.010	0.150	0.020	0.60	0.040	0.030	--	--	--	--	--
	10-08-86	31	<0.010	0.220	0.010	0.60	0.040	0.030	--	--	--	--	--
	10-14-86	31	<0.010	0.200	0.030	0.70	0.040	0.030	--	--	--	--	--
	05-04-87	29	--	--	--	--	--	--	31	<0.5	<1	<3	<10
	05-04-87	27	--	--	--	--	--	--	42	0.8	<1	<3	<10
	05-04-87	30	--	--	--	--	--	--	33	<0.5	<1	<3	<10
	05-09-87	32	--	--	--	--	--	--	43	<0.5	<1	<3	<10

Station identification number	Date	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Lithium, dis- solved (µg/L as Li)	Manga- nese, dis- solved (µg/L as Mn)	Molyb- denum, dis- solved (µg/L as Mo)	Stron- tium, dis- solved (µg/L as Sr)	Vana- dium, dis- solved (µg/L as V)	Zinc, dis- solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053813	05-08-87	<3	<10	38	<1	<10	140	<6	<3	10
	05-14-87	<3	<10	40	1	<10	150	<6	<3	5.8
	05-21-87	<3	<10	44	1	<10	1100	<6	<3	--
	06-04-87	4	<10	41	2	<10	160	<6	<3	5.6
	08-05-87	<3	--	--	3	--	--	--	--	9.2
	08-06-87	5	--	--	3	--	--	--	--	8.7
	08-07-87	<3	--	--	3	--	--	--	--	8.7
	08-12-87	8	--	--	2	--	--	--	--	10
	08-20-87	5	--	--	1	--	--	--	--	7.2
	08-28-87	12	--	--	<1	--	--	--	--	5.8
460731098053814	05-05-87	<3	<10	37	<1	<10	100	<6	<3	13
	05-05-87	<3	<10	37	<1	<10	100	<6	<3	9.5
	05-06-87	<3	<10	38	1	<10	100	<6	<3	8.8
	05-14-87	<3	<10	38	<1	<10	120	<6	<3	6.8
	05-28-87	6	<10	46	1	<10	120	<6	9	5.0
460731098053815	10-01-86	19	--	--	16	--	--	--	--	6.3
	05-05-87	<3	<10	38	1	<10	110	<6	<3	13
	05-05-87	<3	<10	34	<1	<10	130	<6	<3	11
	05-08-87	<3	20	37	<1	<10	130	<6	<3	12
	05-14-87	<3	<10	40	3	<10	140	<6	<3	7.7
	08-04-87	<3	--	--	11	--	--	--	--	10
460731098053815	08-05-87	<3	--	--	11	--	--	--	--	9.1
	08-06-87	<3	--	--	6	--	--	--	--	8.5
	08-07-87	<3	--	--	6	--	--	--	--	8.1
	08-12-87	8	--	--	5	--	--	--	--	7.7
	08-20-87	7	--	--	53	--	--	--	--	7.5
	08-28-87	4	--	--	17	--	--	--	--	6.1
460731098053816	09-18-86	7	--	--	4	--	--	--	--	1.2
	09-18-86	10	--	--	6	--	--	--	--	5.1
	09-19-86	24	--	--	31	--	--	--	--	6.2
	09-19-86	19	--	--	70	--	--	--	--	6.1
	10-08-86	4	--	--	4	--	--	--	--	5.7
	10-14-86	<3	--	--	3	--	--	--	--	5.7
	05-04-87	3	<10	31	6	<10	110	<6	<3	3.0
	05-04-87	<3	<10	38	6	<10	150	<6	<3	10
	05-04-87	<3	10	29	6	<10	110	<6	<3	8.3
	05-09-87	<3	<10	39	<1	<10	110	<6	<3	9.0

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053816	131-059-29DDCC16, well OL-2A (flow path 2)	05-14-87	1155	18.00	673	692	7.80	7.80	21.5	5.0	240
		08-03-87	1600	18.00	693	673	7.60	7.80	28.0	3.8	250
		08-03-87	1710	18.00	680	670	7.62	7.80	26.5	3.2	240
		08-03-87	1900	18.00	696	690	7.75	7.70	23.5	3.9	260
		08-03-87	2310	18.00	626	613	7.50	7.70	22.5	4.3	220
		08-04-87	0839	18.00	618	597	7.59	7.80	23.5	4.5	210
		08-04-87	1625	18.00	590	582	7.77	7.80	28.0	4.9	220
		08-05-87	1050	18.00	592	582	7.65	7.90	26.0	4.1	210
		08-06-87	0950	18.00	566	570	7.70	7.80	23.0	4.1	200
		08-07-87	1005	18.00	590	579	7.77	7.70	22.0	3.4	200
		08-12-87	1105	18.00	615	608	7.64	7.60	23.0	2.2	210
		08-20-87	1300	18.00	611	644	7.71	7.60	24.5	2.2	230
		08-28-87	1405	18.00	639	669	7.71	7.70	23.5	1.4	260
460731098053817	131-059-29DDCC17, discharge water (James River)	09-18-86	1530	--	662	828	8.66	7.90	14.5	7.4	290
		09-19-86	0430	--	695	896	8.50	7.90	12.5	7.1	300
		09-19-86	0830	--	750	897	8.40	8.00	11.5	8.0	300
		09-19-86	1030	--	900	920	7.98	7.90	11.0	6.7	300
		09-19-86	1230	--	940	931	8.11	7.90	12.0	8.2	300
		10-01-86	1600	--	687	637	8.16	7.80	16.5	7.2	230
		10-08-86	1445	--	710	827	8.68	7.90	10.0	8.9	310
		10-14-86	1230	--	912	851	8.64	8.00	7.0	9.6	320
		05-04-87	1600	--	630	672	8.16	7.80	20.0	9.0	230
		05-04-87	1700	--	630	671	8.34	7.80	19.5	10.4	230
		05-04-87	1810	--	630	--	8.31	--	19.0	10.4	--
		05-04-87	2000	--	620	--	8.22	--	17.5	10.4	--
		05-04-87	2200	--	660	663	8.14	8.30	17.0	9.9	220
		05-04-87	2400	--	660	--	8.10	--	17.0	9.4	--
		05-05-87	1730	--	671	--	8.56	--	21.0	9.6	--
		05-06-87	1145	--	620	653	8.25	7.80	19.0	7.8	220
		05-07-87	1045	--	602	--	8.14	--	18.5	7.3	--
		05-08-87	1000	--	593	--	8.30	--	19.0	7.2	--
		05-09-87	0910	--	621	644	8.04	7.80	18.5	6.1	210
		05-14-87	1208	--	649	--	8.16	--	19.5	6.6	--
		05-28-87	1130	--	606	628	8.14	8.00	20.0	7.2	200
		06-04-87	1230	--	728	747	8.47	8.10	20.5	8.9	260
		08-03-87	1600	--	630	612	7.93	7.60	28.0	6.5	230
		08-03-87	1700	--	627	615	7.82	7.90	27.0	6.2	230
		08-03-87	1900	--	610	607	7.94	7.80	25.5	6.5	230

