Prepared in cooperation with the
STATE OF OKLAHOMA OFFICE OF THE ATTORNEY GENERAL

Reconnaissance of the Hydrology, Water Quality, and Sources of Bacterial and Nutrient Contamination in the Ozark Plateaus Aquifer System and Cave Springs Branch of Honey Creek, Delaware County, Oklahoma, March 1999–March 2000

Water-Resources Investigations Report 00–4210

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

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By Jamie L. Schlottmann,
Ralph Tanner, University of Oklahoma, and
Mansour Samadpour, University of Washington

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Conversion Factors and Datum

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F = (1.8 × °C) + 32

Vertical coordinate information is referenced to the North American Vertical Datum of 1998 (NAVD 88).

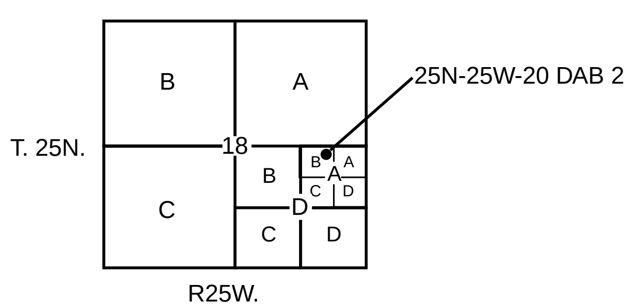
Horizontal coordinate information is referenced to the North American Datum of 1998 (NAD 88).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25˚C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Local identifier: The locations of the wells are specified by latitude and longitude to the nearest second and by a local identifier, which is based on the public land survey. The local identifier includes the township and range followed by the section and a series of letters that designate the quarter-section subdivisions from largest to smallest. The order of the quarter-section subdivisions is opposite of that used by the public land survey. A sequence number is added to make the local identifier unique in the U.S. Geological Survey data base. As illustrated in the following diagram, the public land survey description of the site indicated by the dot is NW 1/4 NE 1/4 SE 1/4 sec. 20, T. 25 N., R. 25 W., which is denoted by the local identifier 08N-02W-18 DAB. If the sequence number is 2, the complete identifier is 25N-25W-20 DAB 2.



Reconnaissance of the Hydrology, Water Quality, and Sources of Bacterial and Nutrient Contamination in the Ozark Plateaus Aquifer System and Cave Springs Branch of Honey Creek, Delaware County, Oklahoma, March 1999-March 2000

By Jamie L. Schlottmann, Ralph S. Tanner, and Mansour Samadpour

Abstract

A reconnaissance investigation of hydrology and water quality was conducted to evaluate possible sources of bacteria and nutrient contamination in the Cave Springs Branch basin and the underlying karstic Ozark Plateau aquifer system. Objectives were to: (1) determine the directions of ground-water flow in the basin and determine whether Cave Springs Branch interacts with ground water, (2) compare water quality in Cave Springs Branch with water quality in nearby wells to determine whether the stream is contaminating nearby wells, and (3) determine sources of fecal coliform bacteria and nitrate contamination in Cave Springs Branch and ground water. Potential sources of bacteria and nitrate in the area include cultivated agriculture, cow and horse on pasture, poultry production, households, and wildlife. Presence of fecal coliform and fecal streptococcal bacteria directly indicate fecal contamination and the potential for the presence of other pathogenic organisms in a water supply. Nitrate in drinking water poses health risks and may indicate the presence of additional contaminants.

Fecal coliform bacteria colony counts were least in wells, intermediate in the poultry-processing plant wastewater outfall and Honey Creek above the confluence with Cave Springs Branch, and greatest in Cave Springs Branch. Bacteria strains and resistance to antibiotics by some bacteria indicate that livestock may have been sources of some bacteria in the water samples. Multiple antibiotic resistances were not present in the isolates from the water samples, indicating that the bacteria may not be from human or poultry sources.

Ribotyping indicates that *Escherichia coli* bacteria in water samples from the basin were from bird, cow, horse, dog, deer, and human sources. The presence of multiple ribotypes from each type of animal source except bird indicates that most of the bacteria are from multiple populations of source animals. Identifiable sources of bacteria in Cave Springs Branch at the state line were dominantly cow and horse with one ribotype from bird. *Escherichia coli* was detected in only one well sample. Bacterial ribotypes in water from that upgradient well indicated human and dog feces as sources for bacteria, and that on site wastewater treatment may not always be adequate in these highly permeable soils.

Greater concentrations of nitrate in Cave Springs Branch and O'Brien Spring relative to the poultry-processing plant wastewater outfall may be due, in part, to conversion of ammonia from poultry processing plant wastewater. The poultry-processing plant wastewater outfall sample collected in March 2000 contained greater concentrations of ammonia and total organic nitrogen plus ammonia than the spring, stream, and well samples collected during August 1999. Cave Springs Branch and Honey Creek contributed approximately equal loads of nitrogen to Honey Creek below the confluence and the greatest loads of nitrogen were introduced to Cave Springs Branch by the poultry processing plant wastewater outfall and O'Brien Spring. Nitrate concentrations in upgradient well samples ranged from 0.38 to 4.60 milligrams per liter, indicating that there are sources of ground-water nitrogen other than Cave Springs Branch, such as animal waste, fertilizer, or human waste. Nitrogen compounds in water from wells downgradient of Cave Springs Branch may be from Cave Springs Branch, fertilizers, animal waste, or human waste.

Introduction

With increased number and size of concentrated poultry operations and an associated poultry-processing plant in the Cave Springs basin and part of the Honey Creek basin, northeastern Oklahoma, and southeastern Missouri (fig.1), concern has grown about the quality of water in the streams and the underlying Ozark Plateau aquifer system. In response to this concern, the U.S. Geological Survey, in cooperation with the Oklahoma Office of the Attorney General, conducted reconnaissance hydrologic and water-quality investigations to evaluate the potential sources of bacteria and nutrient contamination in the Cave Springs Branch basin and the underlying karstic Ozark Plateau aquifer system.

Investigation objectives were to: (1) determine the directions of ground-water flow in the Cave Springs Branch basin and whether Cave Springs Branch interacts with ground water in the Ozark Plateau aquifer system, (2) compare water quality in Cave Springs Branch with the quality of water in water from nearby wells to determine whether water from Cave Springs Branch could be contaminating nearby wells completed in the Ozark Plateaus aquifer system, and (3) determine sources of coliform bacteria and nitrate plus nitrite as nitrogen (referred to as nitrate in this report) contamination in Cave Springs Branch and water in the Honey Creek Basin.

Potential sources of bacteria and nitrate in the area include cultivated agriculture, livestock pasture, poultry production, households, and wildlife. Poultry litter from local poultry production and poultry production in adjacent basins is spread to fertilize hay fields in the Honey Creek Basin. Cattle and horses graze throughout the area and many have access to Cave Springs Branch. Treated wastewater from a poultry-processing plant in Missouri, which includes some human wastewater from plant employees, is discharged to Cave Springs Branch about 0.7 mile upstream of the state line (fig. 1). Household wastewater is disposed of on site in cesspools or septic systems, although many of the soils in the basin are not rated as suitable for onsite disposal by the U.S. Department of Agriculture (table 5, 1970). Wildlife, including deer, coyote, rabbit, turkey, and waterfowl, also are potential sources of the contamination.

Presence of fecal coliform and fecal streptococcal bacteria directly indicate fecal contamination and the potential for the presence of other pathogenic organisms in a water supply. The maximum contaminant level of total coliform bacteria in drinking water is one colony-forming unit per 100 milliliters (U.S. Environmental Protection Agency, 1996).

Nitrate in drinking water poses health risks and may indicate the presence of additional contaminants. Nitrate is derived from the natural breakdown of inorganic fertilizers, soils, and animal wastes. Nitrate concentrations greater than 3 milligrams per liter in ground water are commonly associated with agricultural land use and disposal of human wastes (Madison and Brunett, 1985). Drinking water with nitrate concentrations greater than the recommended limit of 10 milligrams per liter as nitrogen can cause methemoglobinemia (“blue-baby” syndrome) (U.S. Environmental Protection Agency, 1996).

Purpose and Scope

This report describes results of a reconnaissance investigation of the hydrology, water quality, and sources of bacteria and nutrient contamination in streams and ground water near Cave Springs Branch of Honey Creek, and Honey Creek, in Delaware County, Oklahoma, May 1999-March 2000. This report characterizes: (1) The hydrogeologic units in the region and the directions of ground- and surface-water flow with maps of water-table altitudes during greater and lower stream flow and maps showing gaining and losing reaches of the streams; (2) the quality of water with diagrams comparing differences in water chemistry and bacterial counts between streams and wells, and tables describing the distribution of fecal bacteria, antibiotic resistance in *Escherichia coli*, and ribotypes of *Escherichia coli* in the ground and surface water; and (3) indications of probable sources of bacteria and nitrate detected in the ground water.

Description of Study Area

The 34-square-mile study area is in the Ozark Plateau physiographic province. The topography is characterized by steep slopes bounding flat floodplains (fig. 2). A topographic high 70 to 100 feet above the streams divides Cave Springs Branch from Honey Creek.

The greatest amounts of precipitation in the study area occur during March through May and September through October. January, February, July, and August typically have the least precipitation. Fall 1997 and spring 1998 were unusually dry and the spring 1999 rains did not end until late June (fig. 3). Honey Creek and Cave Springs Branch generally respond rapidly to precipitation in the stream basins (fig. 3). The two streams did not rise after it rained heavily at the Mesonet site where the Oklahoma Climatological Survey measures precipitation and other weather characteristics near Jay, Oklahoma (latitude: 36° 28′ 54″ N, longitude: 94° 46′ 59″ W), possibly because those storms were localized near the Mesonet site.

Previous Investigations

Previous investigations have indicated that ground water near Cave Springs Branch and Honey Creek (fig. 1) had been contaminated by nitrate and bacteria. The State of Oklahoma Department of Environmental Quality sampled Honey Creek, Cave Springs Branch, and wells located within one-half mile of Cave Springs Branch and Honey Creek below the confluence with Cave Springs Branch in June 1996 (Jon L. Craig, Oklahoma Department of Environmental Quality, written commun., August 27, 1996). Nineteen of 28 wells yielded water with detectable total coliform bacteria. Ammonia was detected in water samples from seven wells (0.17 to 0.29 milligram per liter); five of those samples also tested positive for total coliform. Nitrate was detected in water samples from 10 wells (0.8 to 2.3 milligrams per liter), nine of which tested positive for total coliform.

Later sampling of a larger network of wells confirmed contamination of ground water by nitrate, bacteria, and arsenic. The Oklahoma Department of Environmental Quality sampled 55 wells on September 9-10, 1996, and detected bacteria and elevated nitrate concentrations. The water samples were analyzed for counts of total coliform, *Escherichia coli*, fecal coliform, and fecal streptococci bacteria, and concentrations of nitrate, and arsenic (Jon L. Craig, Oklahoma Department of Environmental Quality, written commun., September 26, 1996). Thirty-one samples tested positive for total coliform. Five of those

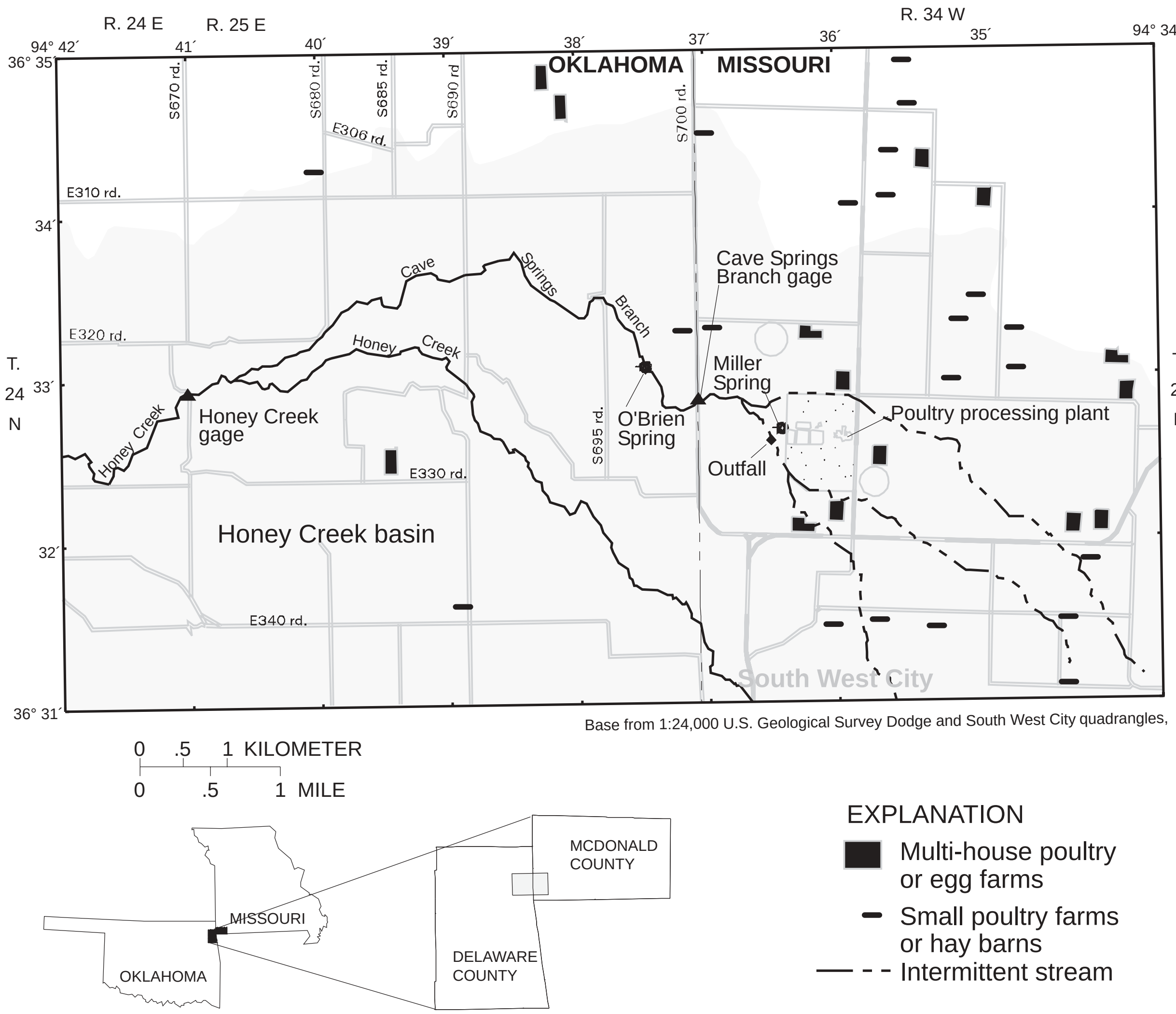


Figure 1. Location of study area.

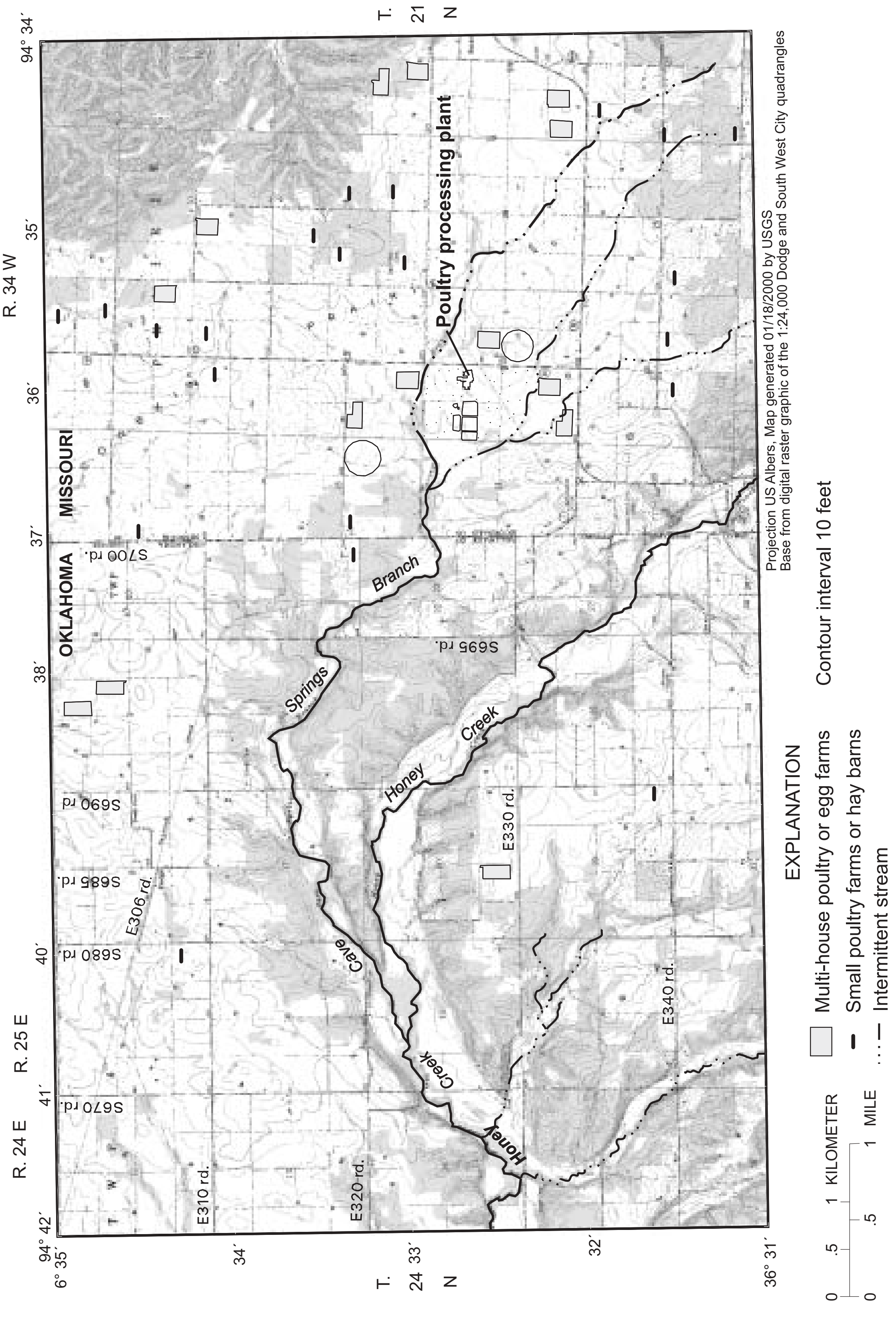


Figure 2. Topography of the study area.

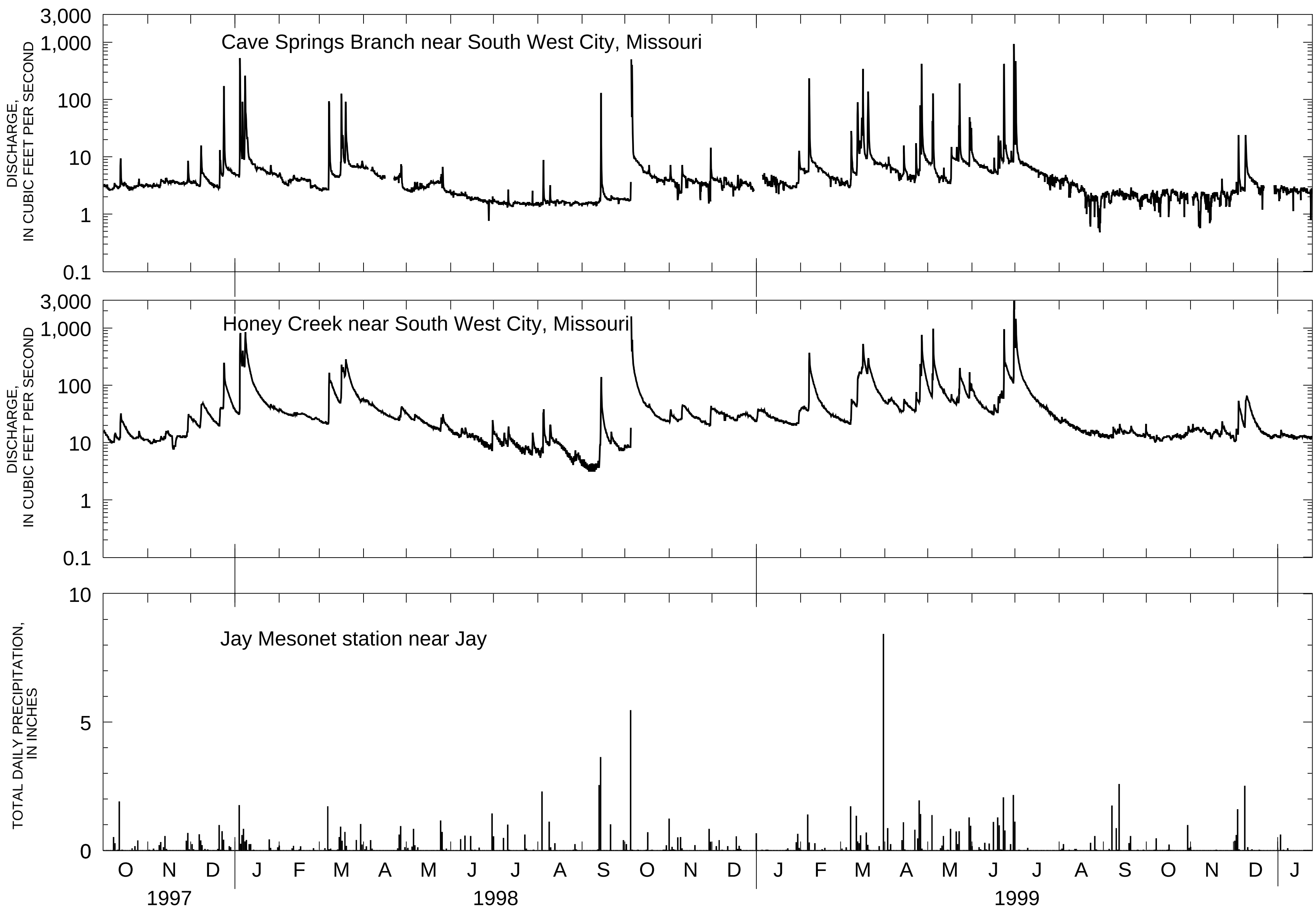


Figure 3. Total daily precipitation at the Jay Mesonet site near Jay Oklahoma, and discharge of Cave Springs Branch and Honey Creek, near South West City, Missouri.

samples also tested positive for fecal coliform and four for *Escherichia coli*. Water from one well had a nitrate concentration of 10 milligrams per liter and water from 13 wells had nitrate concentrations exceeding 3 milligrams per liter. Thirty-nine micrograms per liter of arsenic was detected in one well; otherwise, arsenic concentration was less than 10 micrograms per liter.

A fluorescein-tracer study conducted in 1998 by the Missouri Department of Natural Resources, Geological Survey Program indicated the existence of a hydrogeologic connection between a poultry processing plant storm water basin and Miller and O'Brien Springs (fig. 1) (Jerry L. Prewett, Missouri Department of Natural Resources, Geological Survey Program, written commun., September 1998). Fluorescein tracer was visible in Miller Spring less than 36 hours after injection into the basin and was detected in O'Brien Spring within six days of the injection. Fluorescein tracer transport to Miller Spring was through ground water. Fluorescein tracer transport to O'Brien Spring may have been through both surface and ground water.

Stream discharge measurements made by the Missouri Department of Natural Resources, Geological Survey Program in December 1999, indicated that discharge from the poultry-processing plant wastewater outfall was a substantial part of the water in the stream and that stream discharge was lost to ground water in a reach above the state-line gage (Ed Knight, Missouri Department of Natural Resources, written commun., February 2000). Discharge was measured upstream of the poultry-plant wastewater outfall and at four points downstream of the outfall on five days during December 14-28, 1999. Discharge from the outfall ranged from 0.97 to 2.23 cubic feet per second during stream discharge measurements and 64 to 94 percent of stream discharge below the outfall was attributable to discharge from the outfall. Eight to 22 percent of stream discharge was lost to ground water in a reach extending about 600 feet above the state-line gage.

Water quality has been documented through water sampling and analysis of Cave Springs Branch and Honey Creek at the Oklahoma-Missouri state line by the U.S. Geological Survey in cooperation with the Oklahoma Water Resources Board. The U.S. Geological Survey has monitored bacteria and nutrient concentrations monthly at the state-line gage on Cave Springs Branch from August 1997, to present (April 2000) (August 1997 through September 1999 in table 7, at the back of the report, Blazs and others, 1998, 1999, and 2000). Nitrate concentration was less than 15 milligrams per liter as nitrogen in only three of 19 samples with concentrations as great as 117 milligrams per liter measured prior to March 1999. Since then, nitrate concentrations have been less than 15 milligrams per liter. The greatest nitrate concentration was measured in August 1998, when instantaneous stream discharge was less than 2 cubic feet per second. Total phosphorus concentration was less than 0.66 milligram per liter in only two of 19 samples prior to April 1999, with a greatest concentration of 9.33 milligrams per liter. All 11 samples collected after April 1999 have had total phosphorus concentrations less than 0.66 milligrams per liter. The range of bacterial counts do not appear to have changed since 1997. Counts of fecal coliform, *Escherichia coli*, and fecal streptococcal bacteria colonies ranged from fewer than 1 to an estimated 46,000 per 100 milliliters, estimated 2 to 24,000 per 100 milliliters, and estimated 28 to 38,000 colonies per 100 milliliters, respectively (fig. 4, Appendix 1). The greatest bacterial counts occurred during March and May 1999 when stream discharge was greater than 20 cubic feet per second. Fecal coliform, *Escherichia coli*, and fecal streptococcal bacteria had maximum counts of 2,400, 790, and 5,000 colonies per 100 milliliters, respectively, during the remainder of the monitoring period, when stream discharge was less than 10 cubic feet per second.

Approach and Methods

The altitude of the water table was measured in streams and domestic wells during the weeks of May 17 and August 23, 1999. Water-table altitudes were measured in 36 wells and at 21 stream sites (fig. 5, Appendix 2). Stream discharge was measured at 21 stream sites on May 19-20, 1999, and 19 stream sites on August 24, 1999 (fig. 5, Appendix 2). Wells are reported to be 32.35 to 456 feet deep, with about 40 feet of casing in deeper wells and open-hole beneath (Ed Eckenstein, Oklahoma Water Resources Board, written commun., March 25, 1999).

Altitudes were determined with the differential global positioning system or topographic maps. Water-surface altitudes at seven stream sites on Cave Springs Branch and at sites S.14, S.17, S.18, S.20, and S.21 on Honey Creek were determined to within 0.3 foot using the global positioning system. Altitudes of the water table at site S.13 on Cave Springs Branch and sites S.15, S.16, and S.19 along Honey Creek were determined to within 5.0 feet based on 7.5-minute U.S. Geological Survey topographic maps. One well near Cave Springs Branch (W.13) had a continuous water-level recorder installed to monitor changes in water-table altitude in response to changes in stream altitude. The altitude of the well measuring point was determined using the global positioning system to within 0.3 foot at sites W.5, W.11, W.13, W.18, W.21, W.25, W.28, and W.31 because measurements at those sites indicated the water-table altitude was near or below the stream altitude. Altitudes at additional sites W.19, W.20, W.22, W.33, W.34, and W.35 also were determined to within 0.3 foot. The altitude was read from 7.5-minute U.S. Geological Survey topographic maps for other locations, because water-table altitude appeared to be more than 5 feet above the nearest stream altitude site. Altitude of the water table was determined from the altitude of the measuring point at top of the well with a steel tape.

Well-water levels were considered stable when measurements taken at 5-minute intervals were equal. Water levels at sites W.6, W.9, W.11, W.21, W.32, and W.35 did not stabilize and were recovering at a decreasing rate of about 0.01 foot per five minutes at the time of measurement, so static water levels may have been somewhat greater at those sites. The slow recovery in those wells may indicate they are open to less permeable parts of the aquifer system. Water level at site W.3 did not sta-

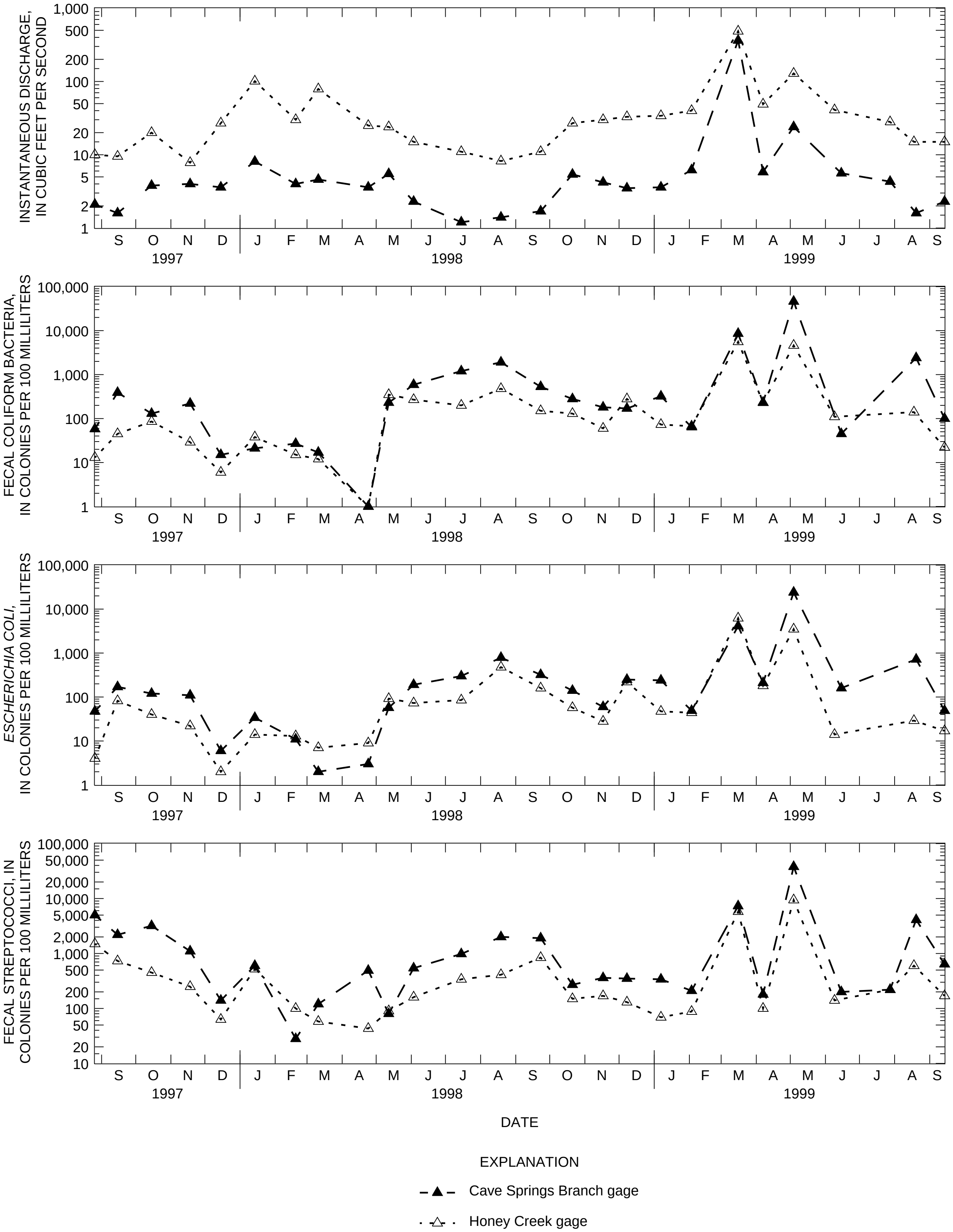


Figure 4. Stream discharge and fecal indicator bacteria in Cave Springs Branch and Honey Creek water samples August 1997 through September 1999.

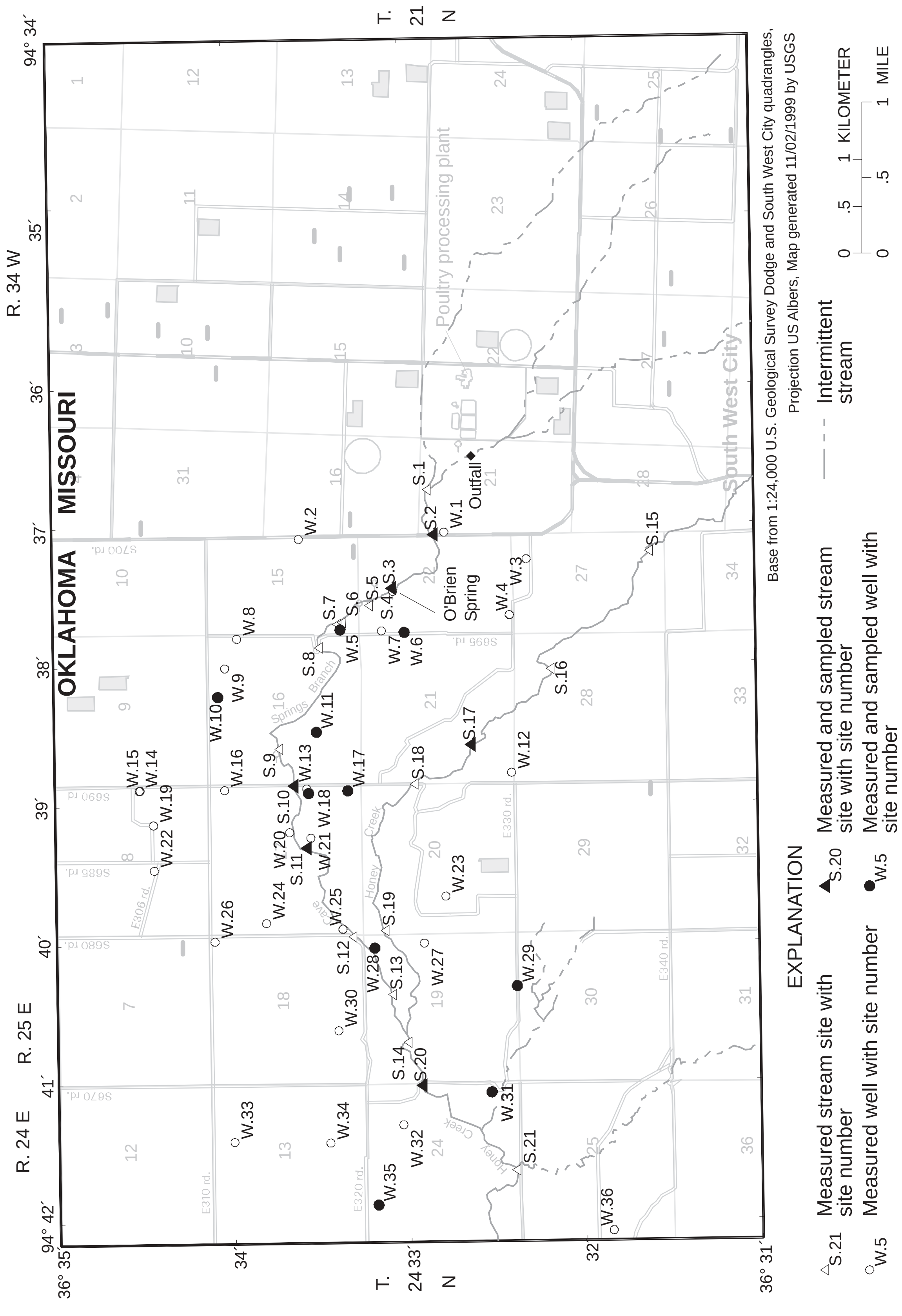


Figure 5. Locations of water-table measurements and sampling sites.

bilize during the August measurement because of intermittent pumping during measurement.

Wells were selected for contouring of the water-table surface based on the altitude of the well bottom and nearly stable water level. Well-water levels for W.11, W.17, W.18, W.21, W.33, and W.35 were not used because the altitudes of the bases of the wells were below 600 feet, whereas the bottoms of other measured wells had base altitudes above 750 feet. Deeper wells may be completed in a deeper flow system, which may be isolated from the flow system tapped by shallower wells. The August water-level measurement for site W.3 was not used because the water level was not stable.

Locations of gaining and losing reaches in the streams were determined by measuring the discharge in Cave Springs Branch and Honey Creek at intervals along the streams. Stream discharge was measured using stream-gaging techniques described in Buchanan and Somers (1969) and Carter and Davidian (1968). Individual or combined intervals where measured discharge decreased by 10 percent or more were considered to be losing reaches. The threshold of 10 percent was selected because that is the accuracy of the measurement technique (Carter and Davidian, 1968).

Seventeen water-sampling sites were selected from the 56 sites where water-table altitude was measured (fig. 5) based on the directions of ground-water flow and on distribution of contaminants reported in earlier studies by the Oklahoma Department of Environmental Quality. Seven sites were on Cave Springs Branch and Honey Creek and 10 sites were wells. Six of the seven stream sampling sites (S.2, S.3, S.4, S.10, S.11, and S.20) were located on Cave Springs Branch and Honey Creek in areas that previous studies had indicated were contaminated. The seventh stream sample (S.17) was collected from Honey Creek upstream of any suspected influence from Cave Springs Branch as a background sample.

Seven of the 10 wells selected for sampling (W.6, W.10, W.11, W.17, W.29, W.31, and W.35) were located on topographically high areas hydraulically upgradient from the stream. Wells W.11 and W.17 were open to deeper parts of the aquifer system (below 600 feet in altitude) and were not used to construct the water-table map because they had water levels higher than water table altitudes. The higher water-table, however, indicates W.11 and W.17 were upgradient of the streams, contrary to the water-table altitude for shallower parts of the aquifer in the same area. Two of the upgradient wells (W.6 and W.31) had bacterial contamination in the Oklahoma Department of Environmental Quality study. The other five wells (W.10, W.11, W.17, W.29, and W.35) were believed to be background wells, based on bacteria and nutrient data available at that time. Three wells (W.5, W.18, and W.28) were located near Cave Springs Branch, where ground water may be most susceptible to contamination by stream water.

Water samples were collected during August 1999 to determine the chemical composition of stream and ground water. Two additional samples were collected during March 2000 at the poultry-processing plant wastewater outfall and site S.2 to determine whether the outfall could be a source of organic chemicals, sodium, chloride, and nutrients in samples previously collected in August 1999. Wells were purged of water by pumping until two equivalent values were determined for specific conductance, pH, water temperature, and dissolved oxygen concentration prior to sampling to ensure that water was representative of water quality in the aquifer. Specific conductance, pH, water temperature, dissolved oxygen, and alkalinity were determined at the sample site with calibrated portable electronic meters. These physical properties for streams were measured by sensors placed in the stream and for wells by sensors inserted in a flow-through cell. Alkalinity was measured by incremental titration (Wells and others, 1990, p. 53-56). Water samples were collected and preserved using techniques described in Wilde and Radtke (1998) (table 1). Stream samples were collected at equal width increments along cross-sections and were composited in Teflon® churn splitters. Filtered well-

Table 1. Field procedures used in the Honey Creek basin for collection and preservation of water samples for laboratory analysis

[dissolved, concentration in filtered sample or method detects only dissolved part; total, total recoverable concentration including suspended and colloidal solids; °C, degrees Celsius]

Constituents	Filter type used	Collection-bottle type	Preservation method
Major cations, iron and manganese, dissolved	0.45-micrometer cartridge filter	250-milliliter acid-rinsed polyethylene	Nitric acid to pH 2 or less
Major anions, dissolved	Unfiltered	250-milliliter polyethylene	Chill to 4°C
Major anions and water properties	Filtered	500-milliliter polyethylene	Chill to 4°C
Nutrients, total	Unfiltered	125-milliliter polyethylene	Sulfuric acid to pH less than 2, chill to 4°C
Nutrients, dissolved	0.45-micrometer cartridge filter	125-milliliter amber polyethylene	Chill to 4°C
Arsenic	0.45-micrometer cartridge filter	250-milliliter acid-rinsed polyethylene	Nitric acid to pH 2 or less
Selenium	0.45-micrometer cartridge filter	500-milliliter acid-rinsed polyethylene	Ultrex nitric acid to pH 2 or less
Stable isotopes of hydrogen and oxygen	Unfiltered	60-milliliter glass with poly-seal cap	None
Wastewater indicator compounds	Unfiltered	1 liter amber glass with Teflon® seal cap	Chill to 4°C

$$\delta D \text{ in permil } = \left[\frac{(\text{Deuterium}/{}^{1}\text{Hydrogen})_{\text{sample}} - (\text{Deuterium}/{}^{1}\text{Hydrogen})_{\text{standard}}}{(\text{Deuterium}/{}^{1}\text{Hydrogen})_{\text{standard}}} \right] 1000$$

$$\delta^{18}O \text{ in permil } = \left[\frac{({}^{18}\text{Oxygen}/{}^{16}\text{Oxygen})_{\text{sample}} - ({}^{18}\text{Oxygen}/{}^{16}\text{Oxygen})_{\text{standard}}}{({}^{18}\text{Oxygen}/{}^{16}\text{Oxygen})_{\text{standard}}} \right] 1000$$

water samples were collected through 0.45-micrometer pore-size cartridge filters and precleaned polyethylene tubing attached directly to faucets located between the well pump and pressure tank, so the pressure tank did not affect water properties or chemistry. Unfiltered samples were collected directly from the same faucet. Faucets were swabbed with methanol prior to collection of samples for bacterial counts to kill any bacteria that may have been on the faucet.

Samples were collected during August 1999 for laboratory determination of major cations and anions; nitrogen and phosphorus nutrients; trace elements including iron, manganese, arsenic, and selenium; stable isotopes of hydrogen and oxygen; and organic wastewater-indicator components. Two samples were collected during March 2000 for laboratory determination of the same components except arsenic and stable isotopes of hydrogen and oxygen. Laboratory determinations, except those for selenium, stable isotopes of hydrogen and oxygen, and bacterial antibiotic resistance and ribonucleic acid ribotyping, were done at the U.S. Geological Survey

National Water Quality Laboratory in Lakewood, Colorado, using methods described in Fishman and Friedman (1989) or Jones and Garbarino (1999). Selenium concentrations were determined at a U.S. Geological Survey Laboratory in Menlo Park, California, with a Perkin Elmer Elan 6000 inductively coupled plasma mass spectrometer. Prior to analysis, a 10-milliliter aliquot of each sample was adjusted to 2 percent acidity with nitric acid distilled in Teflon®, and was amended with a known quantity of germanium as an internal standard. The U.S. Geological Survey Water Quality Laboratory in Reston, Virginia, determined hydrogen-isotope-activity ratios using a hydrogen equilibration technique at 30 degrees Celsius (Coplen and others, 1991). Oxygen-isotope ratios were measured using the carbon dioxide equilibration technique at 25 degrees Celsius (Epstein and Mayeda, 1953).

Stable isotopes of hydrogen and oxygen in water molecules can be used as natural tracers of water sources. The most common stable hydrogen isotopes are ^{1}hydrogen—with one proton in the nucleus—and ^{2}hydrogen or deuterium—with one proton and one neutron in the nucleus. The most common stable oxygen isotopes are ^{16}oxygen and ^{18}oxygen. About one in 500 oxygen atoms in water are ^{18}oxygen. Hydrogen and oxygen isotope ratios are reported as delta values (δD and $\delta^{18}O$) relative to a standard ratio, Vienna Standard Mean Ocean Water (VSMOW) as shown above.

Delta values for hydrogen and oxygen isotopes of precipitation plot along a straight line known as the regional meteoric line. Delta values of isotopes shift slightly when precipitation infiltrates the ground, because water reacts with soil gases and minerals. The slope of a line of delta values for ground-water samples, known as the regional ground-water line, generally parallels the regional meteoric line, which has not been determined for this area.

The proportion of heavier isotopes relative to lighter isotopes changes in water through evaporation. Evaporation enriches concentrations of heavier isotopes in water because water composed of lighter isotopes evaporates more readily. Water in lakes, ponds, and lagoons generally are more enriched with heavier isotopes than water in streams because of increased evaporation. Aeration in lagoons also increases evaporation. Delta values for isotopes of water depleted by evaporation will be greater than those of ground water, plotting to the right of the regional ground-water line.

Water samples collected in August 1999 for organic wastewater indicator compound determination were extracted with methylene chloride using continuous liquid-liquid extraction. The extracts were concentrated, then analyzed by selected ion monitor gas chromatography-mass spectrometry for the determination of the compounds listed in table 2. Concentrations of additional compounds including 17 beta-estradiol (hormone) and stigmastanol (fecal indicator) and cotinine (a breakdown product of nicotine) were measured in water samples collected during March 2000. The National Water Quality Laboratory in Lakewood, Colorado, analyzed a reagent water blank and reagent water spike with each set of samples to monitor method performance as part of quality control.

Table 2. List of wastewater indicator compounds and uses

Compound	Compound
Detergent metabolites	*Pharmaceutical and food*
Para-nonylphenol	Caffeine (stimulant)
NPEO1 (Nonylphenol ethoxylate-1	Codeine (analgesic)
NPEO2 (Nonylphenol ethoxylate1-2	*Plasticizers and polymer precursors*
Octylphenol, monoethoxylate	Bisphenol-A (polymer precursor)
Octylphenol, diethoxylate	Bis(2-ethylhexyl) adipate
Nonylphenol (detergent metabolite)	Bis(2-ethylhexyl) phthalate
Disinfectants	Ethanol, 2-butoxy-phosphate
Phenol	Tributyl phosphate
Triclosan	Triphenyl phosphate
Fecal indicators	Phthalic anhydride (plastic precursor)
3-Beta-coprostanol (carnivore fecal indicator)	*Polynuclear Aromatic Hydrocarbons*
Cholesterol	Anthracene
Fire retardants	Benzo(a)pyrene
Tri (2-chloroethyl) phosphate	Fluoranthene
Tri(dichloroisopropyl) phosphate	Phenanthrene
Flavoring agent	Pyrene
Benzaldehyde	*Preservatives*
Fragrance	Butylated hydroxyanisole (BHA)
Acetophenone	Butylated hydroxytoluene (BHT)
Fumigants	2,6-Di-tert-butylphenol
1,2-Dichlorobenzene	Para-cresol (wood preservative)
1,3-Dichlorobenzene	2,6-Di-tert-parabenzoquinone (antioxidant)
1,4-Dichlorobenzene	*Solvents and degreasers*
Naphthalene (also a Polynuclear Aromatic Hydrocarbon)	Ethyl acetate, 2-(2-butoxyethoxy)
Pesticides	Tetrachloroethylene
Carbaryl	
Chlorpyrifos	
Cis-chlordane	
Diazinon	
Dieldrin	
Lindane	
Methyl parathion	

Fecal coliform, *Escherichia coli*, and fecal streptococcal bacteria were cultured to characterize the distribution of these bacteria in the basin. Water samples for bacterial evaluation were chilled upon collection and were filtered and cultured within 6 hours. Counts of fecal coliform, presumptive *Escherichia coli*, and fecal streptococcal bacteria were obtained within 48 hours of collection by filtration methods described in Wilde and Radtke (1998).

Isolates of individual colonies of the presumptive *Escherichia coli* from water samples were made and analyzed at the University of Oklahoma at Norman, Oklahoma, to verify that the isolates were *Escherichia coli* and to determine the strain and antibiotic resistance of the bacteria. Colonies of the presumptive *Escherichia coli* from filter plates from the water samples were streaked on eosine-methylene blue agar (Difco® no. 0076-17) at the Department of Botany and Microbiology at the University of Oklahoma. Plates yielding flat isolated colonies with a metallic green sheen (presumptive for *Escherichia coli*) were stocked on tryptic soy agar (Difco® no. 0369-17-6). Bacterial strains were identified using the BIOLOG®, Micrology System (Solit, 1999), which is based on metabolism of 93 substrates on a single test plate (Grimont and others, 1996, Fredrickson and others, 1991). Plated isolates of presumptive *Escherichia coli* bacteria were tested by the standardized single disk method (Bauer and others 1966) for resistance to ampicillin (2 micrograms and 10 micrograms), carbenicillin (100 micrograms), cefaclor (30 micrograms), chloramphenicol (30 micrograms), ciprofloxacin (5 micrograms), erythromycin (15 micrograms), gentamicin (10 micrograms), nalidixic acid (30 micrograms), tetracycline (30 micrograms), and trimethoprim (5 micrograms).

Fecal samples were collected from multiple sources in the basin for use in comparing to the *Escherichia coli* ribonucleic acid (RNA) ribotypes of bacteria in samples from streams and wells. A ribotype match would indicate that the contamination was from that animal type within the basin. Twenty cow, 28 chicken, seven dog, eight horse or mule, six deer, two coyote and 34 human fecal source samples were collected from the basin. Animal-manure samples were collected using a sterile plastic bag. *Escherichia coli* was cultured from three septic tanks in the area by lowering a sterile sampling loop into waste and plating an environmental streak on eosine-methylene blue agar plates. The plates were incubated 3 to 5 days at ambient temperature. Iridescent colonies (presumptive *Escherichia coli*) were subcultured on eosine-methylene blue agar. Manure samples and cultures were stored and shipped at 4-degrees Celsius to the University of Washington, Seattle, Washington, and the University of Oklahoma, Norman, Oklahoma, for analysis.

Isolates of *Escherichia coli* bacteria from sites S.2, S.3, S.4, S.10, S.11, and W.31 were sent to the University of Washington, Seattle, Washington, for ribotyping using denaturing gradient gel electrophoresis method. Washington State University, Seattle, Washington, produced fragments of deoxyribonucleic acids (DNA) for ribotyping from the *Escherichia coli* isolates. The fragments were resolved by agarose gel electrophoresis and then transferred onto a nitran filter by blotting in a high salt solution. The filters were baked at 80 degrees Celsius for 1 hour to denature the double stranded DNA into single strands. The DNA on the filters was then hybridized with ribosomal ribonucleic acid (rRNA) that was tagged with radioactive phosphate-labeled d-cytidine triphosphate, while incubating for 30 minutes at 37 degrees Celsius. The radioactively tagged rRNA binds to single stranded DNA containing segments of the rRNA operon. The filters were washed, dried and exposed to X-ray film at -70 degrees Celsius to create an autoradiogram of the DNA banding that was produced during electrophoresis. The banding patterns on the autoradiograms were converted to an alphanumeric code and were compared with a computer data base of banding patterns representing bacteria from animal sources, including ribotypes for source samples collected from the basin. Autoradiograms for potential matches from the data base were then compared directly to the sample autoradiograms to confirm matches.

Acknowledgments

Thanks are extended to Jon Criger for use of his well for monitoring ground-water levels. Thanks are extended to Robert Fabian, Oklahoma Water Resources Board, and Glen Jones, Oklahoma Department of Environmental Quality, for providing drillers' logs and bacteria data from the Cave Springs Branch area. Thanks are extended to the well and land owners who allowed access to the stream and their wells for sampling and water-level measurement.

Hydrology

Ground water in the area is from the Ozark Plateau aquifer system, which includes the Springfield Plateau aquifer, the Ozark confining unit, and the Ozark aquifer. Most wells in the study area are open to the Springfield Plateau aquifer. Some deeper wells extend through the underlying Ozark confining unit into the Ozark aquifer.

The Springfield Plateau aquifer includes the Moorefield Formation, the Keokuk Limestone, and the Reeds Spring and the St. Joe Limestone members of the Boone Formation of Mississippian age (Marcher and Bingham, 1971, Imes and Emmett, 1994). Units of the Springfield Plateau aquifer crop out over the entire study area (fig. 6) and are 195 to 400 feet thick in the study area. The Moorefield Formation crops out in small areas in the northwestern part of the study area and does not supply water to wells. The Keokuk Limestone and the Boone Formation are coarse-grained limestones with abundant chert. Ground-water flow and dissolution of limestone is along fractures, joints, and bedding planes.

The Springfield Plateau aquifer yields small to moderate amounts of water suitable for most uses (Marcher and Bingham, 1971). Imes and Emmett (1994) reported that near the study area, calcium bicarbonate type water is produced from this aquifer, with 200 to 300 milligrams per liter dissolved solids.

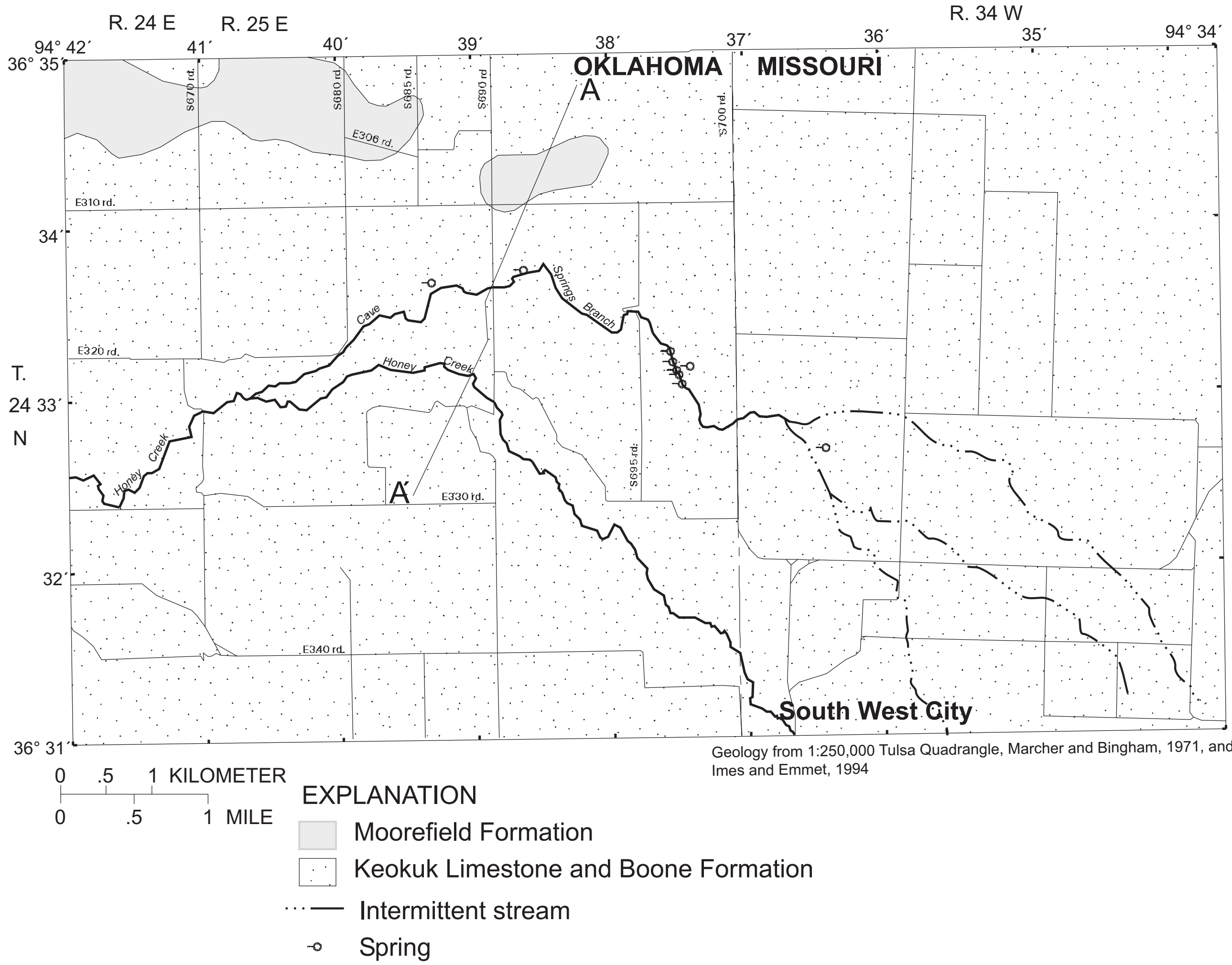


Figure 6. Geology of the study area and location of section A-A′ shown in figure 7.

The Ozark confining unit within the study area consists of 20 to 60 feet of Chattanooga Shale of Devonian age (fig. 7). The unit restricts flow of ground water between the Springfield Plateau aquifer and the underlying Ozark aquifer.

The Ozark aquifer tapped by wells in the study area comprises up to 600 feet of undifferentiated limestones of the Fernvale, Viola, and Fite Limestones, and Tyner Formation of Ordovician age (Marcher and Bingham, 1971, and Imes and Emmett, 1994). A few deeper wells intercept the Burgen Sandstone of Ordovician age.

The limestones of the Ozark aquifer produce small amounts of fair to poor quality water in northeastern Oklahoma (Marcher and Bingham, 1971). Imes and Emmett (1994) reported that the quality of water produced from this limestone near the study area is good and is a sodium calcium bicarbonate type with less than 300 milligrams per liter dissolved solids. Water from the Ozark aquifer in Ottawa County, north of the study area, commonly contains hydrogen sulfide gas that might be derived from the overlying Chattanooga Shale (Reed and others, 1955, p. 44).

Rapid infiltration rates are common in soils that overlie the Springfield Plateau aquifer. Infiltration rates of 1.1 to 30 inches per hour were indicated by percolation-rate tests done to determine the adequacy of a soil for treatment of wastewater discharged from wastewater system lateral lines (Mike Hixon, Oklahoma Department of Environmental Quality, written commun., February 1, 2000). Infiltration rates for most soils in the study area were greater than 6 inches per hour.

Ground water in the study area is rapidly recharged by precipitation. Water-table altitudes in the Cave Springs Branch basin change rapidly in response to precipitation when basin soils are moist, as in May and June 1999 (fig. 8). Effects of precipitation on ground-water levels and streamflow were less, however, after the dry period from July through November 1999 (fig. 8). The water table rose only a small amount after the first precipitation event in December, probably because dry soil and rock above the water table absorbed much of the water. The water-level increase was greater in response to the second precipitation event in December, possibly because the soil and rock above the water table were saturated from the previous event. The increase in stream stage was the same for both precipitation events. Water-table altitude varied in response to precipitation. The ground-water table beneath hills was higher in May 1999, when precipitation was plentiful than in August 1999 after a period of little precipitation (figs. 9 and 10).