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053816	05-14-87	235	--	--	58	22	52	2	--	100	23	--	--
	08-03-87	253	--	--	59	24	50	1	8.4	90	13	0.20	--
	08-03-87	251	--	--	60	23	50	1	8.3	90	13	0.20	--
	08-03-87	263	--	--	61	25	50	1	9.3	88	13	0.20	--
	08-03-87	219	--	--	52	22	45	1	9.0	85	15	0.20	--
	08-04-87	211	--	--	50	21	41	1	9.2	89	13	0.20	--
	08-04-87	205	--	--	51	22	39	1	8.8	87	12	0.20	--
	08-05-87	206	--	--	49	21	41	1	9.3	86	12	0.20	--
	08-06-87	199	--	--	47	21	41	1	9.1	95	12	0.20	--
	08-07-87	202	--	--	47	21	41	1	10	88	12	0.20	--
	08-12-87	215	--	--	49	21	41	1	16	91	13	0.20	--
	08-20-87	234	--	--	55	23	42	1	12	90	12	0.20	--
	08-28-87	244	--	--	83	13	32	0.9	11	92	13	0.20	--
460731098053817	09-18-86	247	56	620	66	31	76	2	10	140	38	0.20	0.062
	09-19-86	263	64	620	68	32	86	2	11	160	50	0.30	0.027
	09-19-86	256	67	610	66	32	90	2	10	160	58	0.20	0.039
	09-19-86	257	69	670	66	33	92	2	9.7	160	61	0.30	0.044
	09-19-86	262	66	630	66	33	94	2	9.9	160	63	0.20	0.040
	10-01-86	195	74	460	50	25	50	1	15	110	25	0.20	<0.010
	10-08-86	260	44	572	65	35	69	2	14	160	33	0.10	<0.010
	10-14-86	271	12	595	69	36	72	2	13	160	34	0.20	<0.010
	05-04-87	213	42	--	49	25	49	1	--	110	17	--	--
	05-04-87	215	39	--	50	26	49	1	--	92	19	--	--
	05-04-87	--	35	--	--	--	--	--	--	--	--	--	--
	05-04-87	--	46	--	--	--	--	--	--	--	--	--	--
	05-04-87	214	45	--	48	25	48	1	--	110	19	--	--
	05-04-87	--	59	--	--	--	--	--	--	--	--	--	--
	05-05-87	--	36	--	--	--	--	--	--	--	--	--	--
	05-06-87	212	36	--	46	25	49	1	--	110	18	--	--
	05-07-87	--	48	--	--	--	--	--	--	--	--	--	--
	05-08-87	--	48	--	--	--	--	--	--	--	--	--	--
	05-09-87	210	47	--	44	24	49	2	--	97	19	--	--
	05-14-87	--	44	--	--	--	--	--	--	--	--	--	--
	05-28-87	194	141	--	44	23	47	1	--	100	17	--	--
	06-04-87	223	--	--	56	29	55	2	--	140	21	--	--
	08-03-87	220	69	--	54	24	40	1	11	83	15	0.20	--
	08-03-87	220	77	--	54	24	39	1	11	83	15	0.20	--
	08-03-87	214	54	--	53	24	39	1	11	86	15	0.20	--