In general, the direction of ground-water flow in the study area is east to west (figs. 9 and 10), however, ground water in the study area is hydraulically connected to Cave Springs Branch and Honey Creek and flow is locally controlled by the streams. The water table in the study area generally was a subdued replica of the land surface, with the exception of a region between Honey Creek and Cave Springs Branch that extends about 1.75 miles upstream of the Honey Creek-Cave Springs Branch confluence (figs. 9 and 10). The water-table altitude in the Springfield Plateau aquifer was lower than the stage of Cave Springs Branch in that region but was higher than the stage of Honey Creek. This distribution of water-table altitudes indicates that some of the water from Cave Springs Branch may flow through the Springfield Plateau aquifer in this region and discharge into Honey Creek.

About one-third of the average flow in Cave Springs Branch at the state line appears to be discharge from the poultry-processing plant. Mean annual discharge for 1998 through 1999 in Cave Springs Branch at the Oklahoma-Missouri state-line gage was 7.04 cubic feet per second and was 49.4 cubic feet per second in Honey Creek below the confluence of the streams (Appendix 1) (Blazs and others, 2000). Permitted mean daily discharge from the poultry-processing plant is 2.48 cubic feet per second (Richard Laux, Missouri Department of Natural Resources, oral commun., May 3, 2000) indicating that, on average, wastewater effluent from the outfall could be as much as 35 percent of Cave Springs Branch discharge at the state line. Wastewater effluent from the plant can be as much as 94 percent of stream discharge below the outfall (Ed Knight, Missouri Department of Natural Resources, written commun., February 2000). The actual percentage of discharge may have been more or less because stream loss has been measured in a reach that extends about 600 feet above the state-line gage. This stream loss would account for low flows during August 1998, when stream discharge was less than 2 cubic feet per second.

Flow was nearly absent in Cave Springs Branch above O'Brien Spring during August because 62 percent of stream discharge was lost to ground water in the reach extending from S.2 to S.3 (fig. 11). Discharge from O'Brien Spring produced most of the streamflow below the spring during August. Fluorescein dye-tracer studies by the Missouri Department of Natural Resources have shown that O'Brien Spring is hydraulically connected to the poultry-processing plant storm-water basin previously used for wastewater retention and located next to the present lagoon (Jerry L. Prewett, Missouri Department of Natural Resources, Geological Survey Program, written commun., September 1998).

The streams are hydraulically connected to the Springfield Plateau aquifer. Stream discharges measured during May and August indicate that Cave Springs Branch had a net gain of water in the reach extending from S.1 to the confluence of Cave Springs Branch and Honey Creek (fig. 11). The increase in stream discharge indicates that discharge of ground water to the stream exceeded the amount of water lost to ground water from the stream. Lower water-table altitudes during August lengthened the reach where stream water probably flows from Cave Springs Branch through the aquifer to Honey Creek (figs. 9 and 10).

Stream discharge decreased, however, over a number of shorter reaches of Cave Springs Branch. These downstream decreases in discharge indicate that water is flowing from the stream into alluvial deposits or the Springfield Plateau aquifer along the reach. The greatest decrease in stream discharge was between sites S.2 and S.3 (fig. 11).

Losing reaches of Cave Springs Branch discharged water to the alluvium or the Springfield Plateau aquifer (figs. 9 and 10). Some water left Cave Springs Branch and moved under the

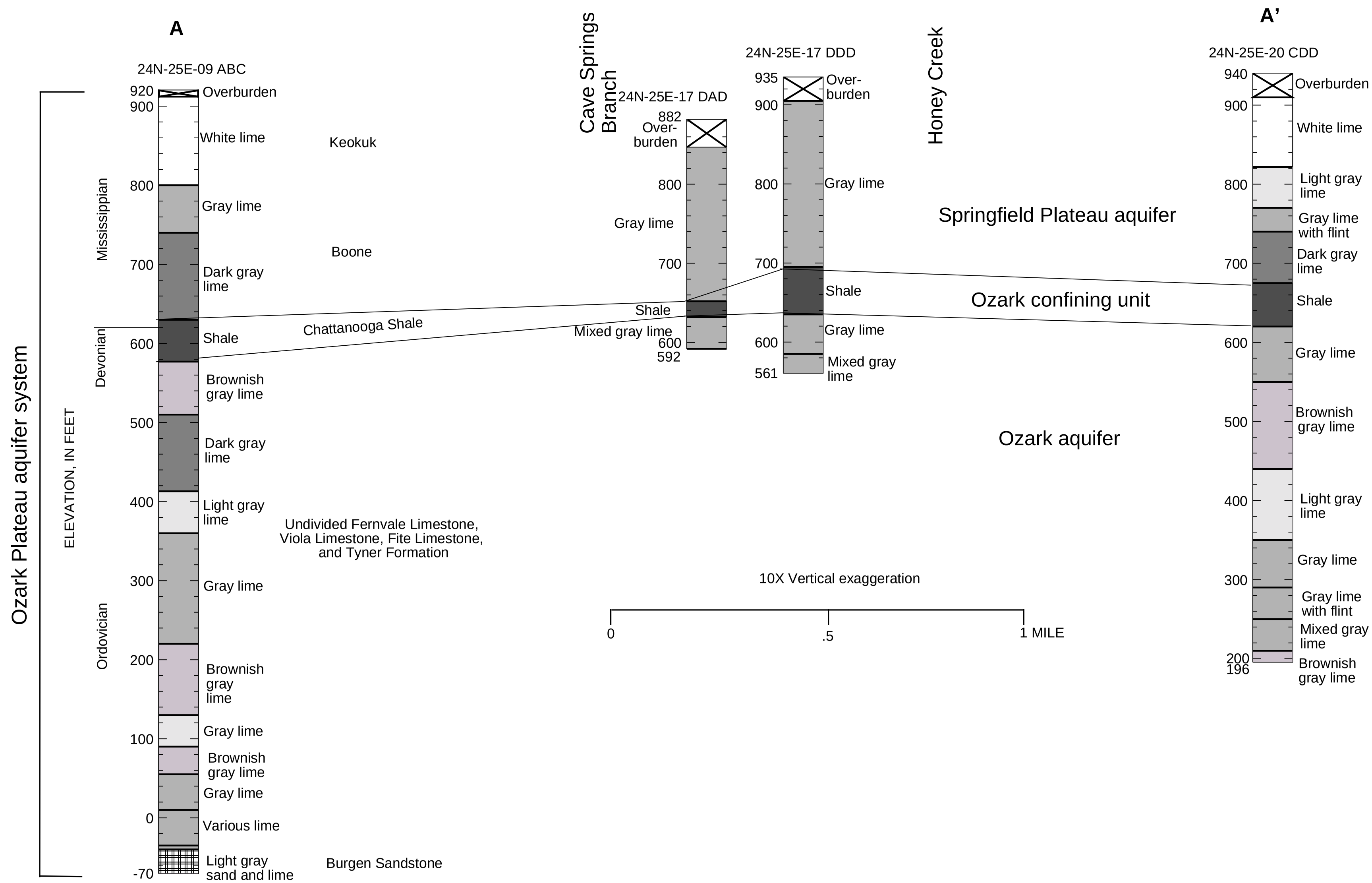


Figure 7. Northeast-southwest section in the Ozark Plateau aquifer system using drillers’ logs along A-A’ (shown on figure 6) showing the distribution of the Ozark confining unit.

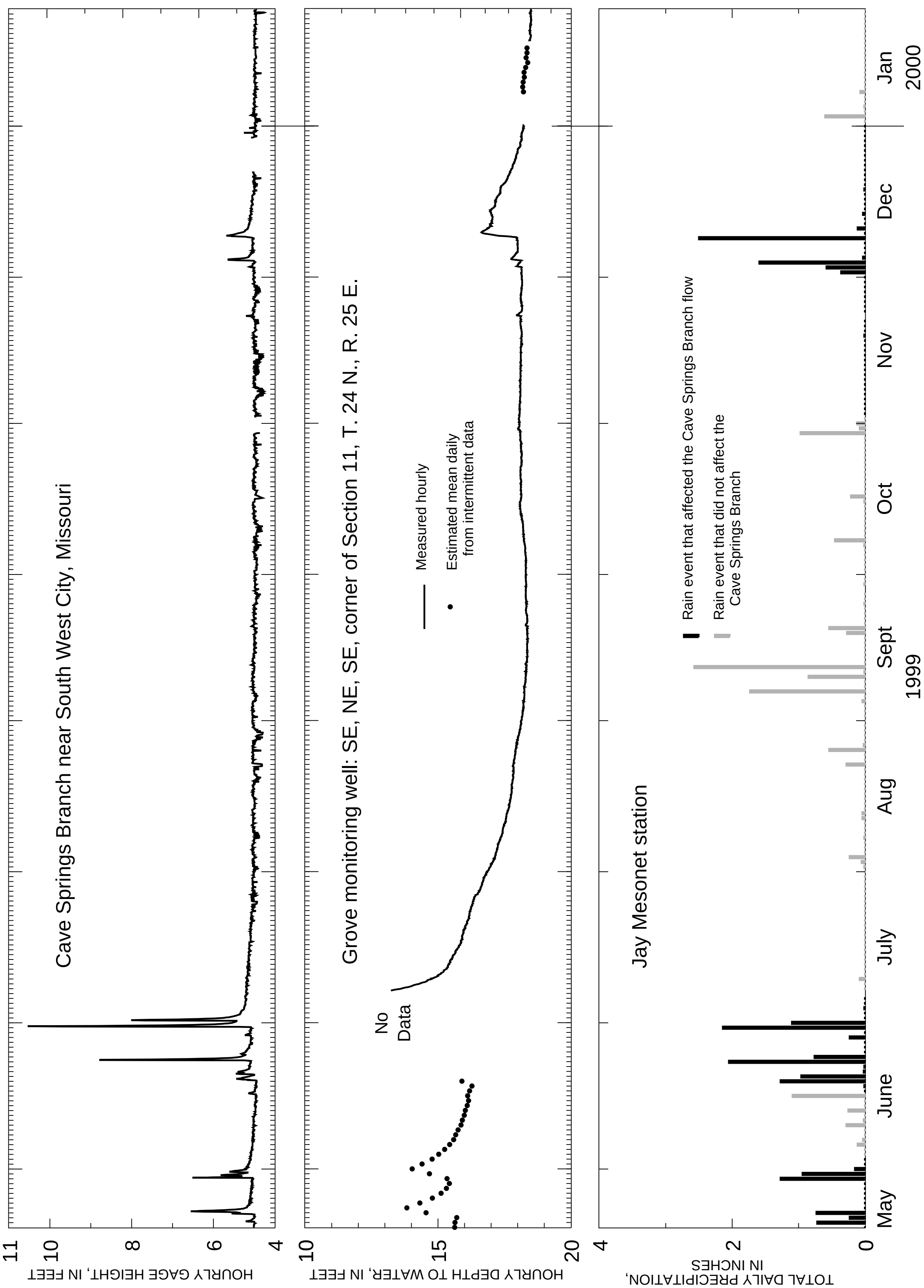
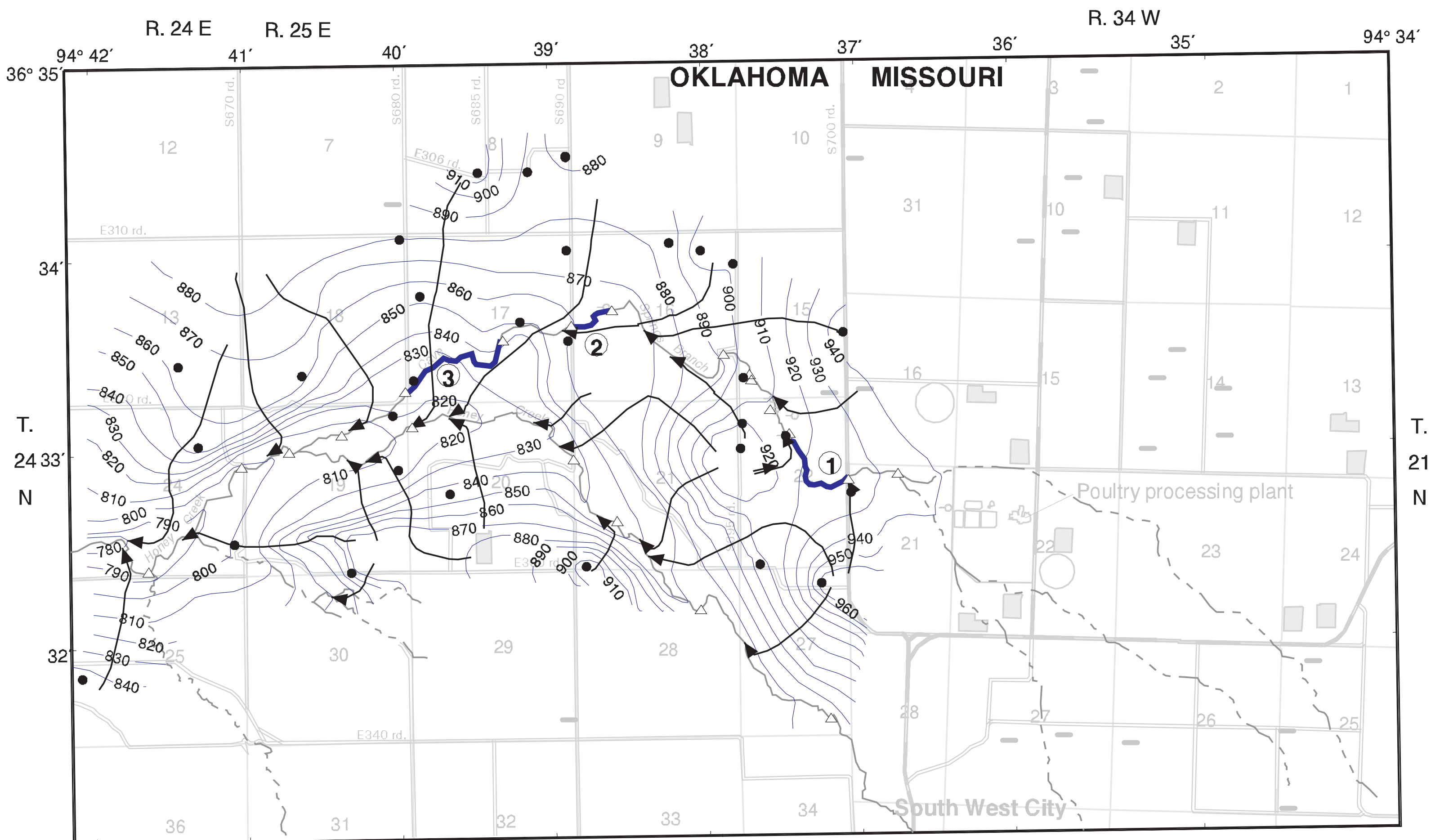


Figure 8. Hourly gage height for May 20, 1999, through January 25, 2000, at Cave Springs Branch gage near South West City, Missouri, hourly depth to water in the Grove monitoring well, and daily total precipitation at the Jay Mesonet station.



Base from 1:24,000 U.S. Geological Survey Dodge and South West City quadrangles, Projection US Albers. Map generated 01/25/2000 by USGS

EXPLANATION

- △ Stream site
- ● Well
- ① Numbered losing reach with 10 percent or greater discharge loss
- Line of equal water–table altitude––contour interval 10 feet
- Direction of ground–water flow
- Intermittent stream

0 .5 1 KILOMETER

0 .5 1 MILE

Figure 9. Water-table altitudes based on measurements May 17–21, 1999.

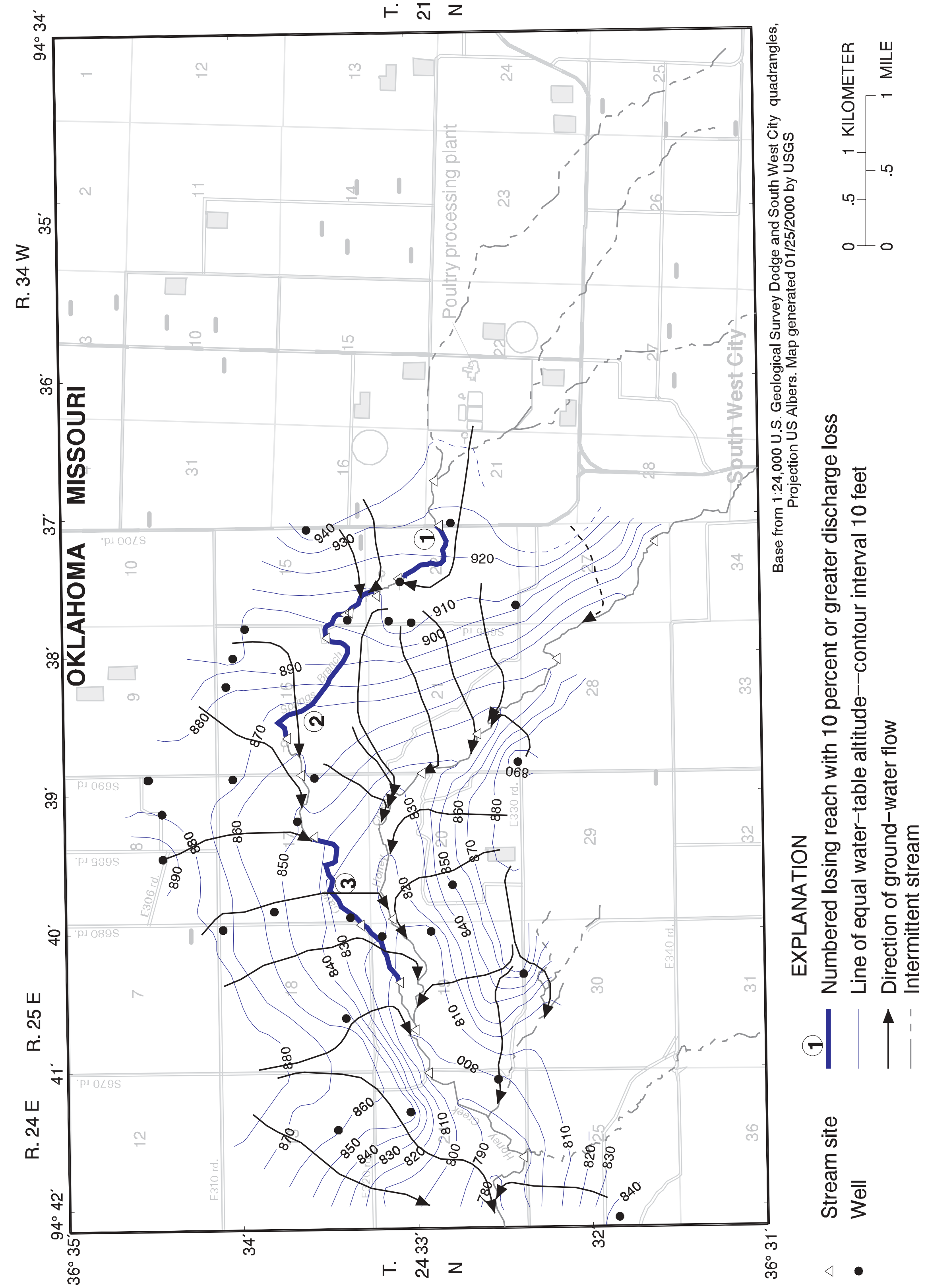


Figure 10. Water-table altitudes based on measurements August 23–27, 1999.

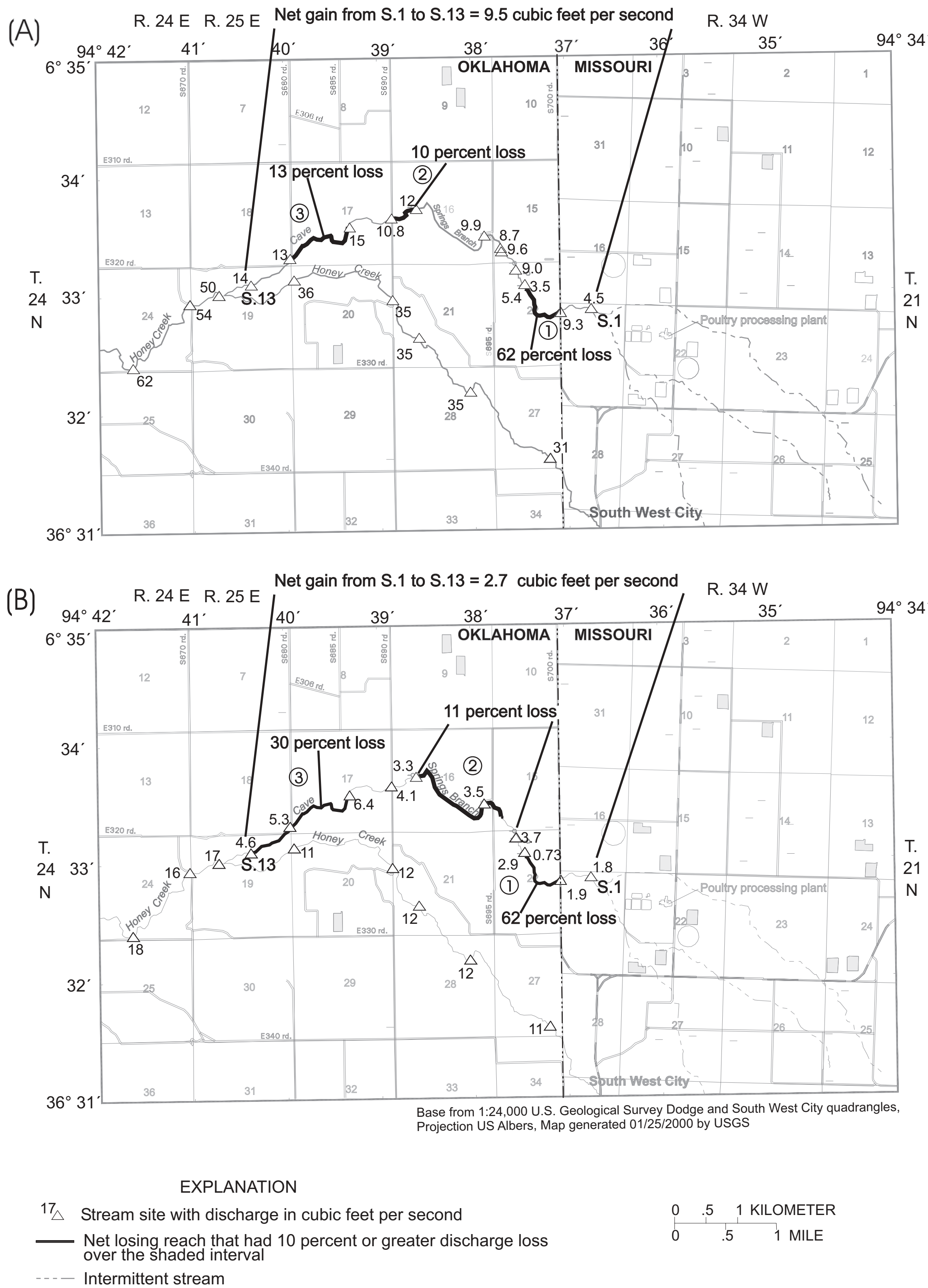


Figure 11. Net gaining and losing stream reaches based on stream measurements made on (A) May 19-20, 1999, and (B) August 24, 1999.

surface-drainage divide to discharge into Honey Creek (figs. 9 and 10). Contours of the May 1999 water table indicate ground-water flow parallels the losing reaches 1 and 2 (figs. 9 and 10). Contours in the region surrounding losing reach 3 indicate that water flowed south from Cave Springs Branch towards Honey Creek.

Water Quality and Indicated Sources of Bacteria and Nutrient Contamination

The following section describes and compares the water quality of stream, spring and ground-water samples to determine whether Cave Springs Branch is different from Honey Creek and ground water in the study area. Ground water upgradient of Cave Springs Branch also is compared with downgradient ground water to determine whether there are differences that would indicate influence of Cave Springs Branch on downgradient ground-water quality or influence of land-based sources of contamination on ground-water quality.

Water samples from the Cave Springs Branch study area can be divided into five groups, based on sampling-site, water-table altitude, and relation to Cave Springs Branch:

- Group 1 sample was collected from the poultry-processing plant wastewater outfall (fig. 5),
- Group 2 stream and spring samples were collected from Cave Springs Branch basin and from Honey Creek below the confluence of the two streams (S.2, S.3, S.4, S.10, S.11, and S.20) (fig. 5),
- Group 3 sample was collected from Honey Creek upstream from any potential mixing with water from Cave Springs Branch (S.17) (fig. 5),
- Group 4 samples were collected from wells upgradient of Cave Springs Branch and Honey Creek (W.6, W.10, W.11, W.17, W.29, W.31, and W.35) (fig. 5), and
- Group 5 samples were collected from wells downgradient from Cave Springs Branch (W.5, W.18, and W.28) (fig. 5).

Cave Springs Branch, O'Brien Spring and Honey Creek below the confluence appear to be affected by discharges from Group 1. The Group 1 sample was of a sodium chloride type with a specific conductance of 2,020 microsiemens, and had substantially greater concentrations of magnesium, sodium, potassium, chloride, sulfate, ammonia, and total organic nitrogen plus ammonia than stream and ground-water samples (figs. 12, 13 and 14, Appendix 3). Group 2 sample specific conductance values were between those of Group 1 and those of the other three groups. Group 2 samples had the greatest concentrations of sodium, potassium, chloride, and sulfate of the stream and ground water samples (figs. 13 and 14). Group 2 samples were of a sodium calcium chloride bicarbonate type (fig. 14). The high concentrations of sodium, chloride, potassium, and sulfate in Group 2 samples likely are contributed by Group 1. Calcium and bicarbonate alkalinity, primarily derived from dissolution of limestones in the basin, were present in lesser concentrations in Group 2 samples than in samples from the other groups (figs. 12, 13, and 14).

Group 3 and ground water of Groups 4 and 5 were chemically similar, indicating that Honey Creek is mostly derived from ground water from the north and south and that Cave Springs Branch has little effect on downgradient ground water. Water in Groups 3, 4, and 5 were calcium bicarbonate type with similar specific conductance (figs. 12, 13, and 14). Specific conductance, pH, bicarbonate alkalinity, and major-ion concentrations in Group 5 samples were similar to those of Group 4 samples, indicating that the quality of water from these downgradient wells is not substantially affected by water from Cave Springs Branch (figs. 12, 13, and 14).

Background concentration of chloride in study area ground water is about 1.5 milligrams per liter. Water from wells W.6, W.10, and W.11, which were located upgradient of Cave Springs Branch and Honey Creek, probably represents ground water that is uncontaminated. Water from those wells contained less than 3 milligrams per liter nitrate.

The elevated chloride concentration in Cave Springs Branch, for which the arithmetic mean was 165 milligrams per liter, was probably derived from the poultry-processing plant and human and animal waste sources along the stream. Chloride can be used as a tracer of water source because it tends to move conservatively with water. Chloride does not react with minerals, and does not precipitate out except at concentrations much greater than those in this area. Potential sources for chloride in the basin include a small natural concentration in ground water, animal wastes, human wastewater, and wastewater from the poultry-processing plant. Chloride concentration in Cave Springs Branch and O'Brien Spring were much greater than in Honey Creek and ground water (fig. 13 and Appendix 3). Poultry-processing plant wastewater sampled from the outfall during March 2000, contained 384 milligrams of chloride per liter (Appendix 3). Chloride load carried by Cave Springs Branch decreased substantially with decreasing stream discharge downstream of the outfall. The load of chloride introduced to Cave Springs Branch during August 1999 by O'Brien Spring was about 750 pounds per day less than that introduced by the outfall during March 2000 (fig.15). Chloride load increased in the reach downstream from O'Brien Spring to site S.10 (fig.15), indicating a nonpoint source of chloride, such as fertilizer or animal or human waste along this reach.

Water from three wells downgradient of Cave Springs Branch with greater chloride concentrations may have had a small percentage of water from Cave Springs Branch. The percentage of Cave Springs Branch water needed to increase ground water chloride concentrations to those of water from wells was calculated using a simple linear mixing model (table 3). The background chloride concentration of 1.5 milligrams

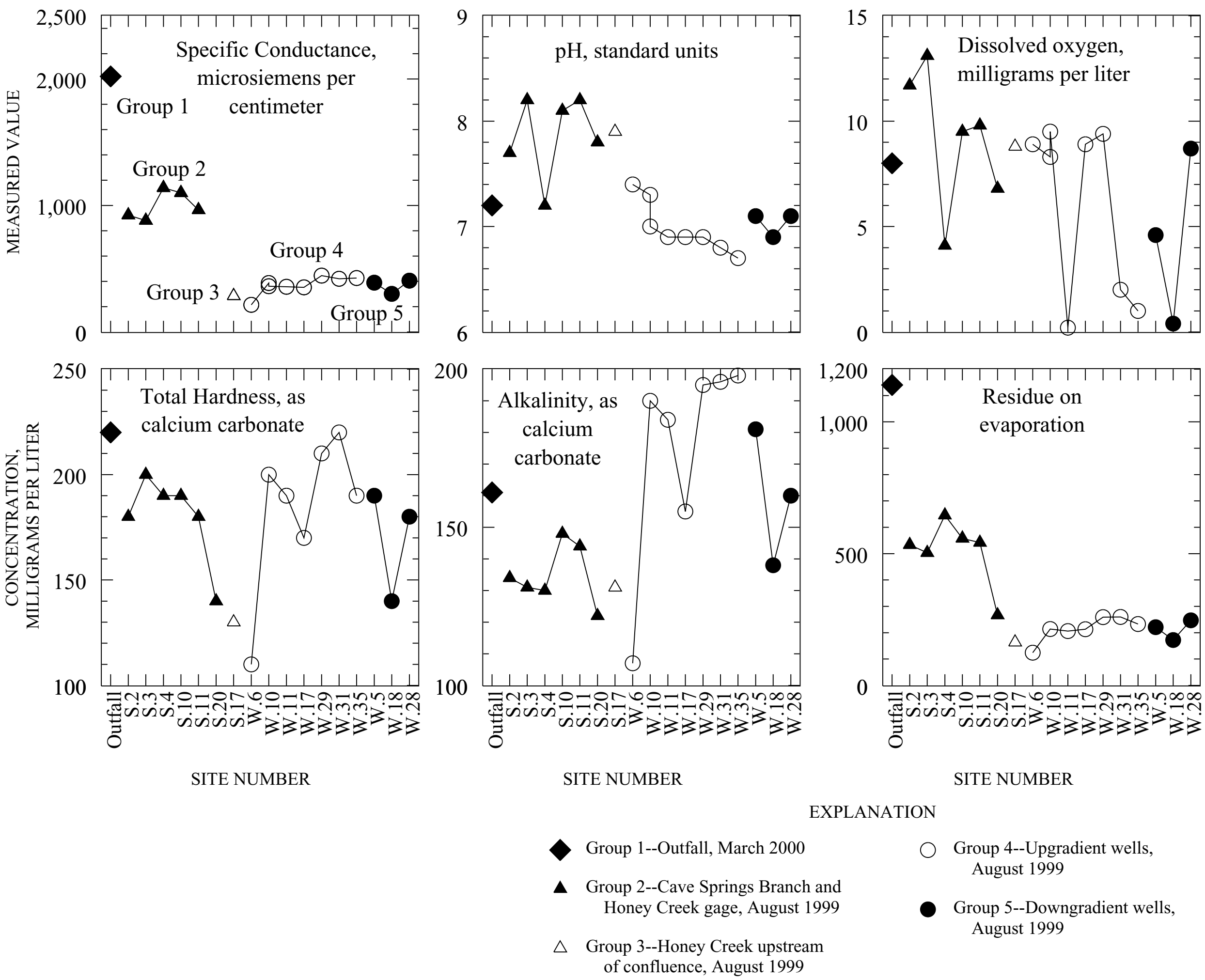


Figure 12. Water properties in water samples collected in the Cave Springs Branch study area August 23-27, 1999, and March 22, 2000, plotted by group in downstream order.

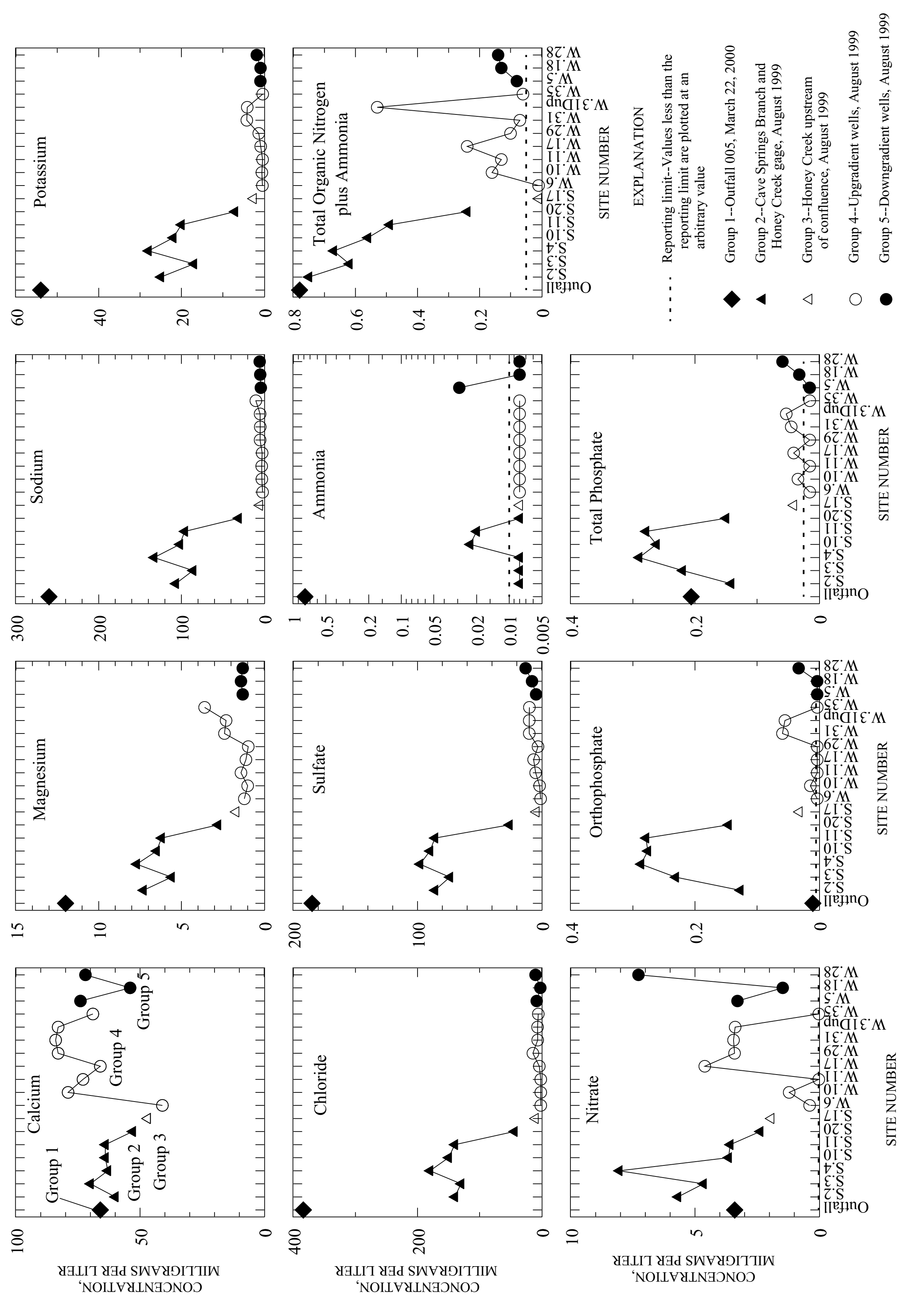


Figure 13. Major ion and nutrient concentrations in water samples collected in the Cave Springs Branch study area August 23–27, 1999, and March 22, 2000, plotted by group in downstream order.

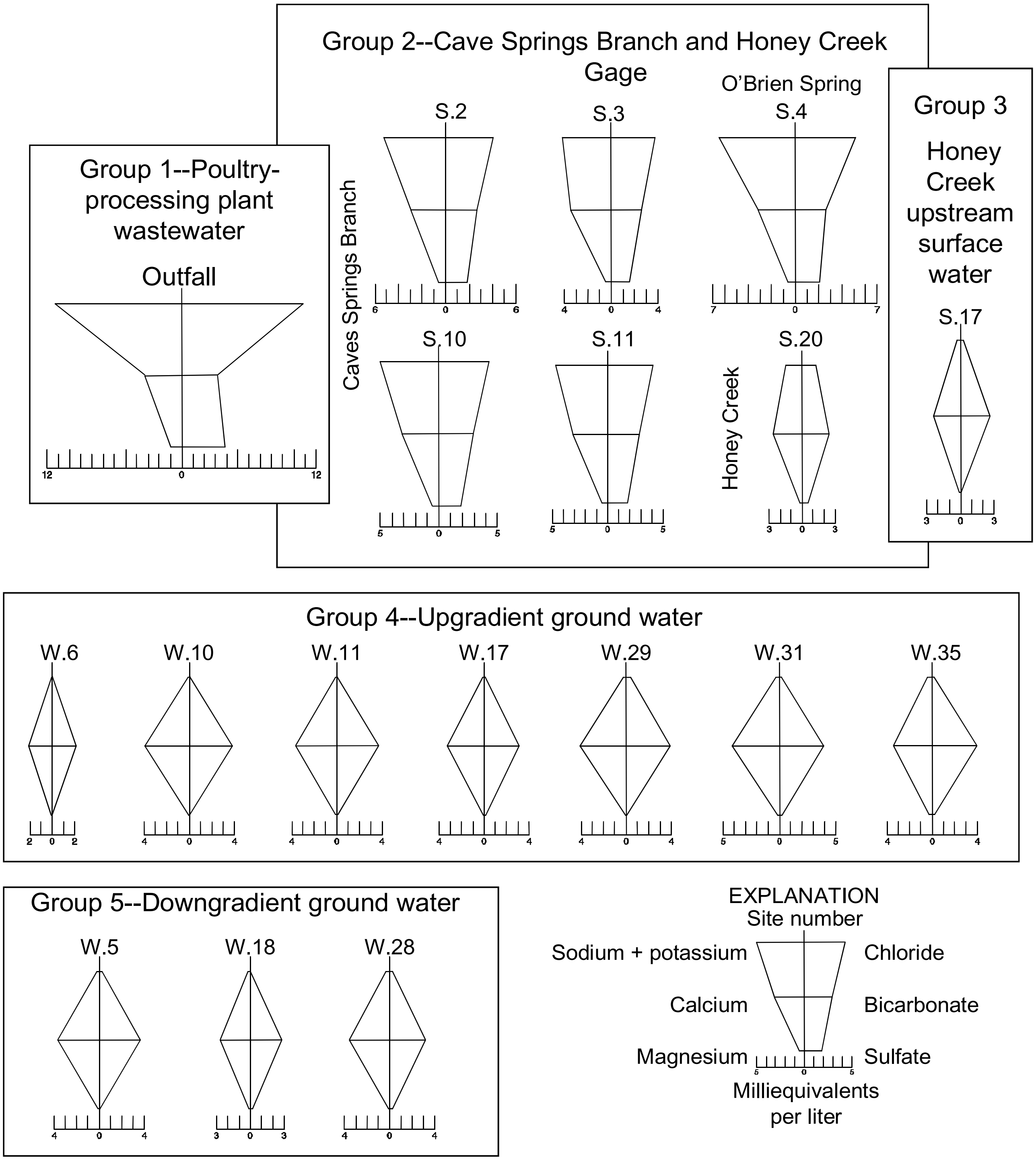


Figure 14. Stiff diagrams of major-ion contents of the poultry processing plant outfall, surface water, and ground water in the study area. The shape of the diagram in Group 3, Honey Creek upstream of Cave Springs Branch is the same as the shape of diagrams in Groups 4 and 5, because Honey Creek is fed by ground-water discharge. Cave Springs Branch also is fed by ground water, but the discharge from Group 1 contributes magnesium, sodium and potassium, chloride, and sulfate and changes the chemistry of Cave Springs Branch so the shape of the diagram is more like that for Group 1. S.20, Honey Creek below the confluence, is a mixture of the two waters, which the shape reflects.

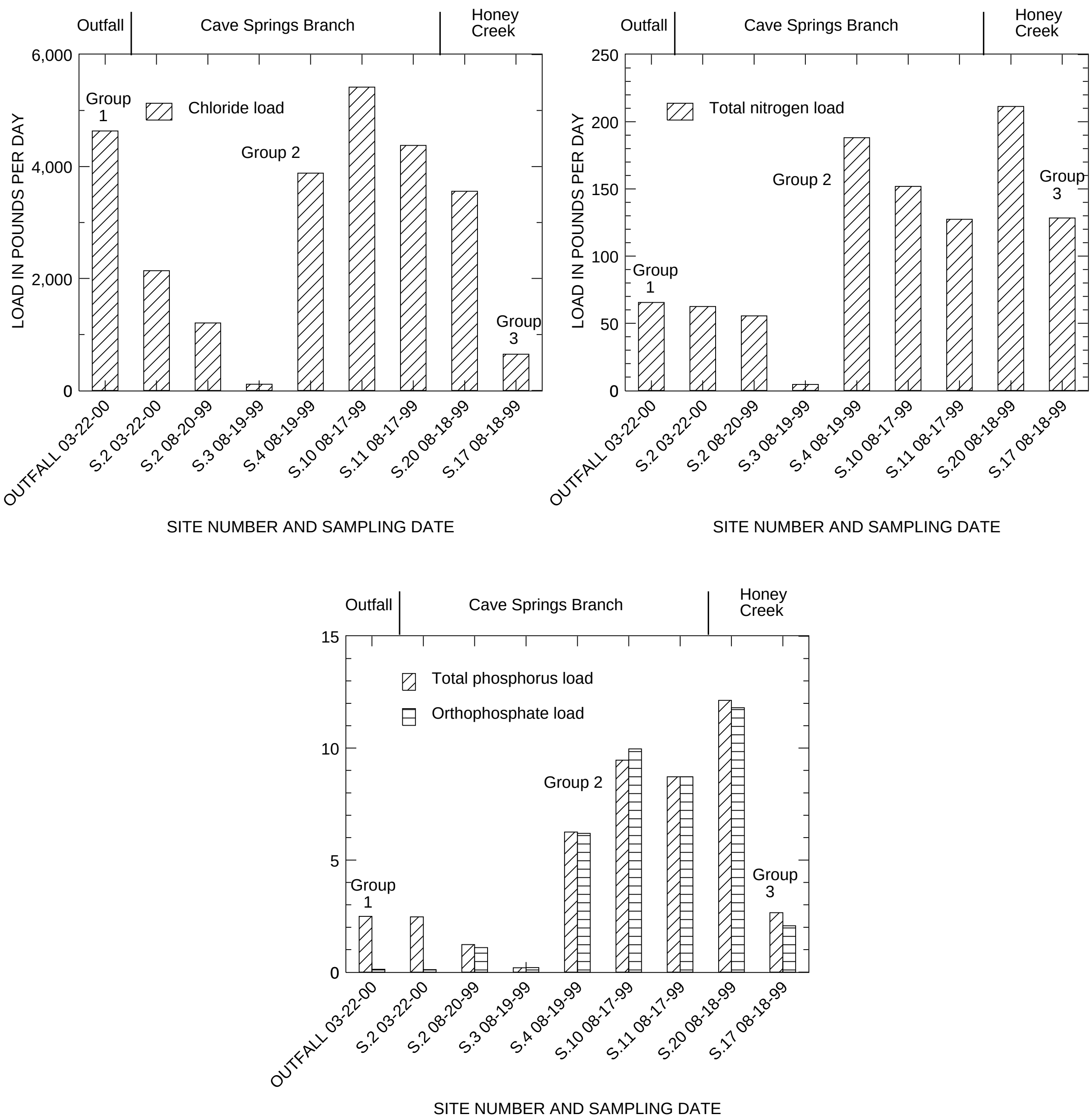


Figure 15. Loads of chloride, total nitrogen, total phosphorus, and orthophosphate measured in Cave Springs Branch and Honey Creek during August 1999 and March 2000.

Table 3. Estimated maximum percent of Cave Springs Branch water that may be contributing to ground water from downgradient wells in the study area related to nitrate concentration

[mg/L, milligrams per liter; as N, as nitrogen]

Site	Chloride, (mg/L)	Percent Cave Springs Branch water[1]	Nitrate, (mg/L as N)
W.5	8.0	4.3	3.29
W.18	2.2	0.5	1.47
W.28	9.8	5.5	7.28

[1]Percent Cave Springs Branch water was estimated based on a mean chloride concentration of 151 milligrams per liter of chloride in Cave Springs Branch and 1.5 milligrams per liter in uncontaminated ground water

per liter was used to represent 0-percent Cave Springs Branch water and the mean concentration of 165 milligrams per liter chloride represented 100-percent Cave Springs Branch water. Using this model, maximum percentages of Cave Springs Branch water ranged from 0.5 to 5.5 percent of water from Group 5 wells (W.5, W.18, and W.28) (table 3).

Chloride concentrations greater than 1.5 milligrams per liter in water from upgradient wells may be from animal waste, human wastewater, or other sources such as salt licks. Water from most upgradient wells with elevated chloride concentrations also contained more than 3 milligrams per liter nitrate (Appendix 2).

Ammonia, which is present primarily as the cation ammonium, is converted rapidly to nitrate in oxygen-rich water and the increased concentration of nitrate at Group 2 site S.2 relative to the poultry-processing plant wastewater outfall probably was, at least in part, the result of conversion of ammonia from the outfall (fig. 13). The Group 1 sample contained the greatest concentrations of ammonia and total organic nitrogen plus ammonia than the samples collected during August 1999 (fig. 13). Nitrate concentration, however, was in the middle range of concentrations in those other samples and was less than the concentration in most Group 2 samples.

Total organic nitrogen plus ammonia from the poultry-processing plant wastewater outfall may have been a continuing source of some of the nitrate downstream as the organic compounds were broken down. Small concentrations of ammonia were detected at two sites and may have been from breakdown of organic nitrogen compounds or from fertilizer or animal waste along the stream (Appendix 3). Total organic nitrogen plus ammonia concentration in Group 2 was similar to that of the Group 1 sample at the state-line gage (S.2), and decreased downstream. Nitrate concentrations in Group 2 samples were greatest at site S.4 and decreased downstream. Neither ammonia nor total organic nitrogen plus ammonia were detected in the Group 3 sample, indicating that the concentrations detected in Group 2 were greater than background concentrations.

Cave Springs Branch and Honey Creek contributed approximately equal loads of nitrogen to Honey Creek below the confluence and the greatest loads of nitrogen were introduced to Cave Springs Branch by the outfall and O'Brien Spring (fig.15). Total nitrogen loads were less at Group 1 and at sites S.2 and S.3 above O'Brien Spring than at O'Brien Spring, Cave Springs Branch downstream of O'Brien Spring, and Honey Creek above and below the confluence (fig.15). The greatest nitrogen load entered Cave Springs Branch from O'Brien Spring (S.4). Fluorescein dye-tracer studies by the Missouri Department of Natural Resources indicated that O'Brien Spring is hydraulically connected to the poultry-processing plant storm-water basin. The large nitrogen load discharged by O'Brien Spring compared to the load from the poultry-processing plant wastewater outfall and the substantial chloride load in O'Brien Spring may indicate that the spring also was in hydraulic connection with the poultry-processing plant wastewater lagoon. Nitrogen load decreased downstream of O'Brien Spring probably as a result of uptake by vegetation and bacterial processes. Nitrogen load at site S.20, Honey Creek below the confluence, was less than the combined loads at upstream sites S.11 in Cave Springs Branch and S.17 in Honey Creek, indicating that nitrate was lost from both streams above the confluence. Honey Creek carried a substantial load of nitrogen at site S.17, probably derived from the South West City wastewater treatment plant, septic systems, and animal-waste runoff upstream (fig.15).

Nitrate concentrations in Group 4 samples ranged from 0.38 to 4.60 milligrams per liter, indicating that there is an upgradient source of ground-water nitrogen, such as animal waste, fertilizer, or human waste. Ammonia tends to adsorb on clay minerals or is converted to nitrate in ground water that contains dissolved oxygen, so that concentrations typically are small in ground water. Ammonia was not detected in any of the Group 4 samples. Total organic nitrogen plus ammonia concentrations varied considerably. The greatest concentration was detected in one of the duplicate samples from W.31. There was little total organic nitrogen plus ammonia in the other duplicate sample from W.31, indicating that organic nitrogen may be transported as suspended solids.

Nitrogen compounds in water from Group 5 may be from Cave Springs Branch, fertilizers, animal waste, or human waste. The greatest ammonia concentration detected in samples collected for this study was in sample W.5 of Group 5 (0.29 milligram per liter). All Group 5 samples contained relatively low total organic nitrogen plus ammonia concentrations (fig. 13, Appendix 3). Sample W.28 had the greatest nitrate concentration of all ground-water samples—7.9 milligrams per liter, which is near the greatest concentration detected in Group 2 samples.

Substantial phosphorus concentrations in Group 2, which were dominantly dissolved orthophosphate-phosphorus (referred to in this report as orthophosphate), may have been derived from the poultry-processing plant wastewater as well as from animal or fertilizer sources along Cave Springs Branch (figs. 13 and 15). Total phosphate from the outfall or other sources may have reacted to form some of the orthophosphate in the stream as indicated by the equilibration of the ratio of total phosphorous load with orthophosphate load downstream. O'Brien Spring introduced a substantial load of orthophosphate to Cave Springs Branch, indicating that the spring probably carries some untreated animal wastewater or fertilizer (fig. 15). Group 3 sample phosphate concentration was less than concentrations in Group 2 samples (fig. 13), indicating that concentrations in Group 2 probably are primarily from a source within the Cave Springs Branch drainage.

Total phosphorus and orthophosphate loads increased in the reach downstream from O'Brien Spring to site S.10 (fig.15), indicating a nonpoint source of orthophosphate, such as fertilizer or animal or human waste along this reach. Total phosphorus and orthophosphate concentrations in Group 3 were similar to concentrations in Group 4 and 5 samples.

Orthophosphate mobility is limited in ground water by sorption on iron oxide surfaces; whereas, other less-soluble forms of phosphorus may be transported in a suspended form. Orthophosphate-phosphorus and total phosphorus concentrations in Group 4 and 5 ground-water samples were less than 0.06 milligram per liter. Most orthophosphate concentrations were less than the detection limit of 0.01 milligram per liter; however, orthophosphate was detected in water form wells W.10, W.28, and W.31, with similar or slightly greater concentrations of total phosphorus. The greatest orthophosphate concentrations were in water from W.28 and W.31. The greatest nitrate concentration measured in this investigation was in water from W.28. *Escherichia coli* bacteria in water from W.31 (table 3 and Appendix 3), indicates that the water from this well may be contaminated by animal or human waste, which also may be an orthophosphate source. Total phosphorus concentration in water from wells W.17 and W.18, but no detectable orthophosphate, indicates phosphorus is transported in a suspended form in the aquifer near these wells.

Iron and manganese concentrations were greater in Group 1 than in Groups 2 and 3 (fig. 16). High concentrations of dissolved oxygen (fig. 12) tend to cause these metals to precipitate as metallic oxides. The Chattanooga Shale may be a source of iron and manganese in ground water. Group 4 and 5 samples contained < 10 to 96 micrograms per liter iron and < 3 to 22 micrograms per liter manganese (fig. 6 and Appendix 3), indicating that the poultry-processing plant wastewater outfall and Cave Springs Branch may not be the source of these elements in ground water.

Dissolved arsenic and selenium can be associated with contamination of water by chicken litter because these elements are commonly used as feed additives to increase poultry growth and are concentrated in chicken litter. Arsenic and selenium concentrations were low (less than 3 micrograms per liter) in all samples, indicating that if water had been contaminated by chicken litter, arsenic and selenium concentrations were not affected. Concentrations generally were less in Group 2 and 3 stream samples and greater in Group 4 and 5 ground-water samples. Group 1, which was collected during March 2000, was not analyzed for arsenic or selenium due to the low concentrations measured in samples collected during August 1999.

The types and concentrations of organic wastewater indicator compounds detected in Group 1 and Group 2 indicate that the poultry-processing plant wastewater effluent may be the source of many of these compounds in the stream. Organic wastewater indicator compounds (table 2) in the Group 1 sample also were detected downstream in some Group 2 samples. Group 1 was sampled during March 2000 and most of Group 2 was sampled during August 1999 (Appendix 4). Further monitoring would assist with determination of the persistence and transport of organic wastewater indicator compounds discharged or emanating from the poultry-processing plant. Group 1 and Group 2 samples generally contained the greatest number of organic compounds, particularly at the poultry-processing plant wastewater outfall and at sites S.2 (the state-line gage) and S.4 (O'Brien Spring) (fig. 17, Appendix 4). Dilution, sorption, biodegradation, or precipitation reduced concentrations of those compounds downstream. No organic wastewater indicator compounds were detected at site S.3, indicating that the compounds had been removed from the stream channel, either through loss to the aquifer or by physical processes listed previously. O'Brien Spring contained 6 of the 12 compounds detected in the outfall, plus fluoranthene and napthalene (Appendix 4). The lack of organic wastewater indicator compounds at site S.3 and the variety of compounds in O'Brien Spring reiterate the possibility of a connection between O'Brien Spring and the poultry-processing plant wastewater outfall or lagoon.

The presence of organic wastewater indicator compounds in Honey Creek, which receives discharge of treated wastewater from South West City, Missouri, indicates some influence by human wastewater. Only two organic wastewater indicator compounds, caffeine and pyrene, were detected in sample S.20.

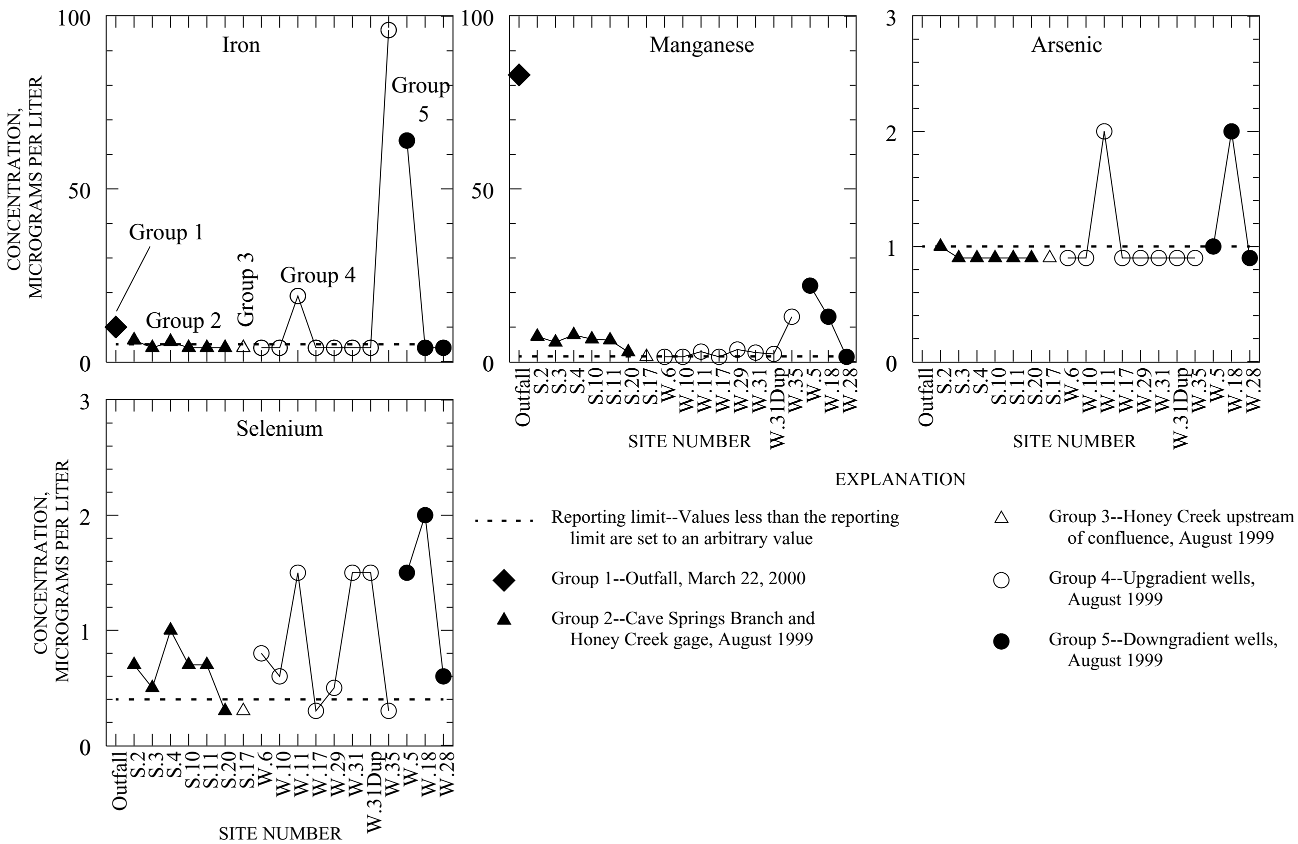


Figure 16. Minor and trace element concentrations in water samples collected in the Cave Springs Branch study area August 23-27, 1999, and March 22, 2000, plotted by group in downstream order.