Station identification number	Date	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, Am-monia + organic dis-solved (mg/L as N)	Phos-phorous, dis-solved (mg/L as P)	Phos-phorous, ortho dis-solved (mg/L as P)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cadmium, dis-solved (µg/L as Cd)	Cobalt, dis-solved (µg/L as Co)	Copper, dis-solved (µg/L as Cu)
460731098053816	05-14-87	34	--	--	--	--	--	--	47	<0.5	<1	<3	<10
	08-03-87	41	--	1.00	0.010	--	0.060	0.030	--	--	--	--	--
	08-03-87	41	--	0.960	<0.010	--	0.060	0.040	--	--	--	--	--
	08-03-87	40	--	2.40	<0.010	--	0.050	0.030	--	--	--	--	--
	08-03-87	39	--	0.330	0.020	--	0.050	0.040	--	--	--	--	--
	08-04-87	38	--	0.170	<0.010	--	0.060	0.030	--	--	--	--	--
	08-04-87	37	--	0.140	<0.010	--	0.050	0.030	--	--	--	--	--
	08-05-87	35	--	0.220	<0.010	--	0.070	0.030	--	--	--	--	--
	08-06-87	33	--	0.170	<0.010	--	0.070	0.030	--	--	--	--	--
	08-07-87	33	--	0.170	<0.010	--	0.050	0.030	--	--	--	--	--
	08-12-87	33	--	0.270	0.020	--	0.040	0.030	--	--	--	--	--
	08-20-87	35	--	0.630	<0.010	--	0.040	0.030	--	--	--	--	--
	08-28-87	--	--	0.870	<0.010	--	0.040	0.030	--	--	--	--	--
460731098053817	09-18-86	16	<0.010	<0.100	0.010	0.60	0.030	0.050	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.020	0.90	0.040	0.060	--	--	--	--	--
	09-19-86	14	<0.010	<0.100	0.030	1.0	0.150	0.080	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	0.80	0.080	0.080	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	1.4	0.110	0.080	--	--	--	--	--
	10-01-86	19	0.020	0.230	0.020	0.30	0.060	0.060	--	--	--	--	--
	10-08-86	21	<0.010	<0.100	0.030	1.0	0.100	0.100	--	--	--	--	--
	10-14-86	21	<0.010	<0.100	0.030	1.1	0.130	0.130	--	--	--	--	--
	05-04-87	9.7	--	--	--	--	--	--	50	<0.5	<1	<3	20
	05-04-87	9.7	--	--	--	--	--	--	50	<0.5	<1	<3	<10
	05-04-87	--	--	--	--	--	--	--	--	--	--	--	--
	05-04-87	--	--	--	--	--	--	--	--	--	--	--	--
	05-04-87	9.6	--	--	--	--	--	--	52	<0.5	<1	<3	<10
	05-04-87	--	--	--	--	--	--	--	--	--	--		--
	05-05-87	--	--	--	--	--	--	--	--	--	--		--
	05-06-87	9.1	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-07-87	--	--	--	--	--	--	--	--	--	--	--	--
	05-08-87	--	--	--	--	--	--	--	--	--	--	--	--
	05-09-87	8.6	--	--	--	--	--	--	50	<0.5	<1	<3	<10
	05-14-87	--	--	--	--	--	--	--	--	--	--	--	--
	05-28-87	12	--	--	--	--	--	--	47	<0.5	<1	<3	<10
	06-04-87	14	--	--	--	--	--	--	61	<0.5	<1	<3	<10
	08-03-87	20	--	<0.100	0.050	--	0.150	0.120	--	--	--	--	--
	08-03-87	20	--	<0.100	0.040	--	0.140	0.110	--	--	--	--	--
	08-03-87	18	--	<0.100	0.030	--	0.130	0.100	--	--	--	--	--

Station identification number	Date	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053816	05-14-87	<3	<10	43	6	<10	120	<6	<3	5.0
	08-03-87	6	--	--	15	--	--	--	--	4.6
	08-03-87	9	--	--	18	--	--	--	--	4.8
	08-03-87	7	--	--	12	--	--	--	--	4.6
	08-03-87	7	--	--	2	--	--	--	--	8.4
	08-04-87	4	--	--	8	--	--	--	--	6.8
	08-04-87	5	--	--	6	--	--	--	--	6.9
	08-05-87	3	--	--	1	--	--	--	--	7.3
	08-06-87	4	--	--	<1	--	--	--	--	6.9
	08-07-87	5	--	--	<1	--	--	--	--	6.4
	08-12-87	3	--	--	10	--	--	--	--	5.7
	08-20-87	5	--	--	6	--	--	--	--	5.1
	08-28-87	<3	--	--	34	--	--	--	--	4.8
460731098053817	09-18-86	15	--	--	100	--	--	--	--	13
	09-19-86	15	--	--	120	--	--	--	--	12
	09-19-86	71	--	--	120	--	--	--	--	14
	09-19-86	40	--	--	100	--	--	--	--	13
	09-19-86	16	--	--	150	--	--	--	--	13
	10-01-86	15	--	--	150	--	--	--	--	11
	10-08-86	9	--	--	72	--	--	--	--	11
	10-14-86	12	--	--	26	--	--	--	--	11
	05-04-87	19	<10	35	110	<10	220	<6	<3	15
	05-04-87	140	<10	37	86	<10	220	<6	<3	28
	05-04-87	--	--	--	--	--	--	--	--	--
	05-04-87	--	--	--	--	--	--	--	--	--
	05-04-87	6	<10	36	82	<10	220	<6	7	29
	05-04-87	--	--	--	--	--	--	--	--	--
	05-05-87	--	--	--	--	--	--	--	--	--
	05-06-87	9	10	35	110	<10	210	<6	<3	17
	05-07-87	--	--	--	--	--	--	--	--	--
	05-08-87	--	--	--	--	--	--	--	--	--
	05-09-87	8	<10	35	130	<10	200	<6	7	29
	05-14-87	--	--	--	--	--	--	--	--	--
	05-28-87	12	<10	32	76	<10	200	<6	7	13
	06-04-87	19	<10	42	43	<10	250	<6	10	14
	08-03-87	11	--	--	710	--	--	--	--	18
	08-03-87	9	--	--	1,000	--	--	--	--	18
	08-03-87	10	--	--	930	--	--	--	--	16

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053817	131-059-29DDCC17, discharge water (James River)	08-03-87	2300	--	609	594	8.00	7.80	23.5	6.3	210
		08-04-87	0825	--	598	581	7.90	7.60	21.0	6.2	210
		08-04-87	1640	--	599	579	8.22	7.80	26.5	7.5	210
		08-05-87	1105	--	570	566	8.13	7.70	24.0	6.2	200
		08-06-87	1005	--	567	569	7.98	7.80	21.5	5.2	200
		08-07-87	1020	--	574	577	8.09	7.80	21.0	5.6	210
		08-12-87	1120	--	597	595	7.94	7.70	21.5	5.5	210
		08-20-87	1312	--	580	616	8.15	8.10	22.5	8.1	210
		08-25-87	0800	--	--	--	--	--	--	--	--
		08-26-87	0745	--	--	--	--	--	--	--	--
		08-27-87	0749	--	--	--	--	--	--	--	--
		08-28-87	0734	--	--	--	--	--	--	--	--
		08-28-87	0755	--	--	--	--	--	--	--	--
		08-28-87	1420	--	583	613	8.07	7.90	20.0	7.9	220
		08-29-87	0800	--	--	--	--	--	--	--	--
		08-30-87	0805	--	--	--	--	--	--	--	--
		08-31-87	0729	--	--	--	--	--	--	--	--
		09-01-87	0728	--	--	--	--	--	--	--	--
		09-02-87	0752	--	--	--	--	--	--	--	--
		09-22-87	1417	--	--	--	--	--	--	--	--
		09-23-87	1020	--	--	--	--	--	--	--	--
		09-24-87	0930	--	--	--	--	--	--	--	--
		09-25-87	1020	--	--	--	--	--	--	--	--
		09-26-87	0750	--	--	--	--	--	--	--	--
		09-27-87	0752	--	--	--	--	--	--	--	--
		09-28-87	0752	--	--	--	--	--	--	--	--
		09-29-87	0745	--	--	--	--	--	--	--	--
		09-30-87	0750	--	--	--	--	--	--	--	--
		10-01-87	0733	--	--	--	--	--	--	--	--
		10-01-87	1920	--	--	--	--	--	--	--	--
460731098053818	131-059-29DDCC18, basin water	09-18-86	1530	--	707	767	8.61	7.80	15.0	7.4	280
		09-19-86	0430	--	660	874	8.56	8.00	11.5	7.7	300
		09-19-86	0830	--	630	863	8.42	8.00	10.5	7.4	290
		09-19-86	1030	--	1,010	883	8.03	7.80	11.5	7.1	300
		09-19-86	1230	--	900	905	8.20	7.80	12.0	8.7	300

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053817	08-03-87	208	77	--	49	22	37	1	11	86	13	0.20	--
	08-04-87	200	68	--	46	22	40	1	11	87	12	0.20	--
	08-04-87	201	66	--	47	23	41	1	11	86	12	0.20	--
	08-05-87	195	17	--	45	22	41	1	10	85	12	0.20	--
	08-06-87	196	68	--	45	22	40	1	11	84	13	0.20	--
	08-07-87	200	65	--	46	22	40	1	10	87	12	0.20	--
	08-12-87	207	42	--	45	23	42	1	11	92	14	0.10	--
	08-20-87	203	38	--	47	23	44	1	12	100	13	0.20	--
	08-25-87	--	56	--	--	--	--	--	--	--	--	--	--
	08-26-87	--	55	--	--	--	--	--	--	--	--	--	--
	08-27-87	--	52	--	--	--	--	--	--	--	--	--	--
	08-28-87	--	52	--	--	--	--	--	--	--	--	--	--
	08-28-87	--	100	--	--	--	--	--	--	--	--	--	--
	08-28-87	205	32	--	49	23	44	1	12	100	12	0.20	--
	08-29-87	--	50	--	--	--	--	--	--	--	--	--	--
	08-30-87	--	51	--	--	--	--	--	--	--	--	--	--
	08-31-87	--	52	--	--	--	--	--	--	--	--	--	--
	09-01-87	--	43	--	--	--	--	--	--	--	--	--	--
	09-02-87	--	49	--	--	--	--	--	--	--	--	--	--
	09-22-87	--	79	--	--	--	--	--	--	--	--	--	--
	09-23-87	--	58	--	--	--	--	--	--	--	--	--	--
	09-24-87	--	48	--	--	--	--	--	--	--	--	--	--
	09-25-87	--	53	--	--	--	--	--	--	--	--	--	--
	09-26-87	--	63	--	--	--	--	--	--	--	--	--	--
	09-27-87	--	57	--	--	--	--	--	--	--	--	--	--
	09-28-87	--	57	--	--	--	--	--	--	--	--	--	--
	09-29-87	--	49	--	--	--	--	--	--	--	--	--	--
	09-30-87	--	46	--	--	--	--	--	--	--	--	--	--
	10-01-87	--	48	--	--	--	--	--	--	--	--	--	--
	10-01-87	--	785	--	--	--	--	--	--	--	--	--	--
460731098053818	09-18-86	258	--	573	64	30	75	2	10	140	38	0.20	0.037
	09-19-86	260	--	600	67	32	82	2	10	150	48	0.20	0.025
	09-19-86	252	--	610	65	31	84	2	10	150	51	0.20	0.034
	09-19-86	252	--	640	66	32	87	2	10	160	54	0.30	0.047
	09-19-86	255	--	601	66	33	91	2	9.8	160	57	0.30	0.032