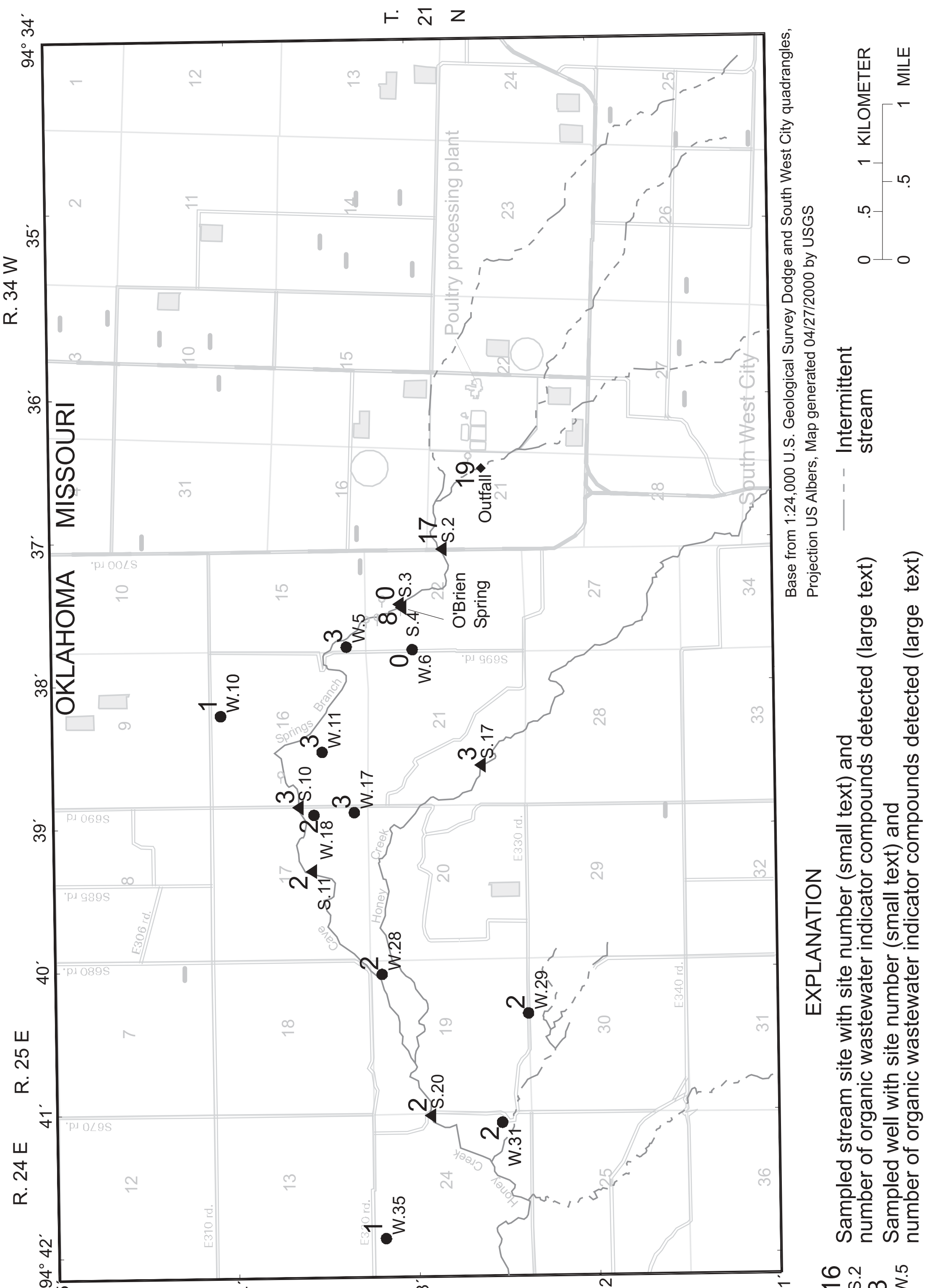


Figure 17. Numbers of organic wastewater indicator compounds detected in stream and ground water.

The caffeine in S.20 (Honey Creek below the confluence) may be from septic tanks around the site, or from the South West City wastewater treatment plant outflow to Honey Creek.

Organic wastewater indicator compounds detected in water from Group 4 wells, other than W.6, indicate water from these wells is influenced by human wastewater.

Organic wastewater indicator compounds detected in Group 5 samples also were detected in Group 1 and Group 2, indicating Group 5 wells may receive some water that originally came from the outfall. Sample W.5 of Group 5, contained fragrance (acetophenone), and two compounds associated with plastics or polymers [bisphenol A and bis (2-ethylhexyl) phthalate]. The fragrance (acetophenone), also detected in Cave Springs Branch, may indicate a link between Cave Springs Branch and ground water near that well. Well W.5 was installed about one month prior to sampling, and the plastics or polymers may have been related to materials used in the pump or in well construction. Sample W.18 contained a plasticizer [bis (2-ethylhexyl) phthalate] and a preservative (para-cresol) (Appendix 4). Para-cresol also was detected in Cave Springs Branch just upstream of W.18, possibly indicating connection between Cave Springs Branch and W.18.

Delta values for stable isotopes of hydrogen and oxygen in samples from Cave Springs Branch, O'Brien Spring, and Honey Creek below the confluence (Group 2) are different from samples of water from Honey Creek (Group 3) and wells (Groups 4 and 5). The differences were not great enough to quantify the percentage of surface water in downgradient well samples. Isotope ratios were not determined for the poultry-processing plant wastewater outfall (Group 1). Isotopic ratios in Group 2 samples downstream of the outfall indicate evaporation, most of which may have taken place in the wastewater lagoons as indicated by the decrease in isotopic enrichment downstream (fig. 18). Delta values for stable isotopes of hydrogen and oxygen indicate that the greatest amount of evaporation had occurred from O'Brien Spring water indicating the spring likely receives some water from lagoons or ponds. The Group 3 delta value plots along the regional ground-water line, indicating a primarily ground-water component in Honey Creek, with a nominal component affected by evaporation, possibly from municipal wastewater lagoons at South West City. Delta values for Group 5 samples are not shifted from the regional ground-water line, indicating limited mixing with water from Cave Springs Branch. If the percentage of Cave Springs Branch water in those wells is 0.5 to 5.5 percent, the effect on the isotopic ratios would be undetectable within the error of measurement.

Fecal coliform bacteria colony counts were least in wells (Groups 4 and 5), intermediate in the poultry-processing plant wastewater outfall (Group 1) and Honey Creek above the confluence (Group 3), and greatest in Cave Springs Branch (Group 2). Fecal bacteria were rare in the Group 1 sample of the outfall during March 2000 (table 4). Fecal bacteria counts for the outfall in August 1999 are not known. Fecal bacterial counts in Group 2 samples exceeded 700 colonies per 100 milliliters at the Oklahoma-Missouri state line and generally decreased downstream (fig. 19). A herd of cows was pastured along Cave Springs Branch above the state line at the time the state-line sample was collected. Fecal bacterial counts were substantially less in O'Brien Spring. *Escherichia coli* and fecal streptococcal bacteria loads were greater in the sample from site S.10 than at any other stream site and decreased downstream, indicating a source of these bacteria along the reach between O'Brien Spring and site S.10 (fig. 20). Fecal bacteria counts in the Group 3 sample were intermediate between Group 2 and Group 4 samples. All four wells that yielded water containing fecal indicator bacteria (W.6, W.29, W.31 and W.35) were upgradient of the streams and could not have received the bacteria from the streams.

Only one ground-water sample in Group 4 (W.31) contained both fecal coliform and fecal streptococcal bacteria (table 4). No viable fecal bacteria were detected in water from Group 5 wells. Ratios of fecal coliform to fecal streptococcal bacteria counts in stream samples indicated no specific animal source (table 4). Different die-off rates of fecal bacteria may change that ratio with time and distance from contaminant sources, making interpretation of ratios difficult (Malard and others, 1994).

Increased *Escherichia coli* counts downstream of the poultry-processing plant outfall and the animal sources determined by ribotyping indicate that bacteria in the stream probably were not from the plant but some may be from chickens or other birds located elsewhere in the basin. However, bacteria counts at the outfall at the time of stream sampling are not known.

Bacteria strains and resistance to antibiotics of some bacteria indicate that livestock may have been sources of some bacteria in the water samples. Fewer than half of the *Escherichia coli* isolates had resistance to any of the tested antibiotics (table 5). Tentative Biolog® identification indicated most presumptive *Escherichia coli* bacteria isolates from the water samples were indeed *Escherichia coli* (table 5).

Three bacterial isolates from S.10 and W.31 samples only had resistance to tetracycline and ampicillin, which indicates that the bacteria may not be from human or poultry sources (Krumperman, 1983 and Parveen and others, 1997) (table 5). Multiple resistance to antibiotics other than tetracycline and ampicillin would indicate probable human- or poultry-sourced bacteria. Two isolates were resistant to tetracycline; nine isolates were resistant to ampicillin. Bacteria identified in isolates from feces of deer, horse, and cow collected from the study area also were *Escherichia coli*. None of these source isolates were resistant to the antibiotics tested.

Ribotyping indicates that ribotypes of *Escherichia coli* bacteria in water samples from the basin were from bird, cow, horse, dog, deer, and human sources (table 6). Twenty-six ribotypes of *Escherichia coli* bacteria were identified. Only the deer ribotype had a pattern that matched the ribotype pattern of a source sample collected from the study area. The animal source for 10 of the 26 identified ribotypes could not be determined, because those ribotypes are not in the data base. Additional source sampling might help distinguish these sources.

The presence of multiple ribotypes from each type of animal source indicates that most of the bacteria are from multiple

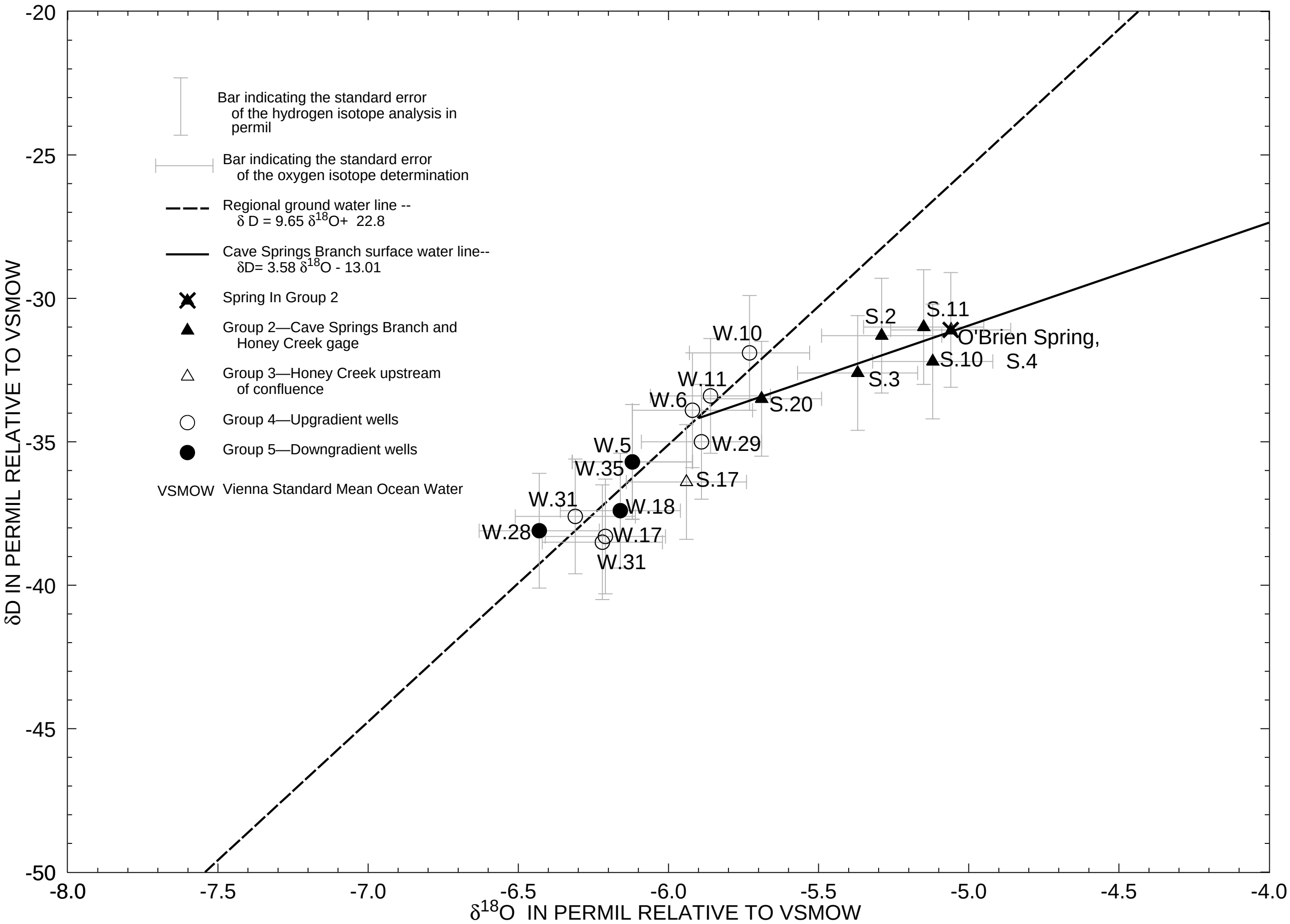


Figure 18. Enrichment of δD and $\delta^{18}O$ of water resulting from evaporation in the water-treatment basins.

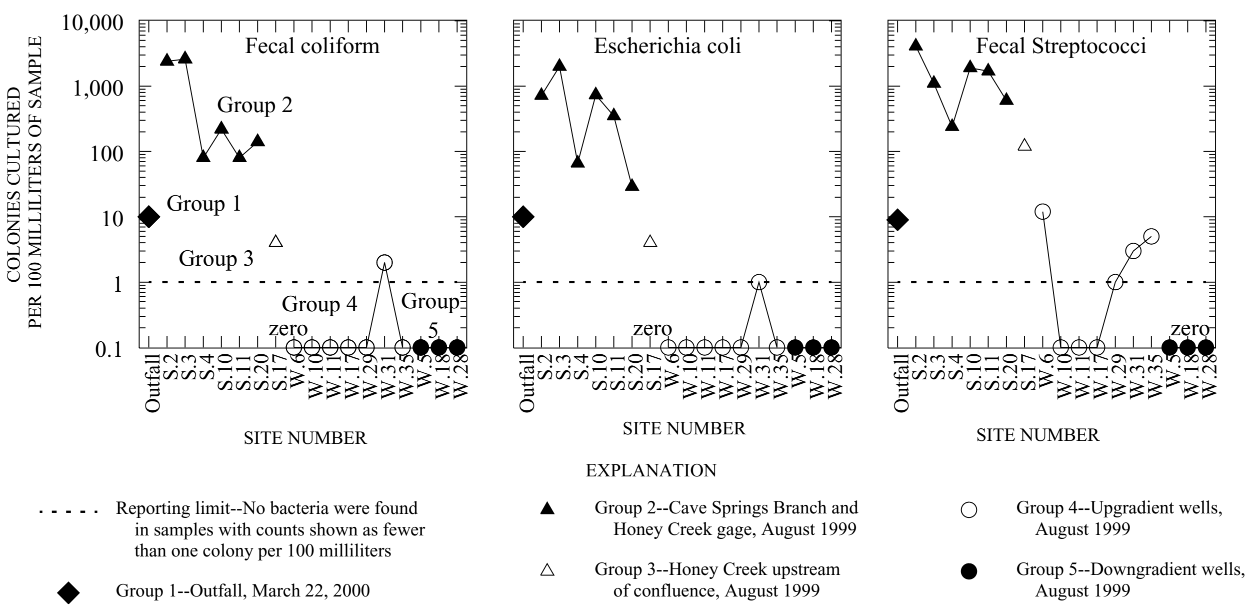


Figure 19. Bacterial counts in water samples collected in the Cave Springs Branch study area August 23-27, 1999, and March 22, 2000, plotted by group in downstream order.

Table 4. Bacterial counts and ratios of fecal coliform to fecal streptococcal bacteria in water samples from the Cave Springs Branch area, August 1999 and March 2000 (Group 1)

[ml, milliliter; E. coli, *Escherichia coli*; FC/FS, fecal coliform to fecal streptococci; K, estimated count based on non-ideal colony count; <1, fewer than 1 colony per 100 milliliters of water were cultured, estimated count based on non-ideal colony count; NC, no presumptive fecal bacteria cultured from 350 milliliters of sample; --, indicates no data available]

Group	Date	Site number shown ion figure 5	Fecal bacteria: Coliform, fecal, (colonies per 100 ml)	Fecal bacteria: E. coli (colonies per 100 ml)	Fecal bacteria: Streptococci fecal, (colonies per 100 ml)	FC/FS ratio	FC/FS-ratio indicated animal source[1]
				Surface water			
1	03-22-00	Outfall	K10	K10	K9	--	--
2	08-20-99	S.2	2,400	720	4,100	0.58	Duck
2	03-22-00	S.2	192	112	106	1.81	Duck/Man
2	08-19-99	S.3	2,600	2,000	1,100	2.36	Man/Duck
2	08-19-99	S.4	80	66	240	0.33	Chicken/Cow
2	08-17-99	S.10	K220	730	1,900	0.12	Turkey/Cow
2	08-17-99	S.11	80	350	1,700	0.05	--
2	08-18-99	S.20	140	K29	600	0.23	Cow/Chicken
3	08-18-99	S.17	K4	K4	120	0.03	--
				Well water			
4	08-20-99	W.6	NC	NC	K12	--	--
4	08-24-99	W.10	NC	K2 *	NC	--	--
4	08-19-99	W.11	NC	NC	NC	--	--
4	08-17-99	W.17	NC	<1 *	NC	--	--
4	08-19-99	W.29	NC	<1 *	<1	--	--
4	08-20-99	W.31	K2	K1	K3	--	--
4	08-18-99	W.35	NC	<1 *	K5	--	--
							--
5	08-17-99	W.5	NC	K1 *	NC	--	--
5	08-18-99	W.18	NC	NC	NC	--	--
5	08-19-99	W.28	NC	K6 *	NC	--	--

[1]Ratios should not be used when fecal streptococcal counts are less than 100 colonies per 100 milliliters (Bordener and Winter, 1978)

*E. coli counts in the absence of fecal coliform counts may not indicate E. coli presence, additional testing indicated these were not E. coli

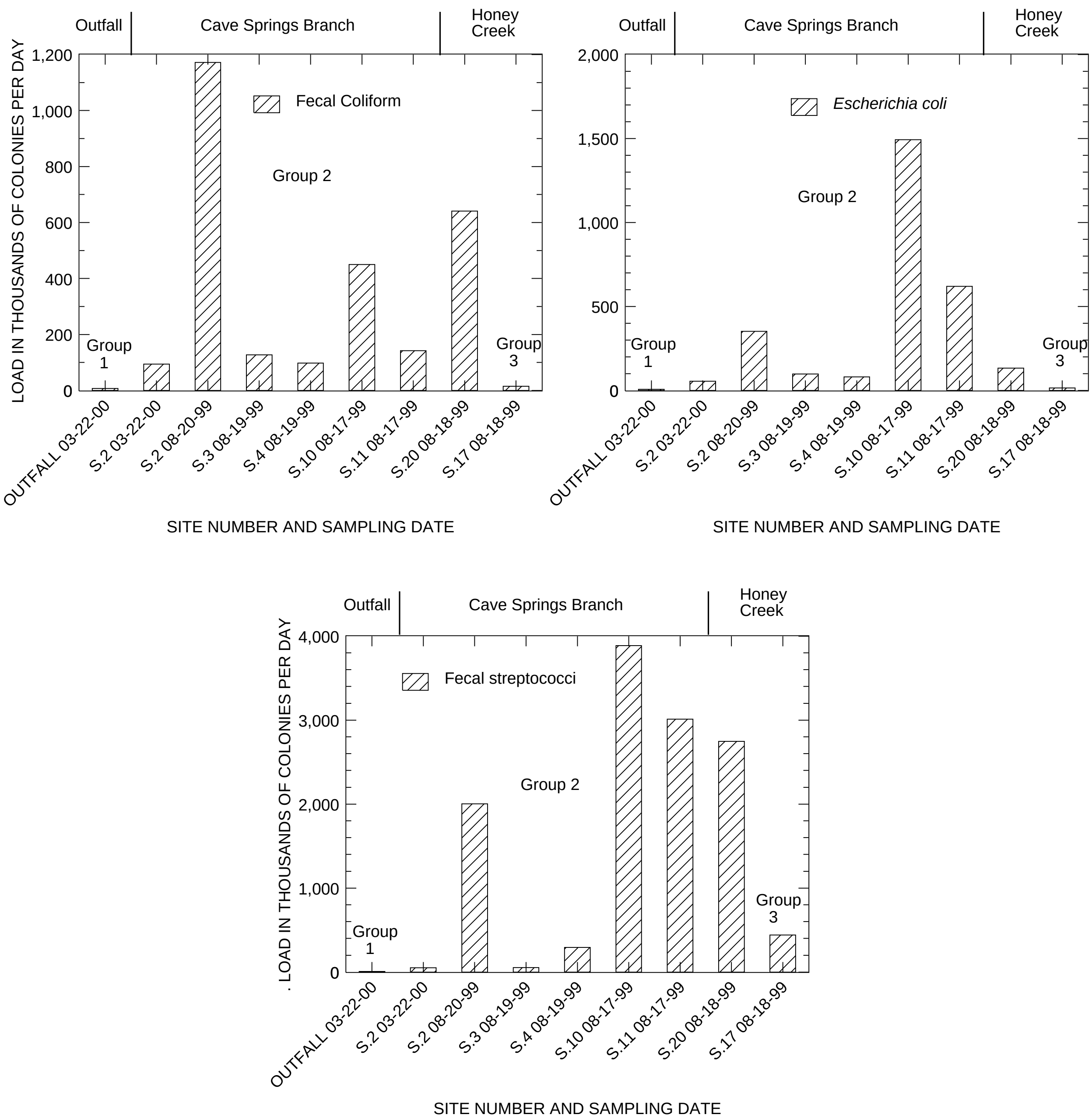


Figure 20. Loads of fecal bacteria measured in Cave Springs Branch and Honey Creek during August 1999 and March 2000.

Table 5. Results of biolog and antibiotic resistance tests on presumptive *Escherichia coli*

[µg, micrograms per liter; (vpm), very poor match to Biolog® data base; T, tetracycline resistant; A, ampicillin resistant; NT, not tested]

Site number (shown on figure 5)	Tentatively identified bacteria strain	Antibiotic resistance	Site number (shown on figure 5)	Tentatively identified bacteria strain	Antibiotic resistance
S.2	*Escherichia coli*		S.11	*Escherichia coli*	
S.2	*Klebsiella terrigena*	T	S.11	*Escherichia coli*	
S.3	*Escherichia hermanii (vpm)*		S.11	*Escherichia hermanii*	
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Photobacterium logei (no match)*	T	S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*	A	S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*	A	S 20	*Escherichia coli*	NT
S.3	*Escherichia coli*	A	S 20	*Escherichia coli*	NT
S.4	*Escherichia coli (vpm)*	A	S 20	*Escherichia coli*	NT
S.4	*Escherichia coli*		S 20	*Escherichia coli*	NT
S.4	*Escherichia coli*[1]	A	S 20	*Escherichia coli*	NT
S.4	*Escherichia coli (vpm)*		W.31	*Escherichia coli*	T, A
S.4*	*Escherichia hermanii*		W.31	*Citrobacter sedlakii*	T, A
S.4	*Escherichia coli*		W.31	*Citrobacter farmeri*	A
S.4	*Escherichia coli*		W.31	*Escherichia coli*	A
S.4	*Escherichia coli*	A	W.31	*Escherichia coli*	
S.4	*Escherichia coli*		W.31	*Escherichia coli*[1]	
S.10	*Escherichia coli*[1]	T, A			
S.10	*Escherichia hermanii*	A			

[1]Firm Biolog® identification of strain

Table 6. Results of ribotyping of *Escherichia coli* isolates from samples collected August 23-27, 1999

Site number	Ribotype number	Source animal	Site number	Ribotype number	Source animal
S.2	3	Bird	S.4	14	Bird
S.2	5	Cow	S.4	14	Bird
S.2	5	Cow	S.4	14	Bird
S.2	5	Cow			
S.2	7	Cow	S.10	14	Bird
S.2	11	Horse	S.10	6	Cow
S.2	11	Horse	S.10	22	Dog
			S.10	10	Horse
S.3	14	Bird			
S.3	14	Bird	S.11	14	Bird
S.3	14	Bird	S.11	14	Bird
S.3	14	Bird	S.11	14	Bird
S.3	14	Bird	S.11	26	Bird
S.3	5	Cow	W.31	19	Dog
S.3	17	Cow	W.31	23	Human
S.3	2	Deer	W.31	23	Human
S.3	25	Dog			
S.3	15	Horse			

populations of source animals. Three ribotypes of bird-sourced bacteria were found. Twelve of the 14 bird-sourced isolates were of the same ribotype (designated by ribotype number) indicating the same type of bird and probably the same population (table 6).

The data base of bird bacterial ribotypes is inadequate to specify the type of bird that produced these bacteria. Five ribotypes of cow-, three ribotypes of horse-, and two ribotypes of dog-sourced bacteria were detected in stream samples, indicating that multiple populations of these animals probably contributed bacteria to the stream. Cows and horses graze and obtain water along reaches of the Cave Springs Branch near the Oklahoma-Missouri state line.

The relative lack of bacteria at the plant outfall and the lack of ribotype 14 bacteria at site S.2 may indicate that the bird bacteria are not from the poultry processing plant, but are from chicken houses, chicken-litter fertilized hay fields, or other bird species in the basin. Identifiable sources of bacteria at site S.2 at the state line gage were dominantly cow and horse, with one *Escherichia coli* ribotype from bird. One bird bacteria isolate was of a different ribotype than bird-sourced bacteria downstream. Half of the identified ribotypes at site S.3 were bird and the remainder were from cows, deer, dogs, and horses. All bird bacteria isolates at site S.3 were of the same ribotype. All bacteria from S.4, O'Brien Spring, also were of that same ribotype of bird-sourced bacteria. Bacteria at S.10 were from birds, cows, dogs, and horses. All bacteria isolates from S.11 were from birds, three of the same ribotype determined at S.3, and one from a unique ribotype. Bacterial ribotypes from upgradient well (W.31) indicate human and dog feces as sources for bacteria in that well. This result confirms detection of caffeine and fragrance in the well indicating human wastewater influence. *Escherichia coli* was detected in only one well sample (W.31).

Hydrology and natural and anthropogenic tracers in the water indicate probable sources of contaminants in Cave Springs Branch and in wells in the Cave Springs Branch basin. Tracers utilized in this study include chloride, stable isotopes of hydrogen and oxygen, wastewater indicator compounds, and bacteria strains and ribotypes.

Summary and Conclusions

The U.S. Geological Survey, in cooperation with the Oklahoma Office of the Attorney General, conducted a reconnaissance hydrologic and water-quality investigation to evaluate the potential sources of bacteria and nutrient contamination in the Cave Springs Branch basin and the underlying karstic Springfield Plateau aquifer.

Most wells in the study area are completed in the Springfield Plateau aquifer. Ground water in the area is rapidly recharged by precipitation due to rapid infiltration rates common in soils that overlie the aquifer. The direction of ground-water flow in the study area generally is east to west, however, ground water in the study area is hydraulically connected to Cave Springs Branch and Honey Creek and flow is locally controlled by the streams. Losing reaches of Cave Springs Branch discharged water to the alluvium or the Springfield Plateau aquifer. Water-table altitudes indicate that some of the water from Cave Springs Branch may flow through the Springfield Plateau aquifer to Honey Creek in a region extending about 1.75 miles upstream from the confluence with Honey Creek.

Honey Creek above the confluence with Cave Springs Branch, and ground water were chemically similar, indicating that Honey Creek consists mostly of ground water base flow and that Cave Springs Branch has little affect on downgradient ground water.

About one-third of the flow in Cave Springs Branch at the state line appears to be discharge from the poultry-processing plant. The poultry-processing plant wastewater outfall sample had substantially greater concentrations of magnesium, sodium, potassium, chloride, sulfate, ammonia, and total organic nitrogen plus ammonia than stream and ground-water samples. Background chloride concentration in study area wells is about 1.5 milligrams per liter. Much of the chloride in Cave Springs Branch, which averaged 165 milligrams per liter, was probably derived from the poultry-processing plant and animal and human waste along the stream. Water from three wells downgradient of Cave Springs Branch with greater chloride concentrations may have a small percentage of water from Cave Springs Branch. Chloride concentrations greater than 1.5 milligrams per liter in water from upgradient wells may be from animal waste or human wastewater, as indicated by associated nitrate concentrations.

Ammonia, which is present primarily as the cation ammonium, is converted rapidly to nitrate in oxygen-rich water and the increased concentrations of nitrate in Cave Springs Branch and O'Brien Spring relative to the poultry-processing plant wastewater outfall may have been the result of conversion of ammonia from the poultry-processing plant wastewater. The poultry-processing plant wastewater outfall sample contained greater concentrations of ammonia and total organic nitrogen plus ammonia than the samples collected during August 1999. Nitrate concentration, however, was in the middle range of concentrations and generally was less than the concentration in Cave Springs Branch, O'Brien Spring, and Honey Creek below the confluence samples. Cave Springs Branch and Honey Creek contributed approximately equal loads of nitrogen to Honey Creek below the confluence and the greatest loads of nitrogen were introduced to Cave Springs Branch by the outfall and O'Brien Spring. Nitrate concentrations in upgradient well samples ranged from 0.38 to 4.60 milligrams per liter, indicating that there is a source of ground-water nitrogen other than Cave Springs Branch, such as animal waste, fertilizer, or human waste. Nitrogen compounds in water from downgradient wells may be from Cave Springs Branch, fertilizers, animal waste, or human waste.