Station identification number	Date	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, Am-monia + organic dis-solved (mg/L as N)	Phos-phorous, dis-solved (mg/L as P)	Phos-phorous, ortho dis-solved (mg/L as P)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cadmium, dis-solved (µg/L as Cd)	Cobalt, dis-solved (µg/L as Co)	Copper, dis-solved (µg/L as Cu)
460731098053817	08-03-87	16	--	<0.100	0.020	--	0.110	0.080	--	--	--	--	--
	08-04-87	15	--	<0.100	0.020	--	0.090	0.070	--	--	--	--	--
	08-04-87	15	--	<0.100	0.030	--	0.090	0.060	--	--	--	--	--
	08-05-87	13	--	<0.100	0.010	--	0.080	0.060	--	--	--	--	--
	08-06-87	14	--	<0.100	0.010	--	0.070	0.050	--	--	--	--	--
	08-07-87	14	--	<0.100	0.010	--	0.070	0.050	--	--	--	--	--
	08-12-87	13	--	<0.100	0.020	--	0.080	0.050	--	--	--	--	--
	08-20-87	16	--	<0.100	0.010	--	0.070	0.040	--	--	--	--	--
	08-25-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-26-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-27-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-28-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-28-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-28-87	8.5	--	<0.100	0.040	--	0.080	0.050	--	--	--	--	--
	08-29-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-30-87	--	--	--	--	--	--	--	--	--	--	--	--
	08-31-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-01-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-02-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-22-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-23-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-24-87	--	--	--	--	--	--	--	--	--	--	--	
	09-25-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-26-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-27-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-28-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-29-87	--	--	--	--	--	--	--	--	--	--	--	--
	09-30-87	--	--	--	--	--	--	--	--	--	--	--	--
	10-01-87	--	--	--	--	--	--	--	--	--	--	--	--
	10-01-87	--	--	--	--	--	--	--	--	--	--	--	--
460731098053818	09-18-86	15	<0.010	<0.100	<0.010	1.5	0.040	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	2.2	0.030	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.030	0.70	0.070	0.060	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.300	1.1	0.080	0.070	--	--	--	--	--
	09-19-86	16	<0.010	<0.100	0.020	1.2	0.040	0.070	--	--	--	--	--

Station identification number	Date	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053817	08-03-87	<3	--	--	270	--	--	--	--	16
	08-04-87	<3	--	--	110	--	--	--	--	16
	08-04-87	7	--	--	71	--	--	--	--	16
	08-05-87	6	--	--	44	--	--	--	--	18
	08-06-87	<3	--	--	40	--	--	--	--	15
	08-07-87	<3	--	--	32	--	--	--	--	15
	08-12-87	7	--	--	60	--	--	--	--	16
	08-20-87	6	--	--	20	--	--	--	--	15
	08-25-87	--	--	--	--	--	--	--	--	--
	08-26-87	--	--	--	--	--	--	--	--	--
	08-27-87	--	--	--	--	--	--	--	--	--
	08-28-87	--	--	--	--	--	--	--	--	--
	08-28-87	--	--	--	--	--	--	--	--	--
	08-28-87	<3	--	--	30	--	--	--	--	11
	08-29-87	--	--	--	--	--	--	--	--	--
	08-30-87	--	--	--	--	--	--	--	--	--
	08-31-87	--	--	--	--	--	--	--	--	--
	09-01-87	--	--	--	--	--	--	--	--	--
	09-02-87	--	--	--	--	--	--	--	--	--
	09-22-87	--	--	--	--	--	--	--	--	--
	09-23-87	--	--	--	--	--	--	--	--	--
	09-24-87	--	--	--	--	--	--	--	--	--
	09-25-87	--	--	--	--	--	--	--	--	--
	09-26-87	--	--	--	--	--	--	--	--	--
	09-27-87	--	--	--	--	--	--	--	--	--
	09-28-87	--	--	--	--	--	--	--	--	--
	09-29-87	--	--	--	--	--	--	--	--	--
	09-30-87	--	--	--	--	--	--	--	--	--
	10-01-87	--	--	--	--	--	--	--	--	--
	10-01-87	--	--	--	--	--	--	--	--	--
460731098053818	09-18-86	3	--	--	42	--	--	--	--	13
	09-19-86	27	--	--	93	--	--	--	--	14
	09-19-86	55	--	--	110	--	--	--	--	13
	09-19-86	49	--	--	120	--	--	--	--	12
	09-19-86	4	--	--	130	--	--	--	--	13

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053818	131-059-29DDCC18, basin water	09-23-86	0850	--	930	807	8.65	7.90	13.0	8.2	280
		05-04-87	1612	--	640	668	8.22	7.80	20.5	8.3	230
		05-08-87	0930	--	594	639	8.41	7.80	19.0	8.2	210
		05-21-87	1130	--	520	537	8.91	8.50	10.5	0.9	170
		05-28-87	1055	--	575	599	8.99	8.70	22.0	7.9	200
		06-04-87	1158	--	731	756	8.13	8.00	22.5	6.2	260
		08-03-87	1600	--	761	613	8.02	7.60	28.0	6.6	220
		08-03-87	1700	--	634	616	8.08	7.60	28.5	7.2	230
		08-03-87	1900	--	611	611	8.11	7.60	25.0	7.3	230
		08-03-87	2300	--	614	596	8.11	7.70	22.5	7.5	220
		08-04-87	0900	--	590	582	8.20	7.80	20.5	8.2	210
		08-04-87	1603	--	593	583	8.38	7.90	28.0	8.4	210
		08-05-87	1035	--	575	573	8.33	7.90	24.5	8.5	210
		08-06-87	0935	--	551	565	8.19	7.90	22.5	7.9	200
		08-07-87	0945	--	581	575	8.36	8.00	20.5	8.0	210
		08-12-87	1048	--	584	590	8.35	7.80	21.5	8.3	210
		08-20-87	1240	--	582	622	8.38	8.10	22.5	8.6	210
		08-28-87	1350	--	589	627	8.50	8.00	19.5	0.2	220
460731098053301	131-059-29DDCD1	09-23-86	1300	23.00	560	491	7.58	7.70	12.5	6.7	240
		09-23-86	1400	23.00	530	494	7.60	7.70	14.5	6.2	240
		09-23-86	1600	23.00	545	504	7.67	7.70	15.5	6.6	240
		09-23-86	1700	23.00	545	500	7.64	7.70	14.0	7.0	240
		09-23-86	1800	23.00	560	513	7.62	7.70	13.0	7.8	250
		09-23-86	2200	23.00	580	552	7.61	7.60	11.5	7.0	270
		09-24-86	0800	23.00	575	546	7.67	7.70	11.5	6.8	270
		09-24-86	1000	23.00	580	541	7.66	7.70	13.5	6.7	260
		10-01-86	1415	23.00	699	825	7.63	7.70	14.0	6.2	350
		10-08-86	1730	23.00	567	645	7.61	7.80	12.5	5.8	340
		10-14-86	1515	23.00	695	623	7.49	7.90	15.0	6.8	320
460731098053302	131-059-29DDCD2	10-01-86	1415	--	685	628	8.15	7.70	16.0	6.8	220
		10-08-86	1645	--	728	812	8.70	7.80	10.5	8.8	310
		10-14-86	1530	--	895	853	8.57	8.00	13.0	9.6	320
460731098053303	131-059-29DDCD3	09-23-86	1400	--	850	791	8.56	7.90	18.0	7.0	260
		09-23-86	1600	--	860	784	8.57	7.90	19.5	7.9	270
		09-23-86	2000	--	815	785	8.53	7.90	18.5	9.3	280
		09-23-86	2200	--	900	--	8.67	--	17.0	9.2	--
		09-23-86	2200	--	900	777	8.67	7.90	17.0	9.2	270

Station identification number	Date	Alkalinity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, suspended (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
460731098053818	09-23-86	252	--	620	62	30	79	2	10	150	37	0.20	0.022
	05-04-87	215	--	--	49	25	49	1	--	120	20	--	--
	05-08-87	210	--	--	45	24	48	1	--	91	17	--	--
	05-21-87	177	--	--	37	20	40	1	--	79	15	--	--
	05-28-87	187	--	--	43	23	45	1	--	92	17	--	--
	06-04-87	230	--	--	56	30	56	2	--	140	22	--	--
	08-03-87	217	--	--	51	23	38	1	14	83	15	0.20	--
	08-03-87	219	--	--	53	24	38	1	13	84	15	0.20	--
	08-03-87	217	--	--	54	23	37	1	12	85	15	0.20	--
	08-03-87	214	--	--	51	23	37	1	12	86	14	0.20	--
	08-04-87	201	--	--	46	22	39	1	11	87	12	0.20	--
	08-04-87	202	--	--	46	22	41	1	11	86	12	0.20	--
	08-05-87	197	--	--	46	22	40	1	11	85	12	0.20	--
	08-06-87	194	--	--	44	21	39	1	11	84	13	0.20	--
	08-07-87	199	--	--	46	22	40	1	11	87	12	0.20	--
	08-12-87	204	--	--	45	23	42	1	12	91	13	0.10	--
	08-20-87	206	--	--	47	23	44	1	11	100	14	0.20	--
	08-28-87	193	--	--	49	24	46	1	13	100	14	0.20	--
460731098053301	09-23-86	189	--	308	59	23	11	0.3	3.1	19	2.7	0.30	0.18
	09-23-86	188	--	335	59	23	11	0.3	2.9	20	3.0	0.30	0.059
	09-23-86	186	--	304	59	23	11	0.3	2.9	18	1.8	0.30	0.038
	09-23-86	186	--	400	59	23	11	0.3	2.9	16	1.3	0.30	0.037
	09-23-86	181	--	320	60	24	12	0.3	3.2	17	1.5	0.30	0.040
	09-23-86	185	--	396	65	26	12	0.3	3.0	23	2.1	0.30	0.040
	09-24-86	188	--	335	66	26	12	0.3	3.0	29	4.4	0.30	0.041
	09-24-86	188	--	415	64	25	12	0.3	3.1	20	2.1	0.30	0.13
	10-01-86	215	--	493	84	33	12	0.3	3.4	110	25	0.30	0.064
	10-08-86	209	--	447	83	32	12	0.3	3.4	120	24	0.30	0.052
	10-14-86	198	--	480	79	30	11	0.3	3.8	120	24	0.30	0.049
460731098053302	10-01-86	193	67	460	50	24	49	1	14	110	25	0.10	<0.010
	10-08-86	259	37	567	66	35	68	2	13	150	33	0.10	0.028
	10-14-86	272	14	604	69	35	68	2	13	160	34	0.20	0.015
460731098053303	09-23-86	250	--	560	59	28	69	2	11	140	29	0.20	0.50
	09-23-86	249	--	545	60	29	69	2	11	140	28	0.20	0.066
	09-23-86	249	--	567	61	30	72	2	11	140	28	0.20	0.023
	09-23-86	--	--	--	--	--	--	--	--	--	--	--	--
	09-23-86	249	--	553	60	29	70	2	10	140	28	0.20	0.025