Substantial phosphorus concentrations in samples from Cave Springs Branch, O'Brien Spring, and Honey Creek below the confluence, which were dominantly dissolved orthophosphate, may have been derived from the poultry-processing plant wastewater as well as from animal or fertilizer sources along Cave Springs Branch. Total phosphorus and orthophosphate loads increased in the reach downstream from O'Brien Spring, indicating a nonpoint source of orthophosphate, such as fertilizer or animal or human waste.

Iron and manganese concentrations were greater in the poultry-processing plant wastewater outfall than in Cave Springs Branch, O'Brien Spring, and Honey Creek. The Chattanooga Shale may be a source of iron and manganese in ground water.

Dissolved arsenic and selenium can be associated with contamination of water by chicken litter. However, arsenic and selenium concentrations were less than 3 micrograms per liter in all samples.

Organic wastewater indicator compounds detected in the poultry-processing plant wastewater outfall sample were detected downstream in O'Brien Spring and some Cave Springs Branch samples. The presence of organic wastewater indicator compounds in Honey Creek, which receives discharge of treated wastewater from South West City, Missouri, indicates some influence by human wastewater. Organic wastewater indicator compounds detected in water from upgradient wells indicate ground water is influenced by human wastewater. Organic wastewater indicator compounds detected in downgradient well samples also were detected in the poultry-processing plant wastewater outfall and Cave Springs Branch indicating downgradient wells may receive some water that originally came from the outfall. However, these organic compounds also could be from septic tanks.

Delta values for stable isotopes of hydrogen and oxygen in Cave Springs Branch, O'Brien Spring, and Honey Creek below the confluence samples are different from Honey Creek and wells, but the differences were not great enough to quantify the percentage of surface water in downgradient well samples. Delta values for stable isotopes of hydrogen and oxygen indicate that the greatest amount of evaporation had occurred from O'Brien Spring water indicating the spring probably receives some water from lagoons or ponds.

Fecal coliform bacteria colony counts were least in wells, intermediate in the poultry-processing plant wastewater outfall, and Honey Creek above the confluence, and greatest in Cave Springs Branch. *Escherichia coli* and fecal streptococcal bacteria loads were greater in the sample from S.10 than at any other stream site and decreased downstream, indicating a source of these bacteria along the reach between O'Brien Spring and S.10.

Bacteria strains and resistance to antibiotics of some bacteria indicate that livestock may have been sources of some bacteria in the water samples. Three bacterial isolates from S.10 and W.31 samples only had resistance to tetracycline and ampicillin, which indicates that the bacteria may not be from human or poultry sources. Multiple resistance to antibiotics other than tetracycline and ampicillin would indicate probable human- or poultry-sourced bacteria.

Ribotyping indicates that *Escherichia coli* bacteria in water samples from the basin were from bird, cow, horse, dog, deer, and human sources. The presence of multiple ribotypes from each type of animal source, except bird, indicates that most of the bacteria are from multiple populations of source animals. Identifiable sources of bacteria in Cave Springs Branch at the state line were dominantly cow and horse with one ribotype from bird. Bacteria from chickens may enter the stream with runoff from hay fields fertilized with poultry-litter or from other bird species in the basin. All bacteria from O'Brien Spring were of the same ribotype of bird-sourced bacteria.

Escherichia coli was detected in only one well sample. Bacterial ribotypes in water from that upgradient well indicated human and dog feces as sources for bacteria, and that on site wastewater treatment may not always be adequate in these highly permeable soils.

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Appendixes

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri

[mi, miles; mi^2, square miles; AC-FT, acre feet; ---, no data available; FT FM L BANK, feet from left bank, DEG C, degrees Celsius; MM OF HG, millimeters of mercury; US/CM, microsiemens per centimeter; Dissolved, determined in unfiltered sample; MG/L, milligrams per liter; COLS./100 ML, colonies per 100 milliliters; K, estimated count based on non-ideal colony count; HCO3, bicarbonate; CO3, carbonate; CaCO3, calcium carbonate; <, less than; N, nitrogen; NO2, nitrate; NO3, nitrate; P, phosphorus; PO4; phosphate]

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO

LOCATION.--Lat 36°32'52", long 94°37'04", in SE 1/4 NE 1/4 sec.22, T.24 N., R.25 E., Delaware County, Hydrologic Unit 11070206, on right bank of downstream side of bridge on Stateline Highway 5, 2.5 mi northwest of South West City, Mo, 4.7 mi upstream from Honey Springs, and at mile 4.7.

DRAINAGE AREA.--7.9 mi^2.

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--October 1997 to current year (2000).

GAGE.--Water stage recorder. Datum of gage is 922.86 ft above sea level.

REMARKS.--No estimated daily discharge. Records fair. U.S. Geological Survey satellite telemeter at station.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1997 TO SEPTEMBER 1998
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	3.1	3.2	3.5	4.9	5.0	2.7	6.4	2.7	2.3	1.7	1.5	1.5
2	3.1	3.1	3.5	4.8	4.2	2.6	6.3	2.6	2.3	1.7	1.5	1.5
3	3.1	3.1	3.7	4.7	3.8	2.7	6.4	2.6	2.3	1.6	1.5	1.5
4	2.8	3.1	3.5	142	3.6	2.7	5.8	2.6	2.2	1.6	3.5	1.6
5	2.6	3.2	3.3	14	3.4	2.7	6.0	2.6	2.2	1.5	2.5	1.6
6	2.7	3.1	3.2	31	3.3	2.7	6.0	2.9	2.1	1.5	1.6	1.6
7	2.8	3.1	3.3	17	3.5	26	6.2	3.0	2.2	1.6	1.6	1.5
8	3.1	3.1	9.1	99	3.8	20	5.5	3.0	2.2	1.6	1.6	1.5
9	3.1	3.1	5.2	24	3.9	5.7	5.1	2.8	2.2	1.5	1.9	1.5
10	3.0	3.8	4.7	12	4.0	5.0	4.8	3.0	2.2	1.5	1.7	1.5
11	2.9	3.8	4.4	9.1	4.5	4.7	4.6	3.0	2.2	1.7	1.6	1.6
12	4.1	3.5	4.1	8.3	4.1	4.5	4.5	3.0	2.0	1.5	1.6	1.6
13	4.6	3.9	3.8	7.6	4.0	4.6	4.2	2.9	1.9	1.4	1.6	1.8
14	3.3	3.9	3.5	7.4	3.9	4.4	4.6	2.9	1.9	1.4	1.7	25
15	3.3	3.6	3.4	6.6	3.9	4.8	4.6	3.1	1.8	1.6	1.6	2.8
16	3.3	3.6	3.3	6.1	4.1	45	4.3	3.2	1.8	1.6	1.6	2.2
17	3.0	3.7	3.1	6.4	4.1	17	4.3	3.4	1.9	1.6	1.6	2.0
18	2.8	3.7	3.1	6.4	4.0	8.9	4.0	3.6	1.9	1.6	1.6	1.9
19	2.8	3.7	3.1	6.1	3.9	36	4.1	3.5	1.9	1.5	1.6	1.8
20	2.8	3.6	2.9	6.0	3.9	15	4.1	3.5	1.8	1.5	1.6	1.8
21	2.8	3.6	7.2	5.8	3.9	8.5	4.1	3.5	1.8	1.5	1.6	1.9
22	3.0	3.5	5.4	5.6	3.8	7.4	4.1	3.7	1.7	1.5	1.6	1.9
23	3.0	3.3	5.1	5.3	3.0	6.9	4.2	3.7	1.7	1.5	1.5	1.9
24	3.1	3.4	54	5.2	3.0	6.8	4.2	3.6	1.7	1.5	1.4	1.8
25	3.4	3.5	7.7	5.2	3.1	6.8	4.3	4.2	1.7	1.5	1.5	1.9
26	3.2	3.4	6.4	6.0	3.1	6.7	4.6	4.4	1.6	1.5	1.6	1.7
27	3.2	3.4	5.9	5.1	2.9	7.0	5.8	2.7	1.4	1.5	1.6	1.8
28	3.1	3.6	5.8	5.1	2.8	6.7	3.0	2.5	1.7	1.6	1.6	1.8
29	3.1	5.3	5.6	5.0	---	6.6	2.8	2.5	1.6	1.5	1.5	1.8
30	3.2	3.8	5.3	4.7	---	6.8	2.7	2.4	1.7	1.5	1.5	1.8
31	3.2	---	5.1	4.6	---	7.5	---	2.4	---	1.5	1.5	---
TOTAL	96.6	105.7	191.2	481.0	104.5	295.4	141.6	95.5	57.9	47.8	51.9	76.1
MEAN	3.12	3.52	6.17	15.5	3.73	9.53	4.72	3.08	1.93	1.54	1.67	2.54
MAX	4.6	5.3	54	142	5.0	45	6.4	4.4	2.3	1.7	3.5	25
MIN	2.6	3.1	2.9	4.6	2.8	2.6	2.7	2.4	1.4	1.4	1.4	1.5
AC-FT	192	210	379	954	207	586	281	189	115	95	103	151

SUMMARY STATISTICS	FOR 1998 WATER YEAR	
ANNUAL TOTAL	1745.2	
ANNUAL MEAN	4.78	
HIGHEST DAILY MEAN	142	Jan 4
LOWEST DAILY MEAN	1.4	Jun 27
ANNUAL SEVEN-DAY MINIMUM	1.5	Jul 19
INSTANTANEOUS PEAK FLOW	539	Jan 4
INSTANTANEOUS PEAK STAGE	8.02	Jan 4
ANNUAL RUNOFF (AC-FT)	3460	
10 PERCENT EXCEEDS	6.4	
50 PERCENT EXCEEDS	3.1	
90 PERCENT EXCEEDS	1.6	

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1998 TO SEPTEMBER 1999
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1.8	4.8	4.2	3.2	6.1	3.7	7.2	8.1	11	147	3.4	2.0
2	1.8	4.3	4.0	8.4	5.8	3.5	6.9	7.8	9.1	19	3.9	2.2
3	1.8	3.9	3.9	4.5	5.8	3.4	8.0	7.7	8.5	10	3.9	2.3
4	1.8	3.7	4.0	4.2	5.6	3.5	7.1	54	8.1	8.5	3.8	2.2
5	291	3.4	3.8	4.2	5.5	3.6	6.2	10	7.4	7.9	4.2	1.6
6	82	2.9	3.9	4.6	47	3.1	6.1	5.7	7.0	7.8	4.0	1.9
7	9.8	2.4	3.5	3.9	52	3.0	6.0	5.0	7.0	7.4	3.4	2.3
8	9.0	2.5	3.5	3.9	9.6	11	5.8	4.4	6.7	7.3	2.7	2.3
9	8.4	2.7	3.7	3.3	8.2	6.5	5.7	4.1	6.5	7.1	3.4	2.4
10	7.9	5.5	4.1	3.4	7.9	5.3	4.9	4.5	6.6	6.9	3.4	2.5
11	7.3	4.6	3.5	3.4	7.4	5.1	4.5	4.1	6.5	6.4	3.3	2.2
12	6.9	4.0	3.4	3.6	6.7	23	4.3	4.8	5.8	6.5	3.2	2.3
13	6.1	3.2	3.1	4.2	6.3	31	4.8	4.1	5.5	6.1	3.3	2.5
14	5.4	4.1	3.2	3.9	6.3	15	8.1	3.8	5.6	6.0	2.6	2.3
15	5.4	3.9	3.0	3.6	6.1	25	5.8	3.6	5.3	5.8	2.5	2.2
16	5.2	3.8	2.8	3.0	5.7	98	5.0	3.5	6.8	5.7	2.9	2.1
17	5.5	3.7	2.8	3.4	5.4	19	4.1	8.9	5.6	5.4	2.8	2.1
18	5.3	3.6	3.0	3.7	5.2	10	4.6	9.6	5.3	5.1	2.6	2.1
19	4.6	3.9	3.7	3.4	4.9	13	4.5	9.2	13	5.3	2.1	1.9
20	4.4	3.7	3.2	3.1	4.7	71	4.6	8.9	13	5.1	1.6	2.4
21	4.5	3.5	3.8	3.4	4.2	14	4.2	11	11	4.8	2.0	2.2
22	4.3	2.8	3.6	3.1	3.9	10	7.0	14	8.9	4.7	1.2	2.2
23	4.1	3.1	3.5	3.0	4.2	9.2	6.6	63	157	4.5	1.8	2.2
24	4.1	3.3	3.6	2.9	4.1	8.6	5.0	10	15	4.1	1.9	2.1
25	3.9	3.4	3.3	2.8	4.1	8.1	29	8.9	11	3.4	1.8	1.7
26	3.9	3.3	3.2	3.0	4.3	7.7	114	8.5	8.8	4.3	2.0	1.5
27	3.7	3.2	3.4	3.1	3.9	7.6	26	8.0	8.3	3.9	1.8	1.8
28	3.8	2.6	2.9	3.0	3.4	7.6	11	7.7	9.4	4.0	1.1	1.9
29	4.2	3.0	2.8	3.4	---	7.4	9.7	7.5	8.4	4.1	.79	2.0
30	3.9	7.1	2.7	4.9	---	7.1	8.8	36	263	4.2	1.8	2.1
31	3.9	---	2.5	8.2	---	7.0	---	19	---	3.8	2.2	---
TOTAL	515.7	109.9	105.6	119.7	244.3	451.0	335.5	365.4	651.1	332.1	81.39	63.5
MEAN	16.6	3.66	3.41	3.86	8.73	14.5	11.2	11.8	21.7	10.7	2.63	2.12
MAX	291	7.1	4.2	8.4	52	98	114	63	263	147	4.2	2.5
MIN	1.8	2.4	2.5	2.8	3.4	3.0	4.1	3.5	5.3	3.4	.79	1.5
AC-FT	1020	218	209	237	485	895	665	725	1290	659	161	126

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1998 - 1999, BY WATER YEAR (WY)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MEAN	9.88	3.59	4.79	9.69	6.23	12.0	7.89	7.81	11.8	6.13	2.15	2.33
MAX	16.6	3.66	6.17	15.5	8.73	14.5	11.2	11.8	21.7	10.7	2.63	2.54
(WY)	1999	1999	1998	1998	1999	1999	1999	1999	1999	1999	1999	1998
MIN	3.12	3.52	3.41	3.86	3.73	9.53	4.59	3.84	1.95	1.54	1.67	2.12
(WY)	1998	1998	1999	1999	1998	1998	1998	1998	1998	1998	1998	1999

SUMMARY STATISTICS	FOR 1998 CALENDAR YEAR		FOR 1999 WATER YEAR		WATER YEARS 1998 - 1999	
ANNUAL TOTAL	2082.9		3375.19			
ANNUAL MEAN	5.71		9.25		7.04	
HIGHEST ANNUAL MEAN					9.25	1999
LOWEST ANNUAL MEAN					4.84	1998
HIGHEST DAILY MEAN	291	Oct 5	291	Oct 5	291	Oct 5 1998
LOWEST DAILY MEAN	1.4	Jun 27	.79	Aug 29	.79	Aug 29 1999
ANNUAL SEVEN-DAY MINIMUM	1.5	Jul 19	1.6	Aug 23	1.5	Jul 19 1998
INSTANTANEOUS PEAK FLOW			1360	Oct 5	1360	Oct 5 1998
INSTANTANEOUS PEAK STAGE			12.08	Oct 5	12.08	Oct 5 1998
INSTANTANEOUS LOW FLOW			.48	Aug 28		
ANNUAL RUNOFF (AC-FT)	4130		6690		5100	
10 PERCENT EXCEEDS	6.7		10		8.6	
50 PERCENT EXCEEDS	3.3		4.2		3.8	
90 PERCENT EXCEEDS	1.6		2.2		1.6	

Appendix 1. Daily mean discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO

LOCATION.--Lat 36°32'56", long 94°41'01", in SE 1/4 NE 1/4 sec.24, T.24 N., R.24 E., Delaware County, Hydrologic Unit 11070206, on downstream abutment of county road bridge, 0.4 mi downstream from Cave Springs Creek, 2.3 mi southeast of Dodge, Ok, and 5.1 mi above Grand Lake and at mile 5.1.

DRAINAGE AREA.--48.2 mi^2.

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--October 1997 to current year (2000).

GAGE.--Water stage recorder. Datum of gage is 789 ft above sea level from topographic map.

REMARKS.--Records fair. U.S. Geological Survey satellite telemeter at station.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1997 TO SEPTEMBER 1998
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	16	11	27	36	37	24	55	32	16	15	7.0	4.4
2	14	10	25	34	36	23	55	30	15	14	6.5	4.4
3	13	9.8	24	32	34	23	54	28	14	12	7.3	4.0
4	12	10	23	407	33	22	50	26	14	11	14	3.9
5	11	11	21	291	32	22	47	26	14	11	23	3.6
6	10	11	20	299	32	22	45	26	14	9.7	12	3.6
7	10	11	19	225	31	46	46	29	13	9.5	10	3.6
8	11	11	39	597	31	123	43	28	15	12	9.7	3.6
9	14	11	47	355	30	109	41	27	16	11	15	3.6
10	12	12	44	247	30	92	39	26	15	9.8	14	3.8
11	12	11	40	183	32	80	37	25	16	15	12	3.9
12	15	12	36	143	32	69	35	24	14	13	10	4.2
13	27	14	32	115	32	61	35	23	13	11	10	7.7
14	23	15	30	101	31	54	34	22	13	11	10	80
15	20	15	28	89	31	50	33	22	13	9.9	9.9	32
16	18	13	26	80	32	129	31	20	14	9.0	9.3	21
17	16	13	24	72	32	187	30	20	12	8.9	8.7	16
18	15	9.0	23	66	31	165	29	19	13	8.6	8.1	14
19	14	8.3	22	60	30	211	28	19	12	8.0	7.7	12
20	13	10	20	56	29	215	28	18	11	7.4	7.2	10
21	12	12	30	53	28	166	27	18	11	7.2	6.5	12
22	12	13	40	49	28	131	26	18	11	7.1	6.0	12
23	12	13	40	46	26	109	26	18	10	7.9	5.7	10
24	12	12	155	43	26	93	25	17	9.2	7.7	5.2	9.7
25	13	13	105	42	26	82	25	23	9.3	7.7	4.7	9.0
26	14	13	86	44	27	74	27	26	9.0	6.9	5.2	8.4
27	12	13	72	41	26	68	38	24	8.6	6.5	5.9	7.6
28	12	14	61	40	26	62	39	21	8.2	11	5.8	7.8
29	11	27	52	39	---	56	36	20	8.4	9.0	5.9	7.6
30	11	28	44	37	---	53	34	18	17	7.5	5.2	7.9
31	11	---	40	36	---	57	---	17	---	7.4	4.4	---
TOTAL	428	386.1	1295	3958	851	2678	1098	710	378.7	302.7	271.9	331.3
MEAN	13.8	12.9	41.8	128	30.4	86.4	36.6	22.9	12.6	9.76	8.77	11.0
MAX	27	28	155	597	37	215	55	32	17	15	23	80
MIN	10	8.3	19	32	26	22	25	17	8.2	6.5	4.4	3.6
AC-FT	849	766	2570	7850	1690	5310	2180	1410	751	600	539	657

SUMMARY STATISTICS	FOR 1998 WATER YEAR	
ANNUAL TOTAL	12688.7	
ANNUAL MEAN	34.8	
HIGHEST DAILY MEAN	597	Jan 8
LOWEST DAILY MEAN	3.6	Sep 5-9
ANNUAL SEVEN-DAY MINIMUM	3.7	Sep 4
INSTANTANEOUS PEAK FLOW	1060	Jan 4
INSTANTANEOUS PEAK STAGE	7.34	Jan 4
ANNUAL RUNOFF (AC-FT)	25170	
10 PERCENT EXCEEDS	67	
50 PERCENT EXCEEDS	19	
90 PERCENT EXCEEDS	7.7	

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1998 TO SEPTEMBER 1999
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	8.5	27	39	27	39	25	51	92	83	826	24	13
2	8.5	33	38	37	41	24	49	76	74	482	23	13
3	8.6	29	37	36	41	23	52	66	63	286	24	13
4	8.4	28	35	36	39	23	54	270	58	207	24	12
5	648	26	34	36	37	23	57	288	53	164	24	13
6	372	25	33	36	53	22	54	188	49	135	23	13
7	183	25	33	33	245	21	49	147	46	119	22	14
8	136	25	31	32	159	39	47	120	43	107	20	16
9	106	26	33	29	124	52	44	100	40	94	20	15
10	87	43	31	28	100	49	41	91	39	86	20	15
11	73	43	29	28	84	45	37	81	38	78	19	16
12	64	41	e28	27	69	57	35	80	36	70	18	18
13	56	37	27	27	59	144	35	69	35	65	18	17
14	50	36	28	26	53	168	48	62	34	61	17	15
15	47	33	27	25	49	174	49	57	32	57	17	15
16	43	31	25	25	44	310	47	53	39	54	16	15
17	43	29	25	24	41	306	44	59	38	51	16	15
18	43	28	25	24	38	213	42	55	34	47	16	15
19	38	27	29	23	36	169	40	51	50	46	16	15
20	35	27	28	23	34	255	37	48	58	44	14	17
21	33	26	31	23	32	198	36	54	67	42	14	16
22	30	25	31	23	30	162	42	54	64	40	14	15
23	29	23	32	22	30	134	58	146	348	40	15	14
24	28	23	31	21	29	113	52	128	222	35	15	13
25	27	23	31	21	28	95	108	111	199	34	15	13
26	26	22	30	21	28	84	336	96	167	33	15	13
27	25	21	29	21	27	76	334	79	143	30	15	13
28	25	21	28	21	25	71	207	69	132	28	15	13
29	24	20	26	22	---	64	152	62	116	27	13	13
30	24	38	25	24	---	58	116	97	1320	26	13	16
31	24	---	24	36	---	54	---	91	---	24	13	---
TOTAL	2353.0	861	933	837	1614	3251	2353	3040	3720	3438	548	434
MEAN	75.9	28.7	30.1	27.0	57.6	105	78.4	98.1	124	111	17.7	14.5
MAX	648	43	39	37	245	310	336	288	1320	826	24	18
MIN	8.4	20	24	21	25	21	35	48	32	24	13	12
AC-FT	4670	1710	1850	1660	3200	6450	4670	6030	7380	6820	1090	861

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1998 - 1999, BY WATER YEAR (WY)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MEAN	44.9	20.8	35.9	77.3	44.0	95.6	57.5	60.5	68.3	60.3	13.2	12.8
MAX	75.9	28.7	41.8	128	57.6	105	78.4	98.1	124	111	17.7	14.5
(WY)	1999	1999	1998	1998	1999	1999	1999	1999	1999	1999	1999	1999
MIN	13.8	12.9	30.1	27.0	30.4	86.4	36.6	22.9	12.6	9.76	8.77	11.0
(WY)	1998	1998	1999	1999	1998	1998	1998	1998	1998	1998	1998	1998

e Estimated

SUMMARY STATISTICS	FOR 1998 CALENDAR YEAR		FOR 1999 WATER YEAR		WATER YEARS 1998 - 1999	
ANNUAL TOTAL	14726.6		23382.0			
ANNUAL MEAN	40.3		64.1		49.4	
HIGHEST ANNUAL MEAN					64.1	1999
LOWEST ANNUAL MEAN					34.8	1998
HIGHEST DAILY MEAN	648	Oct 5	1320	Jun 30	1320	Jun 30 1999
LOWEST DAILY MEAN	3.6	Sep 5	8.4	Oct 4	3.6	Sep 5-9 1998
ANNUAL SEVEN-DAY MINIMUM	3.7	Sep 4	13	Aug 29	3.7	Sep 4 1998
INSTANTANEOUS PEAK FLOW			6140	Jun 30	6140	Jun 30 1999
INSTANTANEOUS PEAK STAGE			12.98	Jun 30	12.98	Jun 30 1999
ANNUAL RUNOFF (AC-FT)	29210		46380		35800	
10 PERCENT EXCEEDS	72		135		101	
50 PERCENT EXCEEDS	26		35		28	
90 PERCENT EXCEEDS	7.7		15		9.9	

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO

WATER-QUALITY DATA

DATE	TIME	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK) (00009)	TEMPER-ATURE WATER (DEG C) (00010)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	AGENCY COL-LECTING SAMPLE (CODE NUMBER) (00027)	AGENCY ANA-LYZING SAMPLE (CODE NUMBER) (00028)	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	GAGE HEIGHT (FEET) (00065)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)
SEP 1997											
15...	1400	.50	27.1	750	1028	1028	1.6	4.98	2120	6.6	7.4
15...	1401	1.50	27.2	750	1028	1028	1.6	4.98	2150	6.7	7.5
15...	1402	2.50	27.3	750	1028	1028	1.6	4.98	2130	6.9	7.5
15...	1403	3.50	27.3	750	1028	1028	1.6	4.98	2130	6.7	7.5
15...	1404	4.50	27.4	750	1028	1028	1.6	4.98	2130	6.8	7.5
15...	1405	5.50	27.4	750	1028	1028	1.6	4.98	2130	6.8	7.5
15...	1406	6.50	27.5	750	1028	1028	1.6	4.98	2130	6.8	7.5
15...	1407	7.50	27.5	750	1028	1028	1.6	4.98	2130	6.9	7.5
15...	1408	8.50	27.6	750	1028	1028	1.6	4.98	2130	7.0	7.5
15...	1409	9.50	27.6	750	1028	1028	1.6	4.98	2130	7.0	7.5
15...	1410	10.5	27.7	750	1028	1028	1.6	4.98	2120	7.2	7.5
15...	1411	11.5	27.8	750	1028	1028	1.6	4.98	2120	7.4	7.5
FEB 1998											
19...	0945	15.0	12.0	751	1028	1028	4.0	5.13	1190	10.1	7.3
19...	0949	13.0	12.1	751	1028	1028	4.0	5.13	1190	10.0	7.4
19...	0950	11.0	12.2	751	1028	1028	4.0	5.13	1190	9.9	7.4
19...	0951	9.00	12.2	751	1028	1028	4.0	5.13	1190	9.9	7.4
19...	0953	7.00	12.2	751	1028	1028	4.0	5.13	1190	9.9	7.4
19...	0954	5.00	12.2	751	1028	1028	4.0	5.13	1190	9.6	7.4
19...	1000	3.00	12.3	751	1028	1028	4.0	5.13	1190	9.3	7.4
19...	1001	1.00	12.3	751	1028	1028	4.0	5.13	1190	9.6	7.4
MAR											
11...	1037	2.00	9.6	768	1028	1028	4.6	5.16	299	12.0	7.1
11...	1038	4.00	9.9	768	1028	1028	4.6	5.16	301	11.7	7.1
11...	1039	6.00	10.0	768	1028	1028	4.6	5.16	301	11.5	7.0
11...	1040	8.00	10.0	768	1028	1028	4.6	5.16	301	11.4	7.0
11...	1041	10.0	10.0	768	1028	1028	4.6	5.16	301	11.5	7.0
11...	1042	12.0	10.0	768	1028	1028	4.6	5.16	301	11.5	7.1
11...	1043	14.0	10.0	768	1028	1028	4.6	5.16	301	11.4	7.1
11...	1044	16.0	10.0	768	1028	1028	4.6	5.16	301	11.5	7.1
AUG											
19...	1125	2.00	29.1	744	1028	1028	1.4	5.05	2170	8.2	7.6
19...	1126	3.00	29.1	744	1028	1028	1.4	5.05	2170	8.2	7.5
19...	1127	4.00	29.1	744	1028	1028	1.4	5.05	2170	8.1	7.5
19...	1128	5.00	29.0	744	1028	1028	1.4	5.05	2170	8.1	7.6
19...	1129	6.00	28.8	744	1028	1028	1.4	5.05	2170	8.1	7.6
19...	1130	7.00	28.9	744	1028	1028	1.4	5.05	2170	8.1	7.6
19...	1131	8.00	28.8	744	1028	1028	1.4	5.05	2170	8.1	7.6
19...	1132	9.00	28.8	744	1028	1028	1.4	5.05	2170	8.1	7.6
19...	1133	10.0	28.8	744	1028	1028	1.4	5.05	2170	8.1	7.6
DEC											
08...	1036	2.00	11.7	757	1028	1028	3.5	4.79	451	11.2	7.2
08...	1037	4.00	11.8	757	1028	1028	3.5	4.79	451	11.2	7.2
08...	1038	6.00	12.0	757	1028	1028	3.5	4.79	450	11.3	7.2
08...	1039	8.00	12.0	757	1028	1028	3.5	4.79	450	11.3	7.2
08...	1040	10.0	12.1	757	1028	1028	3.5	4.79	451	11.3	7.2
08...	1041	12.0	12.1	757	1028	1028	3.5	4.79	451	11.1	7.2
08...	1042	14.0	12.1	757	1028	1028	3.5	4.79	452	11.2	7.2
08...	1043	16.0	12.1	757	1028	1028	3.5	4.79	453	11.1	7.2
08...	1044	18.0	12.2	757	1028	1028	3.5	4.79	453	11.1	7.2
JUN 1999											
09...	0835	--	19.7	743	1028	1028	6.7	5.03	941	8.0	7.3
15...	1235	2.00	22.3	752	1028	1028	5.6	4.96	1130	10.9	7.3
15...	1236	4.00	22.3	752	1028	1028	5.6	4.96	1130	10.7	7.3
15...	1237	6.00	22.3	752	1028	1028	5.6	4.96	1130	10.6	7.3
15...	1238	8.00	22.3	752	1028	1028	5.6	4.96	1130	10.6	7.3
15...	1239	10.0	22.3	752	1028	1028	5.6	4.96	1130	10.6	7.3
15...	1240	12.0	22.3	752	1028	1028	5.6	4.96	1130	10.6	7.3
15...	1241	14.0	22.3	752	1028	1028	5.6	4.96	1130	10.5	7.3
15...	1242	16.0	22.2	752	1028	1028	5.6	4.96	1130	10.3	7.4
15...	1243	18.0	22.2	752	1028	1028	5.6	4.96	1130	10.2	7.4