Station identification number	Date	Silica, dis-solved (mg/L as SiO_2)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, Am-monia + organic dis-solved (mg/L as N)	Phos-phorous, dis-solved (mg/L as P)	Phos-phorous, ortho dis-solved (mg/L as P)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cadmium, dis-solved (µg/L as Cd)	Cobalt, dis-solved (µg/L as Co)	Copper, dis-solved (µg/L as Cu)
460731098053818	09-23-86	14	<0.010	<0.100	0.030	1.6	0.030	0.050	--	--	--	--	--
	05-04-87	9.6	--	--	--	--	--	--	50	<0.5	<1	<3	<10
	05-08-87	8.1	--	--	--	--	--	--	49	<0.5	<1	<3	<10
	05-21-87	2.2	--	--	--	--	--	--	35	<0.5	<1	<3	<10
	05-28-87	2.5	--	--	--	--	--	--	36	<0.5	<1	<3	<10
	06-04-87	13	--	--	--	--	--	--	61	<0.5	<1	<3	<10
	08-03-87	19	--	<0.100	0.250	--	0.170	0.130	--	--	--	--	--
	08-03-87	20	--	<0.100	0.390	--	0.160	0.130	--	--	--	--	--
	08-03-87	19	--	<0.100	0.100	--	0.140	0.110	--	--	--	--	--
	08-03-87	17	--	<0.100	0.040	--	0.110	0.090	--	--	--	--	--
	08-04-87	15	--	<0.100	<0.010	--	0.090	0.070	--	--	--	--	--
	08-04-87	15	--	<0.100	0.010	--	0.100	0.060	--	--	--	--	--
	08-05-87	14	--	<0.100	<0.010	--	0.090	0.050	--	--	--	--	--
	08-06-87	14	--	<0.100	<0.010	--	0.070	0.060	--	--	--	--	--
	08-07-87	14	--	<0.100	<0.010	--	0.070	0.050	--	--	--	--	--
	08-12-87	12	--	<0.100	0.010	--	0.070	0.040	--	--	--	--	--
	08-20-87	9.9	--	<0.100	<0.010	--	0.060	0.030	--	--	--	--	--
	08-28-87	8.3	--	<0.100	<0.010	--	0.060	<0.010	--	--	--	--	--
460731098053301	09-23-86	32	<0.010	16.0	0.050	1.2	0.020	0.020	--	--	--	--	--
	09-23-86	32	<0.010	16.0	0.040	0.50	0.020	0.020	--	--	--	--	--
	09-23-86	31	<0.010	<0.100	0.040	1.1	0.020	<0.010	--	--	--	--	--
	09-23-86	31	<0.010	<0.100	0.040	0.70	0.020	<0.010	--	--	--	--	--
	09-23-86	31	<0.010	<0.100	0.070	0.70	0.020	<0.010	--	--	--	--	--
	09-23-86	31	0.010	23.0	0.030	0.60	0.030	0.020	--	--	--	--	--
	09-24-86	32	<0.010	22.0	0.020	0.60	0.020	0.020	--	--	--	--	--
	09-24-86	32	<0.010	21.0	0.030	1.3	0.020	0.020	--	--	--	--	--
	10-01-86	34	0.010	2.70	0.040	<0.20	0.040	0.020	--	--	--	--	--
	10-08-86	35	<0.010	<0.100	0.020	0.90	0.030	0.020	--	--	--	--	--
	10-14-86	36	<0.010	<0.100	0.020	0.60	0.040	0.030	--	--	--	--	--
460731098053302	10-01-86	19	0.020	0.250	0.030	<0.40	0.060	0.060	--	--	--	--	--
	10-08-86	21	<0.010	<0.100	0.030	0.90	0.090	0.090	--	--	--	--	--
	10-14-86	21	<0.010	<0.100	0.020	0.70	0.130	0.130	--	--	--	--	--
460731098053303	09-23-86	14	<0.010	<0.100	0.020	0.80	0.020	0.050	--	--	--	--	--
	09-23-86	15	<0.010	<0.100	0.020	2.9	0.040	0.050	--	--	--	--	--
	09-23-86	15	<0.010	<0.100	0.040	1.4	0.050	0.030	--	--	--	--	--
	09-23-86	--	--	--	--	--	--	--	--	--	--	--	--
	09-23-86	15	<0.010	<0.100	0.030	1.5	0.050	0.040	--	--	--	--	--