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	TIME	AGENCY COL- LECTING SAMPLE (CODE NUMBER) (00027)	AGENCY ANA- LYZING SAMPLE (CODE NUMBER) (00028)	DIS- CHARGE, INST. CUBIC FEET PER SECOND (00061)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STAND- ARD UNITS) (00400)	TEMPER- ATURE AIR (DEG C) (00020)	TEMPER- ATURE WATER (DEG C) (00010)	BARO- METRIC PRES- SURE (MM OF HG) (00025)	OXYGEN, DIS- SOLVED (MG/L) (00300)
AUG 1997										
26...	0945	1028	80020	2.1	2020	7.3	26.0	24.0	753	5.3
SEP										
15...	1420	1028	80020	1.6	2130	7.5	32.0	27.5	750	6.9
OCT										
15...	1345	1028	80020	3.8	1560	7.0	20.0	21.5	757	6.7
NOV										
18...	1400	1028	80020	4.0	2090	7.5	15.0	12.5	755	10.0
DEC										
15...	1645	1028	80020	3.6	1230	7.0	9.5	12.0	753	8.5
JAN 1998										
14...	1040	1028	80020	8.1	677	6.9	3.0	11.0	752	9.4
FEB										
19...	1010	1028	80020	4.0	1170	7.4	6.5	12.2	751	9.9
MAR										
11...	1045	1028	80020	4.6	301	7.0	-2.3	10.0	768	11.4
APR										
24...	1000	1028	80020	3.6	1490	7.6	22.0	16.5	749	12.8
MAY										
12...	0925	1028	80020	5.5	1590	7.4	22.5	20.4	740	9.9
JUN										
03...	0910	1028	80020	2.3	1870	7.5	30.6	24.3	734	6.0
JUL										
15...	0910	1028	80020	1.2	2170	7.4	29.7	26.2	741	6.4
AUG										
19...	1115	1028	80020	1.4	2170	7.6	34.5	28.8	744	8.1
SEP										
23...	1005	1028	80020	1.7	1940	7.7	22.3	22.6	748	8.3
OCT										
21...	1055	1028	80020	4.5	1640	7.5	16.5	18.4	756	10.0
NOV										
17...	0955	1028	80020	3.8	1630	7.3	15.1	14.7	751	9.4
DEC										
08...	1035	1028	80020	3.5	451	7.2	3.8	12.0	757	11.2
JAN 1999										
07...	1000	1028	80020	3.8	625	7.4	-.5	9.5	755	9.9
FEB										
03...	0950	1028	80020	6.2	1100	7.4	12.3	11.3	740	10.4
MAR										
16...	1430	1028	80020	363	115	7.2	21.0	12.2	748	10.0
APR										
07...	1000	1028	80020	5.8	831	7.4	23.0	16.1	747	12.7
MAY										
04...	1430	1028	80020	24	310	6.7	24.4	17.1	729	6.1
JUN										
15...	1245	1028	80020	5.6	1130	7.3	27.0	22.3	752	10.6
JUL										
28...	1145	1028	80020	4.3	1180	7.2	35.5	25.3	753	10.4
AUG										
20...	1045	1028	80020	1.6	924	7.7	20.4	24.5	745	11.7
SEP										
14...	1428	1028	80020	2.3	1730	7.6	31.5	23.7	750	11.8

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION) (00301)	COLI-FORM, FECAL, 0.7 UM-MF (COLS./ 100 ML) (31625)	E. COLI WATER WHOLE TOTAL UREASE (COL / 100 ML) (31633)	STREP-TOCOCCI FECAL, KF AGAR (COLS. PER 100 ML) (31673)	BICAR-BONATE WATER DIS IT FIELD MG/L AS HCO3 (00453)	CAR-BONATE WATER DIS IT FIELD MG/L AS CO3 (00452)	ALKA-LINITY WAT DIS TOT IT FIELD MG/L AS CACO3 (39086)
AUG 1997							
26...	64	58	47	5000	207	0	170
SEP							
15...	89	390	170	2200	208	0	171
OCT							
15...	77	130	120	3200	168	0	138
NOV							
18...	95	220	110	1100	170	0	139
DEC							
15...	80	15	K6	140	131	0	107
JAN 1998							
14...	87	21	34	600	95	0	78
FEB							
19...	94	K27	K11	K28	168	0	138
MAR							
11...	101	K17	K2	120	109	0	89
APR							
24...	134	<1	K3	490	168	0	138
MAY							
12...	114	230	K57	80	143	0	117
JUN							
03...	75	590	190	540	166	0	136
JUL							
15...	82	1200	300	980	139	0	114
AUG							
19...	108	1800	790	2000	132	0	108
SEP							
23...	99	520	320	1900	167	0	137
OCT							
21...	108	280	140	270	148	0	121
NOV							
17...	94	180	K60	360	148	0	121
DEC							
08...	105	K170	250	350	124	0	102
JAN 1999							
07...	88	320	240	340	121	0	99
FEB							
03...	98	K64	K49	210	125	0	103
MAR							
16...	95	K8600	4100	7300	35	0	29
APR							
07...	132	230	210	180	134	0	110
MAY							
04...	66	K46000	24000	38000	72	0	59
JUN							
15...	124	45	160	200	162	0	133
JUL							
28...	128	--	--	220	116	0	95
AUG							
20...	144	2400	720	4100	163	0	134
SEP							
14...	143	100	K49	640	171	0	140

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N) (00618)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS NO3) (71851)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N) (00613)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS NO2) (71856)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N) (00608)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS NH4) (71846)
AUG 1997							
26...	81.5	360	1.01	3.3	82.6	.856	1.1
SEP							
15...	10.3	45	.748	2.5	11.0	.107	.14
OCT							
15...	56.7	250	.874	2.9	57.5	.519	.67
NOV							
18...	92.8	410	.961	3.2	93.7	.911	1.2
DEC							
15...	46.9	210	.589	1.9	47.5	.820	1.1
JAN 1998							
14...	22.6	100	2.66	8.7	25.3	.374	.48
FEB							
19...	40.2	180	4.59	15	44.8	3.25	4.2
MAR							
11...	--	--	<.010	--	6.57	.110	.14
APR							
24...	66.4	290	.241	.79	66.7	.035	.05
MAY							
12...	36.9	160	.244	.80	37.2	.059	.08
JUN							
03...	92.2	410	.828	2.7	93.0	.341	.44
JUL							
15...	104	460	.884	2.9	105	.188	.24
AUG							
19...	117	520	.392	1.3	117	.171	.22
SEP							
23...	89.8	400	.369	1.2	90.2	.111	.14
OCT							
21...	71.2	320	.250	.82	71.4	.120	.15
NOV							
17...	67.7	300	.435	1.4	68.1	.234	.30
DEC							
08...	10.2	45	.010	.03	10.3	.037	.05
JAN 1999							
07...	19.1	85	.116	.38	19.2	.076	.10
FEB							
03...	51.3	230	.406	1.3	51.7	.164	.21
MAR							
16...	.932	4.1	.032	.11	.964	.207	.27
APR							
07...	4.27	19	.017	.06	4.28	.027	.03
MAY							
04...	2.27	10	.058	.19	2.33	.285	.37
JUN							
15...	3.94	17	.034	.11	3.98	.051	.07
JUL							
28...	3.99	18	.201	.66	4.19	.431	.56
AUG							
20...	5.69	25	.020	.07	5.71	<.020	--
SEP							
14...	13.4	60	.693	2.3	14.1	.164	.21

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189540 CAVE SPRINGS BRANCH NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	NITRO-GEN, ORGANIC TOTAL (MG/L AS N) (00605)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, TOTAL (MG/L AS N) (00600)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHATE, ORTHO, DIS-SOLVED (MG/L AS PO4) (00660)
AUG 1997							
26...	1.6	2.4	85	8.34	8.15	1.12	3.4
SEP							
15...	1.3	1.4	12	7.62	7.28	7.20	22
OCT							
15...	1.3	1.8	59	5.71	5.46	5.28	16
NOV							
18...	1.5	2.4	96	9.33	7.62	10.3	32
DEC							
15...	1.2	2.0	49	5.53	5.17	5.28	16
JAN 1998							
14...	.89	1.3	27	1.78	1.76	1.52	4.7
FEB							
19...	.65	3.9	49	5.07	4.47	4.14	13
MAR							
11...	.21	.32	6.9	.119	.106	.110	.34
APR							
24...	.97	1.0	68	--	5.52	5.55	17
MAY							
12...	1.2	1.2	38	7.68	5.88	4.12	13
JUN							
03...	.97	1.3	94	5.77	5.35	6.11	19
JUL							
15...	1.3	1.5	110	6.68	6.28	5.87	18
AUG							
19...	1.2	1.4	120	8.81	8.15	7.74	24
SEP							
23...	1.0	1.1	91	7.81	--	7.56	23
OCT							
21...	1.3	1.4	73	2.24	6.20	6.52	20
NOV							
17...	1.0	1.3	69	4.05	3.84	3.65	11
DEC							
08...	.38	.41	11	.668	.662	.572	1.8
JAN 1999							
07...	.66	.73	20	.593	.667	.506	1.6
FEB							
03...	1.1	1.3	53	1.63	1.51	1.52	4.6
MAR							
16...	2.3	2.5	3.4	1.66	.954	.885	2.7
APR							
07...	.55	.57	4.9	.401	.390	.357	1.1
MAY							
04...	1.4	1.7	4.0	.654	.505	.446	1.4
JUN							
15...	.77	.82	4.8	.333	.314	.255	.78
JUL							
28...	.93	1.4	5.5	.212	.198	.169	.52
AUG							
20...	--	.75	6.5	.142	.132	.127	.39
SEP							
14...	.98	1.1	15	.161	.144	.131	.40

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO

WATER-QUALITY DATA

DATE	TIME	SAMPLE LOC- ATION, CROSS SECTION (FT FM L BANK) (00009)	TEMPER- ATURE WATER (DEG C) (00010)	BARO- METRIC PRES- SURE (MM OF HG) (00025)	AGENCY COL- LECTING SAMPLE (CODE NUMBER) (00027)	AGENCY ANA- LYZING SAMPLE (CODE NUMBER) (00028)	DIS- CHARGE, INST. CUBIC FEET PER SECOND (00061)	GAGE HEIGHT (FEET) (00065)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	OXYGEN, DIS- SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND- ARD UNITS) (00400)
SEP 1997											
15...	1558	24.0	23.1	750	1028	1028	9.5	4.81	590	8.2	7.6
15...	1559	22.0	23.0	750	1028	1028	9.5	4.81	594	7.9	7.6
15...	1600	20.0	23.0	750	1028	1028	9.5	4.81	594	8.0	7.6
15...	1601	18.0	22.9	750	1028	1028	9.5	4.81	594	7.8	7.6
15...	1602	16.0	22.9	750	1028	1028	9.5	4.81	594	7.8	7.6
15...	1603	14.0	22.8	750	1028	1028	9.5	4.81	594	7.6	7.6
15...	1604	12.0	22.8	750	1028	1028	9.5	4.81	594	7.8	7.6
15...	1605	10.0	22.8	750	1028	1028	9.5	4.81	594	7.6	7.6
15...	1606	8.00	22.8	750	1028	1028	9.5	4.81	594	7.5	7.5
15...	1607	6.00	22.8	750	1028	1028	9.5	4.81	594	7.7	7.5
15...	1608	4.00	22.8	750	1028	1028	9.5	4.81	594	7.5	7.5
15...	1609	2.00	22.8	750	1028	1028	9.5	4.81	594	7.4	7.5
FEB 1998											
19...	0838	38.0	8.6	751	1028	1028	30	5.08	391	10.6	7.8
19...	0839	34.0	8.6	751	1028	1028	30	5.08	392	10.6	7.8
19...	0840	30.0	8.6	751	1028	1028	30	5.08	392	10.5	7.8
19...	0841	26.0	8.6	751	1028	1028	30	5.08	386	10.6	7.8
19...	0842	22.0	8.6	751	1028	1028	30	5.08	387	10.6	7.8
19...	0843	18.0	8.6	751	1028	1028	30	5.08	382	10.6	7.8
19...	0844	14.0	8.6	751	1028	1028	30	5.08	386	10.7	7.8
19...	0845	10.0	8.6	751	1028	1028	30	5.08	391	10.5	7.8
19...	0846	6.00	8.6	751	1028	1028	30	5.08	391	10.6	7.8
19...	0847	2.00	8.6	751	1028	1028	30	5.08	392	10.5	7.8
MAR											
11...	0935	45.0	7.6	768	1028	1028	79	5.44	248	11.6	7.8
11...	0936	40.0	7.5	768	1028	1028	79	5.44	248	11.6	7.8
11...	0937	35.0	7.5	768	1028	1028	79	5.44	249	11.6	7.8
11...	0938	30.0	7.6	768	1028	1028	79	5.44	248	11.6	7.8
11...	0939	25.0	7.5	768	1028	1028	79	5.44	248	11.6	7.8
11...	0940	20.0	7.6	768	1028	1028	79	5.44	248	11.6	7.8
11...	0941	15.0	7.6	768	1028	1028	79	5.44	248	11.6	7.8
11...	0942	10.0	7.6	768	1028	1028	79	5.44	248	11.6	7.8
11...	0943	5.00	7.6	768	1028	1028	79	5.44	248	11.6	7.8
AUG											
19...	1000	4.00	24.4	747	1028	1028	8.2	4.76	641	6.3	7.7
19...	1001	8.00	24.4	747	1028	1028	8.2	4.76	641	6.4	7.7
19...	1002	12.0	24.3	747	1028	1028	8.2	4.76	641	6.4	7.7
19...	1003	16.0	24.4	747	1028	1028	8.2	4.76	641	6.4	7.7
19...	1004	20.0	24.4	747	1028	1028	8.2	4.76	641	6.4	7.7
19...	1005	24.0	24.4	747	1028	1028	8.2	4.76	641	6.5	7.7
19...	1006	28.0	24.4	747	1028	1028	8.2	4.76	641	6.7	7.7
19...	1007	32.0	24.7	747	1028	1028	8.2	4.76	641	6.7	7.7
DEC											
08...	0916	3.00	11.5	759	1028	1028	28	5.14	425	9.8	7.7
08...	0917	7.00	11.6	759	1028	1028	28	5.14	426	9.7	7.7
08...	0918	11.0	11.6	759	1028	1028	28	5.14	426	9.7	7.7
08...	0919	15.0	11.6	759	1028	1028	28	5.14	425	9.7	7.7
08...	0920	19.0	11.6	759	1028	1028	28	5.14	426	9.6	7.7
08...	0921	23.0	11.6	759	1028	1028	28	5.14	425	9.6	7.7
08...	0922	27.0	11.6	759	1028	1028	28	5.14	426	9.6	7.7
08...	0923	31.0	11.6	759	1028	1028	28	5.14	426	9.6	7.7

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO—-Continued

WATER-QUALITY DATA

DATE	TIME	AGENCY COL-LECTING SAMPLE (CODE NUMBER) (00027)	AGENCY ANA-LYZING SAMPLE (CODE NUMBER) (00028)	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	TEMPER-ATURE AIR (DEG C) (00020)	TEMPER-ATURE WATER (DEG C) (00010)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	OXYGEN, DIS-SOLVED (MG/L) (00300)
AUG 1997										
26...	1130	1028	80020	10	606	7.6	27.0	23.0	750	7.8
SEP										
15...	1615	1028	80020	9.5	594	7.6	31.5	23.0	750	7.7
OCT										
15...	1450	1028	80020	20	534	7.4	23.0	17.5	760	9.0
NOV										
18...	1605	1028	80020	7.8	712	7.8	14.0	10.0	750	12.5
DEC										
15...	1736	1028	80020	27	446	7.5	9.0	8.5	753	10.9
JAN 1998										
14...	0945	1028	80020	101	277	7.4	2.5	10.0	752	10.3
FEB										
19...	0830	1028	80020	30	387	7.8	5.3	8.6	751	10.6
MAR										
11...	0945	1028	80020	79	248	7.8	-1.8	7.6	768	11.6
APR										
24...	0900	1028	80020	25	414	7.8	16.8	13.3	750	9.4
MAY										
12...	0805	1028	80020	24	434	7.8	20.3	17.4	738	8.5
JUN										
03...	0805	1028	80020	15	490	7.7	24.0	21.8	737	5.6
JUL										
15...	0800	1028	80020	11	552	7.7	23.2	23.6	744	5.6
AUG										
19...	0950	1028	80020	8.2	641	7.7	26.9	24.4	747	6.7
SEP										
23...	0810	1028	80020	11	616	7.9	18.3	20.9	750	6.4
OCT										
21...	0920	1028	80020	33	449	7.7	14.2	16.0	759	8.1
NOV										
17...	0805	1028	80020	29	474	8.0	5.1	12.4	754	8.3
DEC										
08...	0915	1028	80020	28	426	7.7	.6	11.6	759	9.7
JAN 1999										
07...	0830	1028	80020	34	437	8.0	.1	6.9	758	10.8
FEB										
03...	0810	1028	80020	40	464	8.1	7.9	8.6	745	9.9
MAR										
16...	1615	1028	80020	485	199	7.5	22.0	13.1	749	9.8
APR										
07...	0805	1028	80020	49	325	7.6	16.7	13.9	751	8.9
MAY										
04...	1325	1028	80020	129	261	7.2	20.8	16.3	730	6.9
JUN										
09...	0730	1028	80020	41	375	7.7	23.3	19.9	746	6.9
JUL										
28...	1345	1028	80020	28	385	7.6	35.5	25.3	752	8.1
AUG										
18...	1745	1028	80020	15	458	7.8	41.0	25.7	746	6.8
SEP										
14...	1355	1028	80020	15	487	7.5	31.5	21.0	750	8.6

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	OXYGEN, DIS- SOLVED (PER- CENT SATUR- ATION) (00301)	COLI- FORM, FECAL, 0.7 UM-MF (COLS./ 100 ML) (31625)	E. COLI WATER WHOLE TOTAL UREASE (COL / 100 ML) (31633)	STREP- TOCOCCI FECAL, KF AGAR (COLS. PER 100 ML) (31673)	BICAR- BONATE WATER DIS IT FIELD MG/L AS HCO3 (00453)	CAR- BONATE WATER DIS IT FIELD MG/L AS CO3 (00452)	ALKA- LINITY WAT DIS TOT IT FIELD MG/L AS CACO3 (39086)
AUG 1997							
26...	93	K13	K4	1500	169	0	139
SEP							
15...	92	45	82	730	168	0	138
OCT							
15...	94	86	40	450	164	0	134
NOV							
18...	113	29	22	250	167	0	137
DEC							
15...	94	K6	K2	K63	142	0	116
JAN 1998							
14...	93	38	14	520	116	0	95
FEB							
19...	92	K15	K13	100	143	0	117
MAR							
11...	96	K12	K7	K58	93	0	76
APR							
24...	91	<1	K9	K43	143	0	117
MAY							
12...	92	350	92	90	149	0	122
JUN							
03...	66	270	73	160	159	0	130
JUL							
15...	68	200	85	340	164	0	134
AUG							
19...	82	480	480	410	162	0	133
SEP							
23...	73	150	160	840	162	0	133
OCT							
21...	82	130	K57	150	143	0	117
NOV							
17...	79	K60	K28	170	154	0	127
DEC							
08...	90	280	220	120	149	0	122
JAN 1999							
07...	89	73	47	69	148	0	121
FEB							
03...	87	67	44	88	150	0	123
MAR							
16...	95	5600	6200	5800	64	0	52
APR							
07...	88	230	180	100	129	0	106
MAY							
04...	74	4600	3500	9400	110	0	90
JUN							
09...	78	110	K14	140	138	0	113
JUL							
28...	100	--	--	220	120	0	99
AUG							
18...	85	140	K29	600	149	0	122
SEP							
14...	98	K22	K17	170	161	0	132

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	NITROGEN, NITRATE DISSOLVED (MG/L AS N) (00618)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3) (71851)	NITROGEN, NITRITE DISSOLVED (MG/L AS N) (00613)	NITROGEN, NITRITE DISSOLVED (MG/L AS NO2) (71856)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N) (00608)	NITROGEN, AMMONIA DISSOLVED (MG/L AS NH4) (71846)
AUG 1997							
26...	14.8	66	.011	.04	14.8	.018	.02
SEP							
15...	--	--	<.010	--	13.7	<.015	--
OCT							
15...	--	--	<.010	--	10.9	.027	.03
NOV							
18...	--	--	<.010	--	--	<.020	--
DEC							
15...	10.1	45	.012	.04	10.1	<.020	--
JAN 1998							
14...	6.13	27	.023	.08	6.15	<.020	--
FEB							
19...	7.86	35	.035	.12	7.89	<.020	--
MAR							
11...	--	--	<.010	--	3.71	.105	.14
APR							
24...	--	--	<.010	--	4.41	.022	.03
MAY							
12...	8.78	39	.013	.04	8.80	.037	.05
JUN							
03...	10.8	48	.015	.05	10.8	.026	.03
JUL							
15...	13.8	61	.015	.05	13.8	.026	.03
AUG							
19...	18.9	84	.392	1.3	19.3	.171	.22
SEP							
23...	17.4	77	.012	.04	17.4	<.020	--
OCT							
21...	--	--	<.010	--	10.6	<.020	--
NOV							
17...	--	--	<.010	--	10.0	.049	.06
DEC							
08...	--	--	<.010	--	8.58	.031	.04
JAN 1999							
07...	--	--	<.010	--	8.84	.021	.03
FEB							
03...	--	--	<.010	--	10.5	.026	.03
MAR							
16...	2.72	12	.021	.07	2.74	.126	.16
APR							
07...	--	--	<.010	--	3.01	.051	.07
MAY							
04...	2.88	13	.010	.03	2.88	.076	.10
JUN							
09...	--	--	<.010	--	3.57	<.020	--
JUL							
28...	--	--	<.010	--	2.65	<.020	--
AUG							
18...	--	--	<.010	--	2.38	<.020	--
SEP							
14...	--	--	<.010	--	2.84	.022	.03

Appendix 1. Mean daily discharge and water-quality data collected during water years 1998 and 1999 for U.S. Geological Survey gages 07189540 Cave Springs Branch near South West City, Missouri, and 07189542 Honey Creek near South West City, Missouri—Continued

07189542 HONEY CREEK NEAR SOUTH WEST CITY, MO--Continued

WATER-QUALITY DATA

DATE	NITRO-GEN, ORGANIC TOTAL (MG/L AS N) (00605)	NITRO-GEN, AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, TOTAL (MG/L AS N) (00600)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHATE, ORTHO, DIS-SOLVED (MG/L AS PO4) (00660)
AUG 1997							
26...	--	<.20	--	.665	.619	.667	2.0
SEP							
15...	--	<.20	--	.634	.658	<.010	--
OCT							
15...	--	<.20	--	.734	.688	.693	2.1
NOV							
18...	--	.25	--	1.02	1.07	1.07	3.3
DEC							
15...	--	.27	10	.718	.703	.732	2.2
JAN 1998							
14...	--	<.10	--	.184	.180	.201	.62
FEB							
19...	--	.19	8.1	.515	.508	.536	1.6
MAR							
11...	.00	.10	3.8	.095	.089	.096	.29
APR							
24...	.25	.28	4.7	.371	.236	.225	.69
MAY							
12...	.25	.28	9.1	.446	.507	.504	1.5
JUN							
03...	.30	.32	11	.512	.476	.444	1.4
JUL							
15...	.22	.24	14	.495	.510	.496	1.5
AUG							
19...	.11	.28	20	.571	.536	.543	1.7
SEP							
23...	--	.23	18	.695	.671	.677	2.1
OCT							
21...	--	.27	11	.537	.484	.480	1.5
NOV							
17...	.14	.19	10	.426	.393	.402	1.2
DEC							
08...	--	<.10	--	.320	.358	.322	.99
JAN 1999							
07...	.22	.24	9.1	.252	.235	.210	.64
FEB							
03...	.28	.30	11	.321	.290	.300	.92
MAR							
16...	2.1	2.3	5.0	1.04	.511	.464	1.4
APR							
07...	.16	.21	3.2	.166	.151	.128	.39
MAY							
04...	.53	.61	3.5	.234	.179	.156	.48
JUN							
09...	--	.25	3.8	--	.248	.195	.60
JUL							
28...	--	.29	2.9	.142	.125	.127	.39
AUG							
18...	--	.24	2.6	.150	.114	.146	.45
SEP							
14...	.19	.22	3.1	--	.239	.216	.66

Appendix 2. Description of ground-water and surface-water sites

[Deg, degrees; min, minutes; sec, seconds; altitude methods: M, map; D, differential Global Positioning System; L, land surface; --, no data available; ft^3/s, cubic feet per second]

Well number (shown in figure 5)	Station name	Latitude	Longitude	Land surface altitude (feet)	Altitude method	Altitude accuracy (feet)	Well depth (feet)	Date of measurement
		Deg min sec	Deg min sec					
W.1	21N-34W-21BAD01	36 32 46	94 37 02	942	M	5	32.35	05-20-99
W.2	24N-25E-15DAA01	36 33 35.7	94 37 05.3	983	M	5	230.95	05-18-99
W.3	24N-25E-27AAB01	36 32 18	94 37 14	1,001	M	5	229	05-18-99
W.4	24N-25E-22CCD01	36 32 24	94 37 38	942	M	5	92.5	05-21-99
W.5	24N-25E-15CCC01	36 33 21.92	94 37 44.57	941.6	D	0.3	150	04-29-99
W.6	24N-25E-22BCB01	36 33 00	94 37 45	980	M	5	110	05-18-99
W.7	24N-25E-22BBC01	36 33 07.75	94 37 45.2	970	M	5	142	05-18-99
W.8	24N-25E-18AAD01	36 33 57.00	94 37 47	945	M	5	71	04-30-99
W.9	24N-25E-16AAB01	36 34 01.5	94 38 00.7	942	M	5	96.1	04-29-99
W.10	24N-25E-16ABB01	36 34 04	94 38 13	920	M	5	155	05-15-99
W.11	24N-25E-16CDA01	36 33 3 0.45	94 38 28.56	940.4	D	0.3	456	05-18-99
W.12	24N-25E-21CCC01	36 32 24	94 38 46	963	M	5	164.42	05-20-99
W.13	24N-25E-17 DAD 02	36 33 34.07	94 38 53.00	880.0	D	0.3	38.1	04-15-99
W.14	24N-25E-08DAA02	36 34 03	94 38 53.8	931	M	5	180.45	05-17-99
W.15	24N-25E-08DAA01	36 34 31	94 38 53.02	931	M	5	154.9	05-17-99
W.16	24N-25E-17AAA01	36 34 02.08	94 38 53.21	930	M	5	134.39	05-18-99
W.17	24N-25E-17DDD01	36 33 20	94 38 53	935	M	5	385	05-15-99
W.18	24N-25E-17DAD01	36 33 33.43	94 38 54.93	881.7	D	0.3	292	04-15-99
W.19	24N-25E-08DBD01	36 34 26.55	94 39 08.00	940.7	D	0.3	97.2	04-13-99
W.20	24N-25E-17DBA01	36 33 40.07	94 39 11.73	902.0	D	0.3	415	04-16-99
W.21	24N-25E-17DBD01	36 33 3 2.85	94 39 14.24	861.2	D	0.3	282	04-16-99
W.22	24N-25E-08CAD01	36 34 26.48	94 39 27.60	938.8	D	0.3	90.08	04-13-99
W.23	24N-25E-20CBB01	36 32 47	94 39 40	899	M	5	118.1	05-18-99
W.24	24N-25E-17BCB01	36 33 48.43	94 39 50.80	912	M	5	137.95	05-19-99
W.25	24N-25E-17CCC01	36 33 22.30	94 39 53.7	851.8	D	0.3	90.1	04-29-99
W.26	24N-25E-18AAA01	36 34 06.1	94 39 58.5	922	M	5	118	04-30-99
W.27	24N-25E-19ADD01	36 32 54.6	94 40 00.1	846	M	5	100	05-20-99
W.28	24N-25E-19AAA01	36 33 11.5	94 40 02.1	878.4	D	0.3	420	05-20-99
W.29	24N-25E-19DCD01	36 32 23	94 40 19	925	M	5	125	05-19-99
W.30	24N-25E-18CDB01	36 33 24.22	94 40 37.44	901	M	5	110	05-18-99
W.31	24N-24E-24DDA01	36 32 32.16	94 41 04.64	822.8	D	0.3	46.8	04-15-99

Appendix 2. Description of ground-water and surface-water sites (Continued)

[Deg, degrees; min, minutes; sec, seconds; altitude methods: M, map; D, differential Global Positioning System; L, land surface; --, no data available; ft^3/s, cubic feet per second]

Well number (shown in figure 5)	Station name	Latitude	Longitude	Land surface altitude (feet)	Altitude method	Altitude accuracy (feet)	Well depth (feet)	Date of measurement
		Deg min sec	Deg min sec					
W.32	24N-24E-24ABD01	36 33 02.46	94 41 18.36	910	M	5	114.35	05-18-99
W.33	24N-24E-13ABC01	36 34 00.26	94 41 25.03	905.4	D	0.3	400	04-14-99
W.34	24N-24E-13DCB01	36 33 27.45	94 41 25.85	883.5	D	0.3	79.25	04-15-99
W.35	24N-24E-24BBA01	36 33 11.31	94 41 52.79	872.2	D	0.3	350	04-14-99
W.36	24N-24E-25CBB01	36 31 51.08	94 42 04.83	879.5	D	0.3	78.4	04-15-99

Appendix 2. Description of ground-water and surface-water sites—Continued

Site number (shown in figure 5)	Measuring point height (feet)	May water level date	May water level time	May water level (feet below land surface)	August water level date	August water level time	August water level (feet below land surface)
W.1	3.40	05-20-99	0947	18.30	08-25-99	1714	18.73
W.2	0.65	05-18-99	--	33.38	08-24-99	1623	42.07
W.3	0.8	05-18-99	1725	33.40	08-26-99	1857	80.54
W.4	0.8	05-21-99	1603	34.64	08-25-99	1517	34.99
W.5	1.9	05-20-99	1315	34.81	08-24-99	1505	36.34
W.6	0.427	05-18-99	1233	58.24	08-24-99	1837	64.52
W.7	0	05-18-99	1255	49.92	08-25-99	0931	51.44
W.8	0.26	05-18-99	--	43.67	08-18-99	1308	46.48
W.9	0.05	05-20-99	1100	32.30	08-24-99	1727	41.58
W.10	0.65	05-19-99	--	37.46	08-24-99	0904	38.98
W.11	0.90	05-18-99	0906	73.20	08-25-99	1901	75.95
W.12	0.58	05-20-99	0815	52.57	08-25-99	1437	62.87
W.13	0	05-20-99	1000	15.51	08-25-99	1243	17.81
W.14	0.45	05-17-99	1553	55.98	08-23-99	1511	53.72
W.15	0	05-17-99	1514	53.08	08-23-99	1542	57.29
W.16	-0.73	05-18-99	1540	51.36	08-25-99	1037	55.63
W.17	1.75	05-19-99	0927	53.70	08-25-99	1339	57.36
W.18	1.8	05-20-99	1020	34.87	08-25-99	1212	81.06
W.19	0	05-19-99	0944	55.04	08-24-99	1752	61.97
W.20	0.80	05-20-99	1150	45.3	08-25-99	1605	54.83
W.21	1.5	05-20-99	1124	44.47	08-25-99	1737	60.79
W.22	0	05-17-99	1622	22.37	08-26-99	0827	38.69
W.23	1.1	05-18-99	1401	54.23	08-25-99	1403	58.57
W.24	0.65	05-19-99	--	60.80	08-26-99	1540	55.00
W.25	0.28	05-18-99	--	24.00	08-20-99	0908	28.34
W.26	0.2	05-19-99	1157	42.12	08-18-99	0956	49.73
W.27	0.67	05-20-99	1806	35.66	08-26-99	1650	37.05
W.28	1	05-20-99	1028	56.54	08-20-99	1033	57.16
W.29	1.1	05-19-99	--	52.5	08-25-99	1320	53.37
W.30	1.25	05-18-99	0855	40.13	08-26-99	1355	43.99
W.31	0	05-19-99	1111	21.92	08-26-99	1013	22.49

Appendix 2. Description of ground-water and surface-water sites—Continued

Site number (shown in figure 5)	Measuring point height (feet)	May water level date	May water level time	May water level (feet below land surface)	August water level date	August water level time	August water level (feet below land surface)
W.32	0.46	05-18-99	1030	55.94	08-26-99	1515	57.54
W.33	0.2	05-19-99	1157	21.02	08-25-99	1051	23.49
W.34	1.3	05-20-99	1208	20.99	08-25-99	1121	22.56
W.35	1.08	05-19-99	1650	54.92	08-24-99	1915	61.97
W.36	0.64	05-19-99	1652	32.26	08-26-99	0927	33.51

Appendix 2. Description of ground-water and surface-water sites—Continued

Stream number (shown in figure 5)	Site identifier	Station name	Latitude Deg min sec	Longitude Deg min sec	Stream surface altitude (feet)	Altitude method	Discharge on May 19, 1999 (ft^3/s)	Discharge on Aug. 24, 1999 (ft^3/s)
S.1	07189539	Cave Springs Branch Site 1 near South West City, Mo.	36 32 51.69	94 36 44.59	938.2	D	4.5	1.8
S.2	07189540	Cave Springs Branch near South West City, Mo.	36 32 50.05	94 37 04	927.9	L	9.3	1.9
S.3	071895403	Cave Springs Branch Site 3 near South West City, Mo.	36 33 02.52	94 37 26.84	915.4	D	3.5	0.73
S.4	363303094372801	O'Brien Spring	36 33 03.7	94 37 28.3	914.3	D	5.4	2.9
S.5	071895404	Cave Springs Branch Site 4 near South West City, Mo.	36 33 12.06	94 37 34.19	910.0	D	9.0	3.7
S.6	0718954043	Cave Springs Branch Site 4A near South West City, Mo.	36 33 21.30	94 37 41.39	905.2	D	9.6	--
S.7	0718954046	Cave Springs Branch Site 4B near South West City, Mo.	36 33 23	94 37 42.08	903.0	D	8.7	--
S.8	071895405	Cave Springs Branch Site 5 near South West City, Mo.	36 33 29.37	94 37 52.27	897.2	D	9.9	3.5
S.9	071895406	Cave Springs Branch Site 6 near South West City, Mo.	36 33 43.37	94 38 35.67	863.4	D	12	3.3
S.10	071895407	Cave Springs Branch Site 7 near South West City, Mo.	36 33 38.75	94 38 51.66	858.5	D	11	4.1
S.11	071895408	Cave Springs Branch Site 8 near South West City, Mo.	36 33 34.5	94 39 18.5	847.8	D	15	6.4
S.12	071895410	Cave Springs Branch Site 10 near South West City, Mo.	36 33 18.97	94 39 57.00	822.6	D	13	5.3
S.13	071895411	Cave Springs Branch Site 11 near South West City, Mo.	36 33 05.71	94 40 22.15	805	M	14	4.6
S.14	071895412	Honey Creek Site 12 near South West City, Mo.	36 33 00.60	94 40 42.81	801.3	D	50	17
S.15	071895413	Honey Creek Site 13 Near South West City, Mo.	36 31 36.16	94 37 12.02	875.4	D	31	11
S.16	071895414	Honey Creek Site 14 Near South West City, Mo.	36 3210.36	94 38 02.4	865.6	D	35	12
S.17	071895415	Honey Creek Site 15 Near South West City, Mo.	36 32 38	94 38 34.75	845.6	D	35	12
S.18	071895416	Honey Creek Site 16 Near South West City, Mo.	36 32 57.35	94 38 51.52	838.8	D	35	12
S.19	071895418	Honey Creek Site 18 Near South West City, Mo.	36 33 37.98	94 39 54.44	812.5	M	36	11
S.20	07189542	Honey Creek near South West City, Mo.	36 32 56.15	94 41 01.50	796.5	D	54	16
S.21	071895421	Honey Creek Site 21 Near South West City, Mo.	36 32 24.12	94 41 38.38	783.4	D	62	18

Appendix 3. Water properties, concentrations of dissolved solids, major ions, nutrients, iron, manganese, and arsenic and δ values in permil of stable isotopes of hydrogen and oxygen in water samples collected August 23-27, 1999, and March 22, 2000

Groups: 1, poultry-processing plant wastewater outfall; 2, Cave Springs Branch and Honey Creek gage; 3, Honey Creek upstream of confluence; 4, upgradient well, 5, downgradient well; °C, degerees Celsius; µS/cm, microsiemens per centimeter at 25°C; --, no data available; field, parameter measured in the field; dissolved, determined in filtered sample; total, determined in unfiltered sample; mg/L, milligrams per liter; mg/L as $CaCO_3$, milligrams per liter as calcium carbonate; it, incremental; HCO_3, bicarbonate; SO_4, sulfate; <, less than; SiO_2, silicon dioxide; mg/L as N, milligrams per liter as nitrogen; as P, as phosphorus; as PO_4, as phosphate; µg/L, micrograms per liter; E—concentration was detected but was less than provisional method detection limit, and greater than the lowest calibration standard; δ, delta; VSMOW, Vienna standard mean ocean water; all samples were analyzed by the National Water quality laboratory of the U.S. Geological Survey]

Site number (shown in figure 5)	Station name	Date	Time	Site identifier	Record number	Group	Water properties: Specific conductance (µS/cm)	Water properties: pH, field (standard units)
		Surface water						
Outfall	Poultry processing plant outfall	03-22-00	0930	363237094363001	00000223	1	2,020	7.2
S.2	Cave Springs Branch near South West City, Mo	08-20-99	1045	07189540	99900783	2	924	7.7
	Cave Springs Branch near South West City, Mo	03-22-00	0745		00000221	2	1,420	7.4
S.3	Cave Springs Branch Site 3 near South West City, Mo	08-19-99	1600	071895403	99900789	2	881	8.2
S.4	O'Brien Spring	08-19-99	1530	363303094372801	99900961	2	1,140	7.2
S.10	Cave Springs Branch Site 7 near South West City, Mo	08-17-99	1145	071895407	99900812	2	1,100	8.1
S.11	Cave Springs Branch Site 8 near South West City, Mo	08-17-99	1415	071895408	99900813	2	965	8.2
S.17	Honey Creek Site 15 near South West City, Mo	08-18-99	1315	071895415	99900814	2	285	7.9
S.20	Honey Creek near South West City, Mo	08-18-99	1745	07189542	99900815	3	--	7.8
		Well water						
W.5	24N-25E-15 CCC 01	08-17-99	1500	363321094374401	99900957	5	390	7.1
W.6	24N-25E-22 BCB 01	08-20-99	1300	363300094374501	99900950	4	215	7.4
W.10	24N-25E-16 ABB 01	08-24-99	1015	363402094382401	99900951	4	387	7.3
	24N-25E-16 ABB 01	09-14-99	1450		99900952	4	362	7.0
W.11	24N-25E-16 CDA 01	08-19-99	1630	363330094382801	99901059	4	357	6.9
W.17	24N-25E-17 DDD 01	08-17-99	1300	363320094385301	99900960	4	353	6.9
W.18	24N-25E-17 DAD 01	08-18-99	1200	363333094385401	99900958	5	301	6.9
W.28	24N-25E-19 AAA 01	08-19-99	1100	363311094400201	99900962	5	406	7.1
W.29	24N-25E-19 DCD 01	08-19-99	0830	363224094401701	99900959	4	445	6.9
W.31	24N-24E-24 DDA 01	08-20-99	1000	363232094410401	99900954	4	421	6.8
W.31	24N-24E-24 DDA 01	08-20-99	1001	363232094410401	99900020	4	421	6.8
W.35	24N-24E-24 BBA 01	08-18-99	1000	363311094415201	99900956	4	427	6.7

Appendix 3. Water properties, concentrations of dissolved solids, major ions, nutrients, iron, manganese, and arsenic and δ values in permil of stable isotopes of hydrogen and oxygen in water samples collected August 23-27, 1999, and March 22, 2000—Continued

Site number (shown in figure 5)	Water properties—Continued					Major cations and related data						
	Temperature water (°C)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Hardness total (mg/L as $CaCO_3$)	Alkalinity dissolved total it field (mg/L as $CaCO_3$)	Calcium dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium percent	Sodium adsorption ratio	Potassium, dissolved (mg/L)
Surface water											
Outfall	15.8	8.0	--	220	161	66	12	261	67	8	54
S.2	24.5	11.7	144	180	134	60	7.3	107	52	3	25
	14.1	8.1	--	190	139	60	9.0	170	61	5	41
S.3	27.2	13.1	169	200	131	70	5.6	86	46	3	17
S.4	28.0	4.1	54	190	130	63	7.7	133	56	4	28
S.10	21.7	9.5	110	190	148	64	6.5	102	51	3	22
S.11	24.2	9.8	119	180	144	64	6.2	96	50	3	20
S.17	24.5	8.8	108	130	131	47	1.7	5.4	8	.2	2.6
S.20	25.7	6.8	--	140	122	53	2.8	31	31	1	7.1
Well water											
W.5	16.0	4.6	47	190	181	74	1.3	4.0	4	.1	.92
W.6	17.2	8.9	95	110	107	41	1.2	1.9	4	.1	.44
W.10	16.0	8.3	86	200	190	79	1.0	2.9	3	.1	.57
	15.9	9.5	98	--	--	--	--	--	--	--	--
W.11	17.3	.2	2	190	184	73	1.4	3.0	3	.1	.40
W.17	17.7	8.9	96	170	155	66	1.1	2.4	3	.1	.84
W.18	17.5	.4	4	140	138	54	1.4	4.8	7	.2	.87
W.28	16.7	8.7	92	180	160	72	1.3	5.5	6	.2	1.8
W.29	17.3	9.4	100	210	195	83	.96	5.0	5	.1	1.3
W.31	15.7	2.0	21	220	196	84	2.4	4.8	4	.1	4.2
W.31	15.7	2.0	21	220	196	83	2.3	5.0	5	.1	4.1
W.35	17.4	1.0	11	190	198	69	3.6	10	11	.3	.35

Appendix 3. Water properties, concentrations of dissolved solids, major ions, nutrients, iron, manganese, and arsenic and δ values in permil of stable isotopes of hydrogen and oxygen in water samples collected August 23-27, 1999, and March 22, 2000—Continued

Site number (shown in figure 5)	Major anions: Bicarbonate, dissolved it field mg/L as HCO_3	Major anions: Chloride, dissolved (mg/L)	Major anions: Sulfate dissolved (mg/L as SO_4)	Major anions: Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 °C dissolved (mg/L)	Nutrients: Nitrogen, ammonia dissolved (mg/L as N)	Nutrients: Nitrogen, ammonia + organic, total (mg/L as N)	Nutrients: Nitrogen, nitrite dissolved (mg/L as N)	Nutrients: Nitrogen, nitrite plus nitrate dissolved (mg/L as N)	Nutrients: Nitrogen, nitrate calculated dissolved (mg/L as N)	Nutrients: Nitrogen, total (mg/L as N)
Surface water												
Outfall	196	384	185	<.10	8.6	1140	.78	2.1	.067	3.5	3.33	5.7
S.2	163	140	86	<.10	9.4	534	<.020	.75	.020	5.71	5.69	6.5
	170	248	123	<.10	5.7	788	.09	2.1	.056	5.2	5.14	7.3
S.3	160	130	74	<.10	9.7	503	<.020	.62	.022	4.68	4.66	5.3
S.4	158	180	98	<.10	9.5	646	<.020	.67	<.010	8.06	8.06	8.7
S.10	180	150	90	.14	8.8	558	.023	.56	<.010	3.65	3.64	4.2
S.11	176	140	86	.11	9.1	542	.020	.49	<.010	3.59	3.58	4.1
S.17	160	10	4.3	<.10	11	164	<.020	<.10	<.010	1.94	1.935	--
S.20	149	44	26	<.10	11	267	<.020	.24	<.010	2.38	2.38	2.6
Well water												
W.5	220	8.0	4.5	.14	8.3	221	.029	E.08	.011	3.30	3.29	--
W.6	130	1.5	.79	<.10	8.2	124	<.020	<.10	<.010	.386	0.38	--
W.10	232	1.5	1.6	<.10	8.6	214	<.020	.16	<.010	1.21	1.20	1.4
	--	--	--	--	--	--	--	--	--	--	--	--
W.11	226	1.5	4.8	<.10	8.0	206	<.020	.13	<.010	<.050	<.05	--
W.17	189	3.8	6.5	<.10	9.3	213	<.020	.24	<.010	4.61	4.60	4.8
W.18	168	2.2	7.8	<.10	9.1	172	<.020	.13	.024	1.49	1.47	1.6
W.28	195	9.8	13	<.10	11	247	<.020	.14	<.010	7.28	7.28	7.4
W.29	238	14	3.0	<.10	8.5	259	<.020	E.10	<.010	3.41	3.40	--
W.31	239	6.3	10	<.10	12	260	<.020	E.07	<.010	3.45	3.44	--
W.31	239	6.5	10	<.10	11	265	<.020	.53	<.010	3.39	3.39	3.9
W.35	241	5.5	9.9	.43	7.8	233	<.020	E.06	<.010	<.050	<.05	--

Appendix 3. Water properties, concentrations of dissolved solids, major ions, nutrients, iron, manganese, and arsenic and δ values in permil of stable isotopes of hydrogen and oxygen in water samples collected August 23-27, 1999, and March 22, 2000—Continued

Site number (shown in figure 5)	Nutrients—Continued				Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Arsenic dissolved (µg/L)	Selenium, dissolved, (µg/L)	Stable isotopes		**Discharge, instantaneous cubic feet per second**	**Depth of well, total (feet)**
	Phos-phorus total (mg/L as P)	Phos-phorus dissolved (mg/L as P)	Phos-phorus ortho, dissolved (mg/L as P)	Phos-phate, ortho, dissolved (mg/L as PO4)					δ Deuterium, in permil relative to VSMOW	δ^{18}Oxygen, in permil relative to VSMOW		
Surface water												
Outfall	.206	.05	.01	.03	10	83	--	--	--	--	2.24	--
S.2	.142	.132	.127	.39	E6.2	7.7	1	0.7	-31.3	-5.29	**1.6**	--
	.286	<.05	.013	.04	E8.2	64	--	--	--	--		--
S.3	.220	.237	.231	.71	<10	8.0	<1	0.5	-32.6	-5.37	**.16**	--
S.4	.290	.309	.287	.88	E5.8	3.6	<1	1.0	-31.1	-5.06	**4.0**	--
S.10	.262	.272	.276	.85	<10	12	<1	0.7	-32.2	-5.12	**6.7**	--
S.11	.279	.275	.279	.86	<10	12	<1	0.7	-31.0	-5.15	**5.8**	--
S.17	E.041	<.050	.032	.10	<10	<3.0	<1	< 0.4	-36.4	-5.94	**12**	--
S.20	.150	.114	.146	.45	<10	E2.9	<1	< 0.4	-33.5	-5.69	**15**	--
Well water												
W.5	<.050	<.050	<.010	--	64	22	1	1.5	-35.7	-6.12	--	**150**
W.6	<.050	<.050	<.010	--	<10	<3.0	<1	0.8	-33.9	-5.92	--	**110**
W.10	E.034	<.050	.014	.04	<10	<3.0	<1	0.6	-31.9	-5.73	--	**155**
	--	--	--	--	--	--	--	--	--	--	--	
W.11	<.050	<.050	<.010	--	19	E2.9	2	1.5	-33.4	-5.86	--	**456**
W.17	E.041	<.050	<.010	--	<10	<3.0	<1	< 0.4	-38.3	-6.21	--	**385**
W.18	E.032	<.050	<.010	--	<10	13	2	2.0	-37.4	-6.16	--	**292**
W.28	.059	E.032	.033	.10	<10	<3.0	<1	0.6	-38.1	-6.43	--	**420**
W.29	<.050	<.050	<.010	--	<10	3.5	<1	0.5	-35.0	-5.89	--	**125**
W.31	E.045	E.049	.059	.18	<10	E2.6	<1	1.5	-38.5	-6.22	--	**46.8**
W.31	.053	E.031	.055	.17	<10	E2.2	<1	1.5	-37.6	-6.31	--	
W.35	<.050	<.050	<.010	--	96	13	<1	< 0.4	-35.7	-6.12	--	**350**

Appendix 4. Compounds detected by wastewater indicator compound determinations

[Detected concentrations are shown in bold print; Groups: 1, poultry-processing plant wastewater outfall; 2, Cave Springs Branch and Honey Creek gage; 3, Honey Creek upstream of confluence; 4, upgradient well; 5, downgradient well; *, indicates compound demonstrates poor or variable method performance, therefore, any detected values are always estimated (values probably are larger than reported value); total, determined in unfiltered sample; µg/L, micrograms per liter; <, less than; E, estimated—concentration was detected but was less than method detection limit; --, no data available; SPIKE, recovery from water spiked with 1 microgram per liter of each compound; BLANK, organic free water]

Site Number (shown in figure 5)	Site identifier	Date	Time	Group	Detergents and metabolites					Disinfectants	
					Para-nonylphenol, total* (µg/L)	Nonylphenol ethoxylate1, total* (µg/L)	Nonylphenol ethoxylate1, total* (µg/L)	Octylphenol, mono-ethoxylate* (µg/L)	Octylphenol, di-ethoxylate* (µg/L)	Phenol (µg/L)	Triclosan (µg/L)
					Surface and Spring Water						
Outfall	36323709436300	03-22-00	0930	1	**E4.6**	**E11.3**	**E8.4**	**E2.3**	**E0.24**	**0.74**	**1.47**
S.2	07189540	04-17-99	1000	2	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
S.2	07189540	08-20-99	1045	2	**E0.42**	**E0.64**	<1.0	<0.10	<0.20	<0.15	**0.14**
S.2	07189540	03-22-00	0745	2	<0.50	<1.0	<1.1	<0.10	<0.20	**0.42**	<0.04
S.2	07189540	03-22-00	0745	2	<0.50	<1.0	<1.1	<0.10	<0.20	**0.16**	<0.04
S.3	071895403	08-19-99	1600	2	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
S.4	363303094372801	08-19-99	1530	2	**E0.50**	**E0.36**	<1.0	<0.10	<0.20	<0.15	**0.04**
S.10	071895407	08-17-99	1145	2	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
S.11	071895408	08-17-99	1415	2	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
S.17	71895415	08-18-99	1315	3	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	**0.07**
S.20	07189542	08-18-99	1745	2	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
					Ground Water						
W.5	363321094374401	08-17-99	1500	5	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.6	363300094374501	08-20-99	1300	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.10	363402094382401	09-14-99	1450	4	<0.50	<0.80	<1.0	<0.10	<0.20	**0.96**	<0.04
W.11	363330094382801	08-19-99	1630	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	**0.04**
W.17	363320094385301	08-17-99	1300	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.18	363333094385401	08-18-99	1200	5	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.28	363311094400201	08-19-99	1100	5	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.29	363224094401701	08-19-99	0830	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.31	363232094410401	08-20-99	1000	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.31	363232094410401	08-20-99	1001	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
W.35	363311094415201	08-18-99	1000	4	<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04
SPIKE	--	--	--		E0.86	E0.93	E0.62	E0.89	E0.82	0.73	0.90
BLANK	--	--	--		<0.50	<0.80	<1.0	<0.10	<0.20	<0.15	<0.04

Appendix 4. Compounds detected by wastewater indicator compound determinations—Continued

Site Number (shown in figure 5)	Fecal indicators			Fire retardant	Fragrance	Fumigants		Pharmaceuticals and food		Plastics, polymers and precursors	
	3B-Coprostanol * (µg/L)	Cholesterol * (µg/L)	17B-Estra-diol*	Tri (2-chloroethyl)-phosphate (µg/L)	Aceto-phenone (µg/L)	1,4-Dichloro-benzene (µg/L)	Naphthalene (µg/L)	Caffeine	Cotinine	Bisphenol A (µg/L)	Bis (2-ethylhexyl) adipate (µg/L)
Surface and Spring Water											
Outfall	**E2.5**	**E1.9**	**E02.2**	**0.09**	**E0.10**	**E0.02**	<0.03	**0.81**	<0.04	**0.86**	<1.5
S.2	<0.6	**E1.5**	--	**0.13**	**0.12**	<0.03	<0.03	**0.05**	--	**0.25**	<0.9
S.2	<0.6	**E0.62**	--	**0.07**	<0.15	<0.03	<0.03	<0.06	--	<0.09	**E0.7**
S.2	<0.6	**E0.47**	<0.5	<0.04	<0.10	<0.03	<0.03	**0.08**	<0.04	<0.09	<1.5
S.2	<0.6	**E0.88**	<0.5	<0.04	<0.10	<0.03	<0.03	**0.14**	**0.04**	<0.09	<1.5
S.3	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	<0.06	--	<0.09	<0.9
S.4	<0.6	<1.0	--	**E0.03**	<0.15	**0.04**	**E0.03**	**E0.06**	--	<0.09	<0.9
S.10	<0.6	<1.0	--	<0.04	<0.15	**0.05**	**E0.02**	<0.06	--	<0.09	<0.9
S.11	<0.6	<1.0	--	<0.04	<0.15	**E0.02**	<0.03	<0.06	--	<0.09	<0.9
S.17	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	**0.10**	--	<0.09	<0.9
S.20	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	**E0.02**	--	<0.09	<0.9
Ground Water											
W.5	<0.6	<1.0	--	<0.04	**1.5**	<0.03	<0.03	<0.06	--	**0.82**	<0.9
W.6	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	<0.06	--	<0.09	<0.9
W.10	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	<0.06	--	<0.09	<0.9
W.11	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	**E0.04**	--	**0.11**	<0.9
W.17	**E0.43**	**E0.62**	--	<0.04	<0.15	<0.03	<0.03	**E0.04**	--	<0.09	<0.9
W.18	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	<0.06	--	<0.09	<0.9
W.28	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	<0.06	--	<0.09	<0.9
W.29	<0.6	<1.0	--	**E0.04**	**0.93**	<0.03	<0.03	<0.06	--	<0.09	<0.9
W.31	<0.6	<1.0	--	<0.04	<0.15	<0.03	<0.03	**E0.03**	--	<0.09	<0.9
W.31	<0.6	<1.0	--	**E0.03**	<0.15	<0.03	<0.03	<0.06	--	<0.09	<0.9
W.35	<0.6	<1.0		<0.04	**0.51**	<0.03	<0.03	<0.06	--	<0.09	<0.9
SPIKE	E0.50	E0.47		E1.01	0.84	0.80	0.85	85	56	0.84	0.70
BLANK	<0.6	<1.0		<0.04	<0.15	<0.03	<0.03	<0.06	<0.04	<0.09	<0.9

Appendix 4. Compounds detected by wastewater indicator compound determinations—Continued

Site Number (shown in figure 5)	Plastics, polymers and precursors				Polynuclear Aromatic Hydrocarbons			Preservatives		Surrogates	
	Bis (2-ethylhexyl) phthalate (µg/L)	Ethanol, 2-butoxy-phosphate (µg/L)	Pthalic anhydride (µg/L)	Triphenyl phosphate (µg/L)	Tributyl phosphate (µg/L)	Fluoranthene (µg/L)	Pyrene (µg/L))	2,6-di-t-p-Benzo-quinone (µg/L)	Para-cresol (µg/L)	Butylated hydroxytoluene-d9 (BHT-d9) (percent recovered)	4-n-Nonylphenol (percent recovered)
Surface and Spring Water											
Outfall	<2.0	**3.3**	<0.20	**E0.05**	--	<0.03	<0.03	**0.13**	**0.056**	78	116
S.2	<1.5	<0.07	1.1	<0.10	<0.06	<0.03	<0.03	**0.13**	**0.12**	--	--
S.2	<1.5	**0.34**	<0.20	<0.10	**0.32**	<0.03	<0.03	**0.19**	<0.03	102	112
S.2	<2.0	<0.07	<0.20	<0.10	--	<0.03	<0.03	<0.03	**0.051**	61	78
S.2	<2.0	<0.07	<0.20	<0.10	--	<0.03	<0.03	<0.03	**0.057**	75	93
S.3	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	77	85
S.4	<1.5	<0.07	<0.20	<0.10	<0.06	**E0.02**	<0.03	<0.07	<0.03	84	79
S.10	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	**0.04**	89	74
S.11	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	**0.06**	75	75
S.17	<1.5	<0.07	<0.20	<0.10	<0.06	**0.04**	<0.03	<0.07	<0.03	60	66
S.20	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	**E0.02**	<0.07	<0.03	55	58
Ground Water											
W.5	**3.0**	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	73	79
W.6	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	40	57
W.10	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	70	71
W.11	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	77	70
W.17	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	90	85
W.18	**7.7**	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	**0.05**	66	60
W.28	<1.5	**0.20**	<0.20	<0.10	**0.08**	<0.03	<0.03	<0.07	<0.03	91	81
W.29	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	83	88
W.31	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	72	67
W.31	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	97	84
W.35	<1.5	<0.07	<0.20	<0.10	<0.06	<0.03	<0.03	<0.07	<0.03	71	86
SPIKE	0.94	0.93	0.60	0.71	1.16	0.85	0.68	1.14	0.94	64	75
BLANK	<1.5	<0.07	0.30	<0.10	0.3	<0.03	<0.03	E0.05	<0.03	53	69