Station identification number	Date	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Lithium, dis- solved (µg/L as Li)	Manga- nese, dis- solved (µg/L as Mn)	Molyb- denum, dis- solved (µg/L as Mo)	Stron- tium, dis- solved (µg/L as Sr)	Vana- dium, dis- solved (µg/L as V)	Zinc, dis- solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053818	09-23-86	9	--	--	100	--	--	--	--	12
	05-04-87	9	<10	35	94	<10	220	<6	<3	15
	05-08-87	6	<10	35	61	<10	200	<6	5	10
	05-21-87	<3	<10	24	20	<10	170	<6	<3	10
	05-28-87	19	<10	35	29	<10	200	<6	8	14
	06-04-87	6	<10	42	19	<10	250	<6	<3	6.6
	08-03-87	13	--	--	550	--	--	--	--	19
	08-03-87	10	--	--	820	--	--	--	--	18
	08-03-87	9	--	--	940	--	--	--	--	17
	08-03-87	7	--	--	470	--	--	--	--	17
	08-04-87	<3	--	--	76	--	--	--	--	16
	08-04-87	6	--	--	48	--	--	--	--	16
	08-05-87	5	--	--	13	--	--	--	--	15
	08-06-87	15	--	--	7	--	--	--	--	15
	08-07-87	7	--	--	4	--	--	--	--	15
	08-12-87	7	--	--	4	--	--	--	--	14
	08-20-87	6	--	--	<1	--	--	--	--	14
	08-28-87	<3	--	--	2	--	--	--	--	12
460731098053301	09-23-86	40	--	--	9	--	--	--	--	2.4
	09-23-86	9	--	--	15	--	--	--	--	1.9
	09-23-86	5	--	--	20	--	--	--	--	1.9
	09-23-86	13	--	--	21	--	--	--	--	3.5
	09-23-86	5	--	--	38	--	--	--	--	4.9
	09-23-86	<3	--	--	19	--	--	--	--	2.4
	09-24-86	4	--	--	10	--	--	--	--	2.1
	09-24-86	7	--	--	13	--	--	--	--	2.7
	10-01-86	8	--	--	21	--	--	--	--	1.7
	10-08-86	4	--	--	10	--	--	--	--	4.0
	10-14-86	8	--	--	8	--	--	--	--	
460731098053302	10-01-86	15	--	--	120	--	--	--	--	5.7
	10-08-86	10	--	--	76	--	--	--	--	11
	10-14-86	17	--	--	20	--	--	--	--	11
460731098053303	09-23-86	21	--	--	100	--	--	--	--	12
	09-23-86	27	--	--	97	--	--	--	--	
	09-23-86	7	--	--	76	--	--	--	--	12
	09-23-86	--	--	--	--	--	--	--	--	14
	09-23-86	17	--	--	73	--	--	--	--	--

Station identification number	Local identifier	Date	Time	Sampling depth (feet below land surface)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Temperature water (deg. C)	Oxygen, dissolved (mg/L)	Hardness total (mg/L as $CaCO_3$)
460731098053303	131-059-29DDCD3	09-24-86	1000	--	900	773	8.70	8.10	15.5	7.1	270
		09-24-86	1300	--	880	756	8.72	8.10	18.5	6.9	270
460731098053304	131-059-29DDCD4	09-24-86	0750	3.00	860	--	8.04	--	15.0	6.1	--
		09-26-86	1000	3.00	--	--	--	--	--	--	--
		10-01-86	1530	3.00	752	661	8.36	8.20	17.0	6.2	220

Station identification number	Date	Alka-linity lab (mg/L as $CaCO_3$)	Solids, residue at 105 deg. C, sus-pended (mg/L)	Solids, residue at 180 deg. C, dis-solved (mg/L)	Calcium dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Sodium ad-sorp-tion ratio	Potas-sium, dis-solved (mg/L as K)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)
460731098053303	09-24-86	257	--	547	59	29	69	2	11	140	28	0.20	<0.010
	09-24-86	244	--	512	60	29	66	2	10	130	28	0.20	0.029
460731098053304	09-24-86	--	--	--	--	--	--	--	--	--	--	--	--
	09-26-86	--	--	--	--	--	--	--	--	--	--	--	--
	10-01-86	206	--	--	64	14	54	2	--	110	29	0.20	--

Station identification number	Date	Silica, dis- solved (mg/L as SiO_2)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, NO_2+NO_3 dis- solved (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, Am- monia + organic dis- solved (mg/L as N)	Phos- phorous, dis- solved (mg/L as P)	Phos- phorous, ortho dis- solved (mg/L as P)	Barium, dis- solved (µg/L as Ba)	Beryl- lium, dis- solved (µg/L as Be)	Cadmium, dis- solved (µg/L as Cd)	Cobalt, dis- solved (µg/L as Co)	Copper, dis- solved (µg/L as Cu)
460731098053303	09-24-86	15	<0.010	<0.100	0.040	1.0	0.040	0.030	--	--	--	--	--
	09-24-86	16	<0.010	<0.100	0.040	1.2	0.030	0.040	--	--	--	--	--
460731098053304	09-24-86	--	--	--	--	--	--	--	--	--	--	--	--
	09-26-86	--	--	--	--	--	--	--	--	--	--	--	--
	10-01-86	--	--	--	--	--	--	--	--	--	--	--	--

Station identification number	Date	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Lithium, dis- solved (µg/L as Li)	Manga- nese, dis- solved (µg/L as Mn)	Molyb- denum, dis- solved (µg/L as Mo)	Stron- tium, dis- solved (µg/L as Sr)	Vana- dium, dis- solved (µg/L as V)	Zinc, dis- solved (µg/L as Zn)	Carbon, organic total (mg/L as C)
460731098053303	09-24-86	11	--	--	56	--	--	--	--	14
	09-24-86	6	--	--	51	--	--	--	--	
460731098053304	09-24-86	--	--	--	--	--	--	--	--	13
	09-26-86	--	--	--	--	--	--	--	--	--
	10-01-86	12	--	--	--	--	--	--	--	